hearing for scheduling those who have not notified the EPA contact earlier. This testimony will be scheduled on a first-come, first-served basis to follow the previously scheduled testimony.

EPA requests that approximately 50 copies of the statement or material to be presented be brought to the hearing for distribution to the audience. In addition, EPA would find it helpful to receive an advance copy of any statement or material to be presented at the hearing at least one week before the scheduled hearing date. Such advance copies would give EPA staff adequate time to review the materials before the hearing. Advance copies should be submitted to the EPA contact person listed in this proposal. The official records of the hearing will be kept open until the close of the comment period to allow submission of rebuttal and supplementary testimony.

Materials relevant to this notice, including the regulatory language, are contained in the Public Docket ID No EPA–HQ–OAR–2006–0841. Publicly available docket materials are available either electronically in *http://www.regulations.gov* or in hard copy at the Air Docket, EPA/DC, EPA West, Room B102, 1301 Constitution Ave., NW., Washington, DC. The Public Reading Room is open from 8:30 a.m. to 4:30 p.m., Monday through Friday, excluding legal holidays. The telephone number for the Public Reading Room is (202) 566–1744, and the telephone number for the Air Docket is (202) 566–1742.

The hearing will be conducted informally, and technical rules of evidence will not apply. A written transcript of the hearing will be placed in the docket for review. Anyone who desires to purchase a copy of the transcript should make individual arrangements with the court reporter recording the proceeding.

Dated: January 26, 2007.

Margo Tsirigotis Oge,

Director, Office of Transportation and Air Quality.

[FR Doc. E7–1726 Filed 2–1–07; 8:45 am]

BILLING CODE 6560–50–P

DEPARTMENT OF THE INTERIOR

Fish and Wildlife Service

50 CFR Part 17

Endangered and Threatened Wildlife and Plants; 12-Month Finding on a Petition To List the American Eel as Threatened or Endangered

AGENCY: Fish and Wildlife Service, Interior.

ACTION: Notice of 12-month petition finding.

SUMMARY: We, the U.S. Fish and Wildlife Service (USFWS), announce our 12-month finding on a petition to list, under the Endangered Species Act of 1973, (Act) as amended, the American eel (*Anguilla rostrata*) as a threatened or endangered species throughout its range. After a thorough review of all available scientific and commercial information, we find that listing the American eel as either threatened or endangered is not warranted at this time. We ask the public to continue to submit to us any new information that becomes available concerning the status of or threats to the species. This information will help us to monitor and encourage the ongoing conservation of this species.

DATES: The finding in this document was made on February 2, 2007.

ADDRESSES: Data, information, comments, or questions regarding this finding should be sent by postal mail to Martin Miller, Chief, Division of Endangered Species, Region 5, U.S. Fish and Wildlife Service, 300 Westgate Center Drive, Hadley, Massachusetts 01035–9589; by facsimile to 413–253–8428; or by electronic mail to *AmericanEel@fws.gov.*

FOR FURTHER INFORMATION CONTACT: Heather Bell, at the street address listed in **ADDRESSES** (telephone 413–253–8645; facsimile 413–253–8428). Persons who use a telecommunications device for the deaf (TDD) may call the Federal Information Relay Service (FIRS) at 800–877–8339, 24 hours a day, 7 days a week.

SUPPLEMENTARY INFORMATION: The complete administrative file for this finding is available for inspection, by appointment and during normal business hours, at the street address listed in **ADDRESSES.** The petition finding, the status review for American eel, related **Federal Register** notices, and other pertinent information, may be obtained online at *http://www.fws.gov/northeast/ameel/.*

Background

Section 4(b)(3)(B) of the Act, as amended (16 U.S.C. 1531 et seq.), requires that, for any petition to revise the Lists of Endangered and Threatened Wildlife and Plants that contains substantial scientific and commercial information that listing may be warranted, we conduct a status review and make a finding within 12 months of the date of receipt of the petition (hereafter referred to as a 12-month finding) on whether the petitioned action is (a) not warranted, (b) warranted, or (c) warranted but the immediate proposal of a regulation implementing the petitioned action is precluded by other pending proposals to determine whether any species is threatened or endangered, and expeditious progress is being made to add or remove qualified species from the Lists of Endangered and Threatened Wildlife and Plants.

On May 27, 2004, the Atlantic States Marine Fisheries Commission (ASMFC), concerned about extreme declines in the Saint Lawrence River/Lake Ontario (SLR/LO) portion of the species' range, requested that the USFWS and the National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NMFS) conduct a status review of the American eel. The ASMFC also requested an evaluation of the appropriateness of a Distinct Population Segment (DPS) listing under the Act for the SLR/LO and Lake Champlain/Richelieu River portion of the American eel population, as well as an evaluation of the entire Atlantic coast American eel population (see Finding for definition of DPS) (ASMFC 2004a, p. 1). The USFWS responded to this request on September 24, 2004; our response stated that we had conducted a preliminary review regarding the potential DPS as described by the ASMFC, and determined that the American eel was not likely to meet the discreteness element of the policy requirements due to lack of population subdivision (further analysis is provided under Finding). Rather, the USFWS agreed to conduct a rangewide status review of the American eel in coordination with NMFS and ASMFC (USFWS 2004, p. 1).

On November 18, 2004, the USFWS and the NMFS received a petition, dated November 12, 2004, from Timothy A. Watts and Douglas H. Watts, requesting that the USFWS and NMFS list the American eel as an endangered species under the Act. The petitioners cited destruction and modification of habitat, overutilization, inadequacy of existing regulatory mechanisms, and other natural and man-made factors (such as contaminants and hydroelectric turbines) as the threats to the species.

On July 6, 2005, in response to the petition, the USFWS issued a 90-day finding on the petition (70 FR 38849), which found that the petition presented substantial information indicating that listing the American eel may be warranted. The finding noted concern that the dramatic decrease in recruitment of American eel noted at the Moses-Saunders Dam in Canada (on the St. Lawrence River), coupled with the significant decline seen in the European eel (ASMFC 2000, pp. 12–14), could indicate a decline in the American eel. Information on possible reasons for this suggested decline included the following threats: Commercial harvest, habitat loss and degradation (primarily the loss of wetlands and upper tributary habitat), hydropower turbine mortality, and inadequacy of existing regulatory mechanisms. Other potential threats, such as seaweed harvest, benthic (sea or lake bottom) habitat destruction, alterations of stream flow, disease, predation, and contaminants, were not fully addressed or supported by the information presented in the petition. Further analysis of oceanic variations (such as changes in the Gulf Stream) were recommended in the 90-day finding, particularly in light of the scant direct evidence and the potential for oceanic variations to be compounding or confounding the impact of other threats. Additionally, the 90-day finding concluded that the complex life history and the incompleteness of historical data (abundance, stock composition, life stage mortality rates, and exploitation rates) made it challenging to understand the potential influence of multiple threats to the American eel (USFWS 2005a, p. 38860).

In response to our 90-day finding's request for information for use in the species' status review, we received comments and information on American eel from the majority of the State fish and wildlife agencies within the range of the eel; State universities; State and university museums; the U.S. Forest Service (USFS); National Park Service (NPS); U.S. Geological Survey (USGS); Army Corp of Engineers (ACOE); the Department of Defense; the ASMFC; the Great Lakes Fisheries Commission; Department of Fisheries and Oceans (Canada); Tribal Nations; academics and researchers from the United States, Canada, Japan, and several European countries; hydropower and fishing industries; nongovernmental organizations; private citizens; and other entities. Additionally, we coordinated with the USFWS's International Affairs Program (IAP) to obtain information on international trade and with State and Federal law enforcement officials on illegal trade. Although all countries where the American eel is native were contacted regarding information, there was no available data on eel distribution, habitat use, habitat degradation or loss, or other threats (other than international harvest data) from Central or South America. Distribution information was provided by some Caribbean Islands. Therefore, the status review focused on where data is available within the North American Continent.

A status review allows for additional collection, clarification, and interpretation of information on the status of the species by the USFWS. The resulting status review, from which the 12-month finding is based, relied on our extensive review of the existing literature, data resulting from the 90-day finding request for information, and new information obtained during the status review period. Among the new information we received, the documents most relevant to the status review include the recently completed stock assessments for the Atlantic coast (ASMFC 2006a and b), the American eel data assembled for the Canadian stock assessment (Cairns et al. 2005), and recently completed research on life history and potential threats to the American eel (van den Thillart et al. 2005; Oliviera in USFWS 2006; Machut 2006; Lamson et al. 2006; Devarut et al. 2006; Knights et al. 2006).

Also, because of the large body of literature and the uncertainty surrounding several threats, we hosted two scientific workshops with over 25 scientific experts. The goal of the workshops was to insure that the USFWS properly utilized the best and most current scientific and commercial data available in conducting the status review. To reach this goal, each of the experts was asked a series of facilitated questions to assess the presented information (which included multiple factual inputs, data, models, assumptions, etc.), including the completeness of the literature selected, and to comment on the relevance and quality of the literature for purposes of our status review (see workshop summaries Web site at *http://www.fws.gov/northeast/ameel/*). The USFWS recorded each expert's individual assessments and the basis for those assessments in a compendium (cited in the finding as USFWS 2005b and 2006). Workshop objectives included determining the following: Utility of the information; life history stages vulnerable to certain threats; the geographic scope of the threats; the immediacy of the threats; and uncertainties in the available information and the potential implications of those uncertainties in making a status determination.

The selection of the expert panelists was based on recommendations from within and outside of the USFWS and NMFS (the Services). The panelists selected represented a broad and diverse range of scientific perspectives relevant to the status review of the American eel coming from State and Federal agencies, fishery commissions, Tribes, academia, domestic and foreign research institutions (Canada, Japan, and England), industry organizations, and nongovernmental organizations. Participating individuals had expertise on threats or life history characteristics associated with threats to the American eel.

Therefore, in addition to the published literature, our review considered: (1) Each expert panelist's characterization of the threat (the life stages acted upon by the threat, the severity of the threat, and the timing of the threat) based on their own and other published and unpublished research on the species; (2) the basis for each expert panelist's assessments of the literature in the context of a rangewide status review; and, (3) each expert panelist's assessments of the implications of the uncertainty in the information. This finding therefore builds on, clarifies, reinterprets, and, in some cases, supersedes information presented in the 90-day finding.

In conducting our 12-month finding for American eel, we considered all scientific and commercial information on the status of American eel that we had in our files. Parallels in life history traits that are unknown for the American eel are drawn from other species of Anguilla.

Evolution and Population Structure

The American eel is one of 15 ancient species (evolving circa 52 million years ago) of the worldwide genus Anguilla, whose members spawn in ocean waters, migrate to coastal and inland continental waters to grow, and then return to ocean spawning areas to reproduce and die—a life history strategy known as catadromy (McCleave 2001a, p. 800; Avise 2003, p. 31; Knights et al. 2006, pp. 2–3).

The North Atlantic is home to two, closely related, recognized species of Anguilla—the American eel and the European eel (*A. anguilla*) (Avise 2003, p. 31). Genetic research indicates that the American eel lacks appreciable phylogeographic population structure, meaning that American eels are one, well-mixed, single breeding population, termed panmixia or panmictic (Avise 2003, pp. 34–35). This likely occurs from a combination of the random distribution of the eel's larval stage when they reach continental waters and random mating among all adults throughout the species' range. This is in contrast to many anadromous species (which, even though they have an oceanic phase, return to their rivers of origin to spawn), where mating is within separate populations that are geographically or temporally isolated.

This panmictic life history strategy maximizes adaptability to changing environments and is well suited to species that have unpredictable larval dispersal to many habitats (Stearns 1977 in Helfman et al. 1987, p. 52). Additionally, by not exhibiting geographic or habitat-specific adaptations, eels have the ability to rapidly colonize new habitats and to re-colonize disturbed ones over wide geographical ranges (McDowall 1996 in Knights et al. 2006, p. 7).

Life History

In brief, the life history of the American eel begins in the Sargasso Sea, where eggs hatch into a larval stage known as ''leptocephali.'' These leptocephali are transported by ocean currents to the Atlantic coasts of North America and upper portions of South America. They enter coastal waters, where they may stay, or they may move into estuarine waters or migrate up freshwater rivers, where they grow as juveniles and mature. Upon nearing sexual maturity, these eels begin migration toward the Sargasso Sea, completing sexual maturation en route. Spawning occurs in the Sargasso Sea. After spawning, the adults die; a species with this life history trait is known as a semelparous species. For a detailed description of the life cycle and other life history characteristics, see McCleave 2001a, Tesch 2003, and Cairns et al. 2005. Aspects of the species' life history most relevant to this finding are discussed in more detail below.

Egg and Larval Life History Stage

The egg and larval stage of the American eel occur in the Atlantic Ocean, the Sargasso Sea, ocean currents, and Continental Shelf waters.

Sargasso Sea. The Sargasso Sea is part of the North Atlantic Ocean, lying roughly between the West Indies and the Azores. The Sargasso Sea is part of the western half of a large clockwise gyre (circular pattern of ocean circulation). It is here that American eel eggs hatch into a larval stage known as ''leptocephali.'' The leptocephali are distributed in the upper 300 meters (m) of the ocean and are subject to transport from surface currents in the Sargasso Sea. These surface currents can be complex due to the fronts that form in the Subtropical Convergence Zone (where equatorial and temperate waters meet) primarily in the winter and spring, and the eddies that are likely present year round.

Ocean current transport. The Sargasso Sea includes a powerful western boundary current, the Florida Current and Gulf Stream, which flows to the north and northeast along the Atlantic coast of North America. The Florida Current is the southern half of this flow, from the Straits of Florida to Cape Hatteras (Schott et al. 1988 in Miller 2005, p. 3). The Florida Current transports water from the Caribbean, Gulf of Mexico, and more distant regions through the Straits of Florida. It then combines with Gulf Stream recirculation water from the Sargasso Sea as it flows north of the Bahamas (Marchese 1999, pp. 29, 549), and forms the Gulf Stream off Cape Hatteras, North Carolina. Once past Cape Hatteras, the Gulf Stream (which is at least 48 km or 30 miles offshore but more typically 160 km or 100 miles or greater offshore) usually has pronounced meanders, which, if large enough, can get separated and cast off to the north into the continental slope water (a water mass found in the permanent thermocline between the Gulf Stream and the continental shelf north of Cape Hatteras (35 °N)). The flow of the Gulf Stream continues to the northeast, mostly paralleling the Atlantic coast, towards Europe and becomes the North Atlantic Current (Miller 2005, pp. 3–4).

The majority of the leptocephali enter the Florida Current just south of Cape Hatteras (just south of where the Florida Current enters the Gulf Stream) directly from the Sargasso Sea. The remainder may enter the Florida Current by a more southern route (e.g., transported on the Caribbean Current through the Yucatan Straights (Kleckner and McCleave 1985, p. 89), to the Gulf Loop Current and then to the Florida Current, which would be the route most likely taken for Gulf of Mexico recruitment) (Kleckner and McCleave 1982, p. 329–330; Miller 2005, p. 3).

The distribution of American eel leptocephali in the Florida Current was first described by Kleckner and McCleave (1982, pp. 334–337; 1985, pp. 73–77). Additionally, they found evidence of westward movement of leptocephali across the current toward the coastal waters. Because the distances of transport, to southern and northern points along the Atlantic coast, differ by thousands of kilometers, it has been suggested that the timing of metamorphosis from leptocephali to the next life history stage may determine where individuals arrive in Continental Shelf waters.

Other than likely current transport, we know very little about the American eel leptocephali. Recent studies on other species have indicated that leptocephali may feed on marine snow or specific detrital particles, such as discarded larvacean (planktonic tunicates that secrete a gelatinous house) houses and zooplankton fecal pellets (Otake et al. 1993, pp. 28–32; Mochioka and Iwamizu 1996, p. 447).

Continental shelf waters. The American eel undergoes metamorphosis twice. The first occurs when the leptocephali enter the Continental Shelf waters (the area of shallow seas just off the coast to the area of marked increase in slope to greater depths); the second is during sexual maturation. The leptocephalis' leaf-like, laterally compressed shape transforms during metamorphosis into a reduced, characteristically eel-like shape, as they become transparent ''glass'' eels. Leptocephali are unusual fish larvae that are filled with a transparent gelatinous energy storage material, and they can swim either forwards or backwards (Miller and Tsukamoto 2004 in Miller 2005, pp. 1–2); this may be an important aspect in detraining from (getting off of) the Gulf Stream. According to Miller (2005), this directional swimming appears to be the only way that leptocephali can cross and detrain from the Gulf Stream system and cross the Continental Shelf waters, due to the lack of any persistent oceanic transport mechanism that can account for the large-scale transport of millions of larvae across the current.

Juvenile Life History Stage

Arrival in coastal waters. When juvenile eels arrive in coastal waters, they can arrive in great density and with considerable yearly variation (ICES 2001, p. 2). Arriving juvenile eels (unpigmented ''glass eels'' and pigmented ''elvers'') have been collected and recorded for 10 years from two sites in North Carolina in the Beaufort estuary. Densities as high as 13.5–14.0 eels/100m^3 and as low as 1.5 eels/100m^3 have been recorded (Powles and Warlen 2002, p. 301). In the East River, Canada, Jessop (2000, p. 520) had daily counts of 30,000 elvers entering the mouth of the river. Between May and August 200,000 elvers were recorded by trap method, and a population estimate of 960,000 elvers was conducted by mark-recapture (Jessop 2000, pp. 518–520). Variation in recruitment between years can be quite significant. In the 9 years of records between the years 1982 to 1999, estimated recruitment to the Petite rivière del la Trinité varied roughly four-fold, from a low of 14,014 to a high of 61,308 (ICES 2001, p. 36). Some arrivals remain in brackish (estuarine) or marine (salt) waters, others migrate up rivers to a variety of fresh water habitats, and still others, as they mature, will show inter-habitat movement patterns (Jessop et al. 2002, pp. 217–218; Morrison et al. 2003, pp. 90–92; Cairns 2006a, p. 2; Thibault et al. 2005, p. 36; Lamson et al. 2006, p. 1567; Daverat et al. 2006, p. 2).

Juvenile mortality. Information on mortality rates for all of the life stages is limited. In Jessop (2000, p. 514), the recruitment of elvers to the East River, Chester, Nova Scotia, during May through July was estimated by mark-recapture population estimates to be 960,000 elvers. The population size following migration to recapture sites about 1.3 kilometers (km) upstream during late July–October was 2,894 elvers. These data indicate high juvenile mortality rates, in this case at a rate of 99 percent. This high mortality was attributed to the effects of low pH (4.7–5.0), high initial elver density (4.7 elvers/m^2) (which may lead to predation, including cannibalism, starvation, and competition for space), and predation by resident, presumably older, eels. Vøllestad and Jonsson's (1988 in Jessop 2000, p. 523) research indicates that eel mortality in fresh waters is density-dependent when elver numbers exceed a certain abundance. Although it is not certain if early juvenile mortality is this high throughout the range of the species, this supports the observation, according to Jessop, that oceanic conditions may deliver relatively high quantities of elvers to rivers, such as those along the south shore of Nova Scotia (Jessop 1998 in Jessop 2000, p. 523), even to the point that elver abundances too great for habitat capacity can occur (Jessop 2000, p. 523). Surviving juvenile eels mature into fully pigmented ''yellow eels.''

Mortality rates likely decrease with size. One study in Prince Edward Island, Canada, calculated loss from the population due to mortality and emigration. Estimates of loss in American yellow eels from the Prince Edward Island study are reported at 22 percent, with mortality rates decreasing to 12 to 15 percent as the juvenile yellow eels age (Anonymous 2001 in Morrison and Secor 2003, p. 1498), likely due to lower mortality from predation and starvation as size increases.

Juvenile diet. The enormous dietary breadth of eels reflects their great adaptability with respect to nearly all conditions of water bodies. Yellow eels are opportunistic, consuming nearly any live prey that can be captured. Smaller eels eat benthic invertebrates; larger eels include mussels, fish, and even other eels in their diet. Yellow eels also adapt to seasonal changes, decreasing intake or ceasing to eat during the winter. Eels can also respond to local abundances of appropriately sized prey through the seasons (Tesch 2003, pp. 152–163). This adaptable diet allows for resource partitioning as well as the ability to withstand changes in local environmental conditions and the ability to occupy a geographically wide variety of habitats.

Density-dependent dispersion. As young eels begin to grow, density-dependent competition promotes eels to disperse into less crowded areas (Feunteun et al. 2003, pp. 201–204; Ibbotson et al. 2002 in Knights et al. 2006, p. 10). Aggressive interactions at high density inhibit feeding and growth, but stimulate dispersive swimming activity in smaller eels (Knights 1987 in Knights et al. 2006, p. 10), the latter likely as a defense against predation. As size differences in these juveniles increase, cannibalism can also be an important cause of mortality (Knights 1987 in Knights et al. 2006, p. 10). Density dependent dispersion ensures wider distributions, further minimizing intra-specific competition. Benefits of density dependent dispersion include selection of optimal habitat productivity and temperature, lower predation risks, rapid colonization or re-colonization of habitats, and avoidance of inter-specific competition. Larger individuals farther upstream tend to become more sedentary and occupy territories, densities of eels decline, and females predominate (Feunteun et al. 2003, p. 201).

Distribution clines. It has been suggested that there are latitudinal clines in eel distribution related to river typologies. For example, the American eel tends to extend farther inland in southerly lowland drainages compared to distributions in the shorter and steeper post-glacial stream systems in the Northeast (Jessop et al. 2004 in Knights et al. 2006, p. 11). Smogor et al. (1995, p. 799) and Knights (2001 in Knights et al. 2006, p. 8) have documented decreases in densities with increasing distance from the Continental Shelf in a predictable pattern, likely as a result of density dependant dispersion and mortality due to predation. Although mean watershed densities decrease by an order of magnitude with distance inland from the Continental Shelf, mean biomass only declines by about 50 percent because mean body weight and eel length increase (and hence relative fecundity). This, according to Knights et al. (2006, p. 10), helps maintain biomass relative to carrying capacity. Machut (2006, p. 13) indicates that as barrier intensity increases, so does eel growth above the barrier. Recent research (Knights et al. 2006, pp. 11–13) has documented that as eel density decreases, the proportion of females increases, which, assuming females are the limiting sex, would be, according to Knights et al. (2006, p. 13), a compensatory mechanism during times or in areas of low density.

Sexually Maturing Life History Stage

Sex determination. There are no morphologically differentiated sex chromosomes in the American eel (McCleave 2001a, p. 803). Prior to sexual differentiation, eels are intersexual, meaning they can develop into either sex. It is only when yellow eels reach a length of about 20–35 cm that it is possible to distinguish males from females visually, and there is considerable variation in age and size at differentiation. The determination of sex is likely influenced by environmental factors, including eel densities (Tesch 2003, pp. 43–46). Studies indicate that as the density of eels in a particular area increases the number of male eels increases; decreasing density favors more females. It has been argued by Knights et al. (2006, p. 13), that an advantage of this life history strategy is that when recruitment declines, so will density and tendencies to migrate far upstream in rivers. In turn, this will lead to relative increases in the number of (larger) females and hence compensatory increases in fecundity. This may take a number of generations (and hence decades) to manifest itself, but this strategy confers enormous benefits in the face of threats, past, present and future, such as tectonic events and changes in ocean currents and climate (Knights et al. 2006, p. 13).

Silvering. After a number of years, the yellow eels begin metamorphosis. Beginning at 3 years old and up to 24 years, with the mean becoming greater with increasing latitude (e.g., 6–16 years in the Chesapeake Bay region; Helfman et al. 1987, pp. 44–45; and 8–23 years in Canada; Cairns et al. 2005, p. 11), yellow eels metamorphose into ''silver eels'' (Cairns et al. 2005, p. 13). This metamorphosis from bottom-oriented yellow eels to silver eels (termed ''silvering'') is a key physiological event preparing these future spawners for oceanic migration and reproduction (van den Thillart et al. 2005, p. 12).

Environmental factors may play a role in the triggering of silvering. Habitat conditions, such as food availability and temperature, will influence the size and age of silvering eels via growth conditions. Thus, variation in length and age at maturity can occur in different habitats (e.g., freshwater habitat versus estuarine habitat) within a restricted geographic range and over larger geographic scales as well.

The length of the growing season and the temperature are negatively correlated with latitude, so age at maturity is strongly correlated with latitude (McCleave 2001a, p. 803). Characteristics of silver eels vary across the species' range. Eels from northern areas, where migration distances are great, show slower growth and greater length, weight, and age at migration, preparing them, it could be assumed, for the longer migration.

Indeed, favorable growth conditions cause eels to silver more rapidly (Vøllestad and Jonsson1988 in Jessop 2000, p. 522; Vøllestad 1988 and 1992 in van den Thillart 2005, p. 56; De Leo and Gatto 1995 in van den Thillart 2005, p. 56) such as is the case in aquaculture, under experimental conditions (Tesch 1991 and Beullens et al. 1997 in van den Thillart et al. 2005, p. 56), or in brackish water and at low latitudes (Lee 1979 and Fernandez-Delgado et al. 1989 in van den Thillart et al. 2005, p. 56). For example, Morrison et al. (2003, p. 95–96) found annual growth rates in brackish water were two times higher than growth rates of eels that resided entirely in fresh water. Also American eels in U.S. southern Atlantic coast waters develop into silver eels about 5 years sooner than northern populations (Hansen and Eversole 1984, p. 4; Helfman et al. 1984, p. 139), likely as a result of warmer, more stable water conditions (Helfman et al. 1984, p. 138).

Variation in maturation age benefits the population by allowing different individuals of a given year class to reproduce over a period of many years, which increases the changes of encountering environmental conditions favorable to spawning success and offspring survival. For example, variability in the maturation age of eels born in 2006 may result in spawners throughout 2010–2030, during which time favorable environmental conditions are likely to be encountered at least once.

Additionally, males and females differ in the size at which they begin to silver. Eels appear to need to reach a certain size to begin the silvering process, with this size increasing with age (thus, rapidly growing eels will silver at smaller sizes than slow-growing eels). In males, silvering happens at a very early stage, at a size typically greater than 35 centimeters (cm). In females, silvering happens at a size greater than 40 to 50 cm (Goodwin and Angermeier 2003, p. 530; van den Thillart et al. 2005, pp. 31, 55).

Actual metamorphosis is a gradual process occurring during the summer, and in the fall eels metamorphosing in preparation for migration back to the spawning grounds have a silvery body color, enlarged eyes and nostrils, and a more visible lateral line (Dave et al. 1974; Lewander et al. 1974; Pankhurst 1983; and Barni et al. 1985 in van den Thillart 2005, p. 12). As the structure and metabolism of the liver changes, the swim-bladder also changes, allowing for increased gas deposition rates and decreased loss of gas (McCleave 2001a, p. 804).

A drop in temperature appears to trigger the final events of metamorphosis (gut regression and cessation of feeding), which will lead to migratory movements under the appropriate environmental conditions. It is theorized that responding to a drop in temperature would help to synchronize out-migrating eels, thus increasing their chances of reaching the Sargasso Sea simultaneously. Conversely, increasing temperatures, delays in migration, or possibly low fat content will cause eels to start feeding again and to revert to a yellow resident stage. This would happen in the natural environment if eels did not reach the sea before the end of the migrating season. It has been observed that even after eggs and sperm have developed, eels are capable of gut regeneration and feeding (Fontaine et al. 1982, Dollerup and Graver 1985, in van den Thillart et al. 2005, p. 56). Van den Thillart et al. (2005, p. 56) confirmed that silvering may occur more than once in the lifetime of an eel. It has been said that this phenomenon would explain the extreme variability in age and size of silver eels. It has been hypothesized that conditions encountered during oceanic migration, such as the high pressure they would experience at depth in the open ocean, may complete the sexual maturation of eels (Fontaine et al. 1985 in van den Thillart et al. 2005, p. 13).

Outmigration Life History Stage

Energy requirements. To successfully complete the migration from the continent to the Sargasso Sea (out-migration), great endurance and an extensive fat reserve are required. Larger, fatter eels have an advantage over smaller eels in reaching the Sargasso Sea and having sufficient energy stores to reproduce. Eels are very efficient swimmers (eels swim approximately four to six times more efficiently than salmonids), and larger eels appear more efficient than smaller eels (van den Thillart et al. 2005, pp. 106–107). Also, larger eels usually have larger fat stores per body weight. Silver eels have ceased feeding, and use their stored fat for energy during their migration and for completing gonadal growth. In a study conducted on European eel, the most recent estimate of necessary energy (fat) needed to successfully complete the migration to the Sargasso Sea from Europe and spawn is 20 percent fat reserves, of which 13 percent is for transport, and an additional 7 percent for completing gonadal growth. In European silver eel, about 50 percent of the eels studied had a fat percentage of 20 percent (van den Thillart et al. 2004 in van den Thillart et al. 2005, p. 109).

It is unknown if American eels require 20 percent fat reserves. American eels travel a shorter distance to reach the Sargasso Sea than do European eels. Actual distances, routes, and depths of migration for adult eels are unknown. Distances traveled by migrating silver American eels likely vary from under 1,500 km to over 4,500 km, shorter than the 5,000 km to 7,000 km likely traveled by European eels. An American eel maturing in the Mississippi River, Louisiana, would travel a distance of over 2,200 km; from South Carolina, 1,440 km; from Chesapeake Bay, Virginia, 1,550 km; from Newfoundland, Canada, over 2,800 km (McCleave 2001a, p. 805); and from western Lake Ontario, over 4,500 km. Silver eels, it has been hypothesized by Knights (2003, p. 240), may follow the deep currents (for American eel, the Deep Western Boundary Current) to return to the Sargasso Sea. However, others believe the American eel migrates in the upper portions of the ocean (see van Ginneken and Maes 2005, pp. 385–387; Tesch 2003, pp. 206–207).

Fecundity. Fecundity also varies with size. Fecundity increases exponentially with length, ranging from about 0.6 million to almost 30 million eggs depending on the size of the female (McCleave 2001a, p. 804). As an example, in the lower Potomac watershed, the average silver female length of 734 mm would produce 2.7 million eggs; farther up the watershed the average silver female length of 870 mm would produce 5.2 million eggs (Goodwin and Angermeier 2003, p. 533). Fecundity is also linked to the habitat which the eel occupies. In an eel farm growth experiment, favorable nutrition was one of two factors (the other being genetic heterozygosity, where 2 different alleles are at one loci) producing eels with a high reproductive capacity (van den Thillart et al. 2005, p. 232). This high fecundity is thought to compensate for very high larval mortality (reported by Knights et al. 2006, p. 4, as most probably well in excess of 99 percent).

Spawning. Spawning takes place in the Sargasso Sea (Schmidt 1922 in Boëtius and Harding 1985, p. 122). Here, in the area where northern and southern waters meet, it has been hypothesized that there is some unidentified feature of the surface water (perhaps the abrupt horizontal temperate change of the frontal zone located within the subtropical convergence) that serves as a cue for migrating adults to cease migration and begin spawning (Kleckner et al. 1983, p. 289; Kleckner and McCleave 1988, pp. 647–648; Tesch and Wegner 1991 in Miller 2005, p. 1). Spawning has not been witnessed by humans, but the assumption is that adult eels die after spawning.

Range

The extensive range of the American eel includes all accessible river systems and coastal areas having access to the western North Atlantic Ocean and to which oceanic currents would provide transport. These drainages and coastal areas are along more than 50 degrees of latitude (from 5° to 63°) of the western North Atlantic Ocean coastline, from Northern Brazil/Venezuela to southern Greenland (Scott and Crossman 1973, pp. 624–625; Tesch 2003, pp. 92–97; Helfman et al. 1987, p. 42), including most Caribbean Islands and Bermuda, the eastern Gulf of Mexico and associated drainages including the extensive Mississippi River watershed (e.g., Mississippi River, Ohio River, Tennessee River, Arkansas River, and Missouri River) as far north as Minnesota, the Gulf of St. Lawrence and the associated rivers, and Lake Ontario and associated drainages. It is believed that the eel was absent from the waters of Lakes Erie, Huron, and Superior before the completion of the Welland Canal in 1829 (Patch 2006, p. 2). In 1878, the Michigan Fish Commission planted young eels in southern Michigan waters, and for more than a decade, beginning in 1882, the Ohio Fish Commission released young eels throughout Ohio, including drainages to Lake Erie (Trautman 1981, pp. 192–193) (Figure 1). This extensive range should provide the American eel with a buffer against adverse conditions, as spawners would still be coming from areas not experiencing adverse conditions, and would, due to random dispersal and relatively homogeneous genetic structure, be capable to successfully re-colonize areas once the threat has abated.

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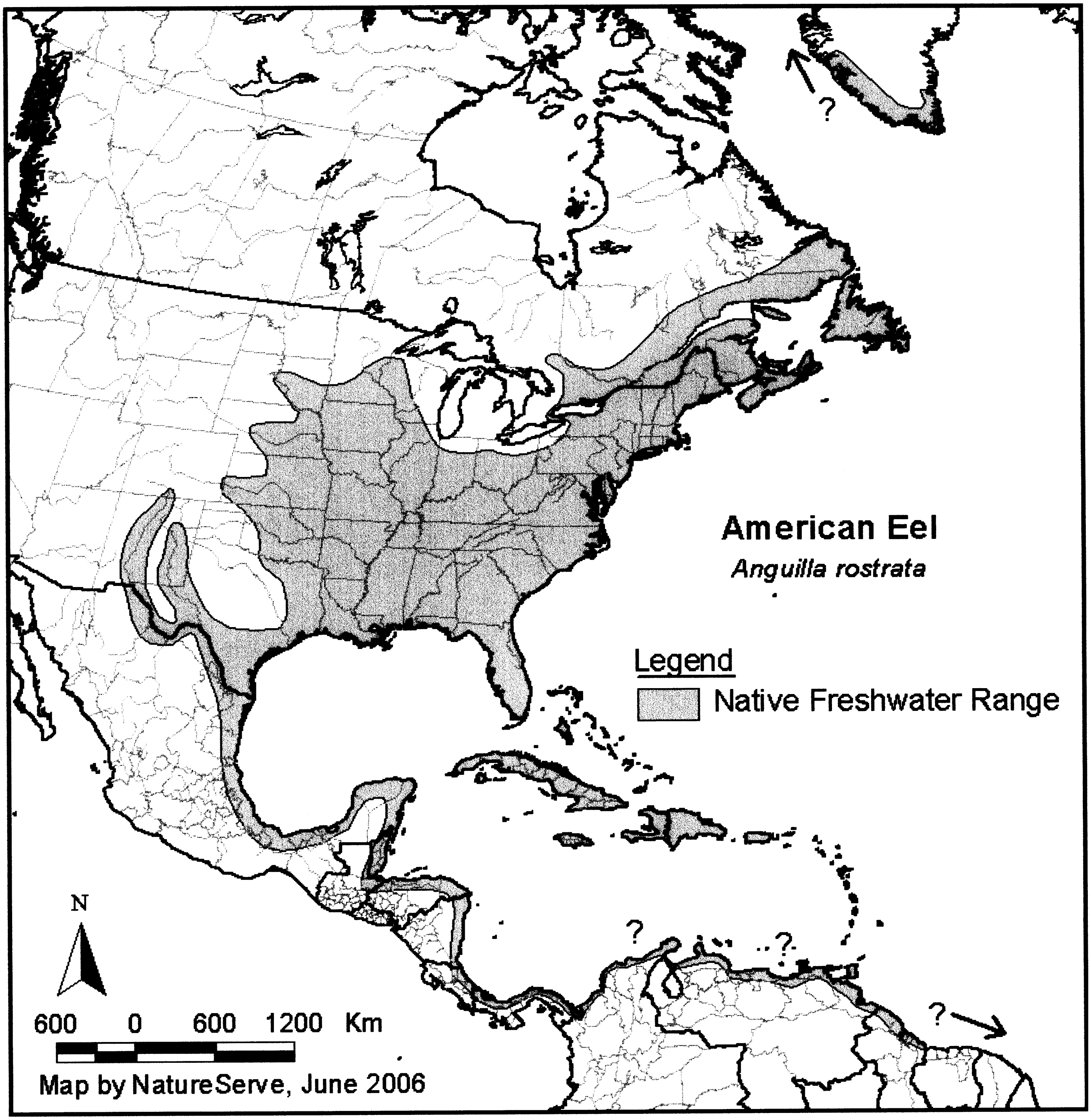

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It has been reported in other documents that Boëtius and Harding (1985) estimated that the American eel range covers more than 10,000 km of coastline; however, we could not locate this information. Utilizing current mapping technology, our estimate of the available coastline (including barrier islands) from Maine to Texas (Atlantic and Gulf coast) is 29,612 km (Castiglione 2006, p. 1).

As a result of oceanic currents, the majority of the American eel population is located along the Atlantic seaboard of the United States and Canada. The historic and current distribution of the American eel within its extensive continental range is well documented along the United States and Canadian Atlantic coast, and the SLR/LO. The distribution is less well documented and likely rarer, again due to currents, in the Gulf of Mexico, Mississippi watershed, and Caribbean Islands, and least understood in Central and South America.

Habitat

The American eel is said to have the broadest diversity of habitats of any fish species (Helfman et al. 1987, p. 42) by occupying multiple aquatic habitats. From an evolutionary standpoint, this generalist use of habitats is favored in fluctuating environments, while specialists excel under constant or slowly changing environmental conditions (Richmond et al. 2005, pp. 279–280).

During their spawning and oceanic migrations, eels occupy saltwater, and in their continental phase, they use all salinity zones: Fresh, brackish, and marine (for detailed habitat use by life stage, see Cairns et al. 2005). Eels occur in waters highly productive to fish species and those that are not, and from waters of near tropical temperatures to waters that are seasonally ice-covered (McCleave 2001a, p. 800).

Growing eels are primarily benthic, utilizing substrate (rock, sand, mud) and bottom debris such as snags and submerged vegetation for protection and cover (Scott and Crossman 1973, p. 627; Tesch 2003, pp. 181–183). In Canadian waters, American eels hibernate in mud during the winter. Wintering areas include fresh water, brackish estuaries, and bays with full strength salt water (Cairns et al. 2005, p. 3.4.6).

Barring impassable natural or human-made barriers, eels occupy all freshwater systems, including large rivers and their tributaries, lakes, reservoirs, canals, farm ponds, and even subterranean springs. The anquillid (eel-shaped) body form allows for climbing when at young stages and under certain conditions (e.g., rough surfaces), allowing it to pass up and over some barriers encountered during upstream migrations in freshwater streams (Craig 2006, pp. 1–4). Eels are able to survive out of water for an exceptionally long time (eels can meet virtually all their oxygen needs through their skin), as long as they are protected from drying (for which their ability to produce mucus is of great adaptive significance), and eels have been seen using overland routes (while moist) when they encounter a barrier, explaining their entrance into landlocked waters (Tesch 2003, pp. 184–185) and their presence above numerous dams and weirs (USFWS 2005b, pp. 16–18).

Abundance. Abundance (density) and distribution of eels within habitats may be a function of distance from the ocean and may not be related to habitat features (Smogor et al. 1995, pp. 796–797) (see also *Density-Dependant Dispersion*). According to Smogor et al. (1995, p. 799) when examining Virginia streams, they found little connection between habitat features and the distribution and abundance of American eels at least at a large scale. Their results, they suggest, demonstrate a diffusion pattern of eel occurrence. This lack of eel-habitat relations (at least at a large scale) within freshwater systems suggests that comparison of abundance for purposes of identifying quality habitat would be misleading. Rather, it has been suggested (USFWS 2006, pp. 13–14, 22) that the reproductive contribution of an area to the total American eel population would be the best manner of identifying quality habitat; however, reproductive contribution estimates from throughout the range of the American eel are not available. Examples of densities provided below are to illustrate the variation of densities, not for comparison of habitat importance. Machut (2006) summarized freshwater and brackish water density research and standardized to eel densities per 100m^2. In Lake Champlain, Vermont, densities ranged from 2.32–6.36 eel/100m^2 (LeBar and Facey 1983 in Machut 2006, p. 50). In a tidal creek, Georgia, densities ranged from 1.82–2.32 eel/100m^2 (Bozeman et al. 1985 in Machut 2006, p. 50). A Massachusetts salt marsh yielded densities of 8.46–9.28/100m^2 (Ford and Mercer 1986 in Machut 2006, p. 50). In Machut's own study in the Hudson River freshwater tributaries densities ranged from 0.28–155.06/100m^2 (Machut 2006, p. 50), while in brackish waters Morrison and Secor (2003 in Machut 2006, p. 50) reported densities of 0.03–0.24/100m^2 . In four Maine freshwater rivers, densities ranged from 1.80–35.40/100m^2 (Oliveira and McCleave 2000, p. 144). Recent population estimates of juvenile eels (mostly elvers) on the South Anna River in Virginia were 1.88 eels/100m^2. On the North Anna River, where the eels were smaller, the population estimate was greater at 4.48/100m^2 (Odenkirk 2006, p. 1). No estimates of abundance or density are yet available for marine waters.

Habitat associations at a finer scale, such as areas within a lake, have recently been researched by Cudney (2004). In her studies, she was able to associate certain short-term habitat conditions, such as non-stagnant waters and to a lesser extent long-term habitat features such as water depth and percent organic matter, to a higher probability of eel capture (Cudney 2004, pp. 57–60).

Facultative Catadromy. Contrary to the earlier dominating paradigm that the eel growth phase is restricted to fresh water, it has been suggested that brackish (or estuarine) waters produce eels that grow faster, mature earlier, and emigrate as silver eels sooner than eels in fresh water, and that some eels complete their life cycle in brackish or marine waters without ever entering fresh water. Facultative catadromy, therefore, refers to migrations into fresh water as not being obligatory (Tsukamoto and Arai 2001, p. 2651).

Morrison et al. (2003, p. 94) found annual growth rates in brackish water were two times higher than growth rates of eels that resided entirely in fresh water. The mechanism for this higher growth in brackish water is not well understood. Possible causes include an increase in quality or quantity of food, increase in habitat quality (Helfman et al. 1987 in Morrison et al. 2003, p. 94), lower resting metabolism resulting from living in near-isoosmotic (same salinity within the eel as the external environment) conditions, increased water temperature (which reduces the amount of time that eels are dormant during winter) (Walsh et al. 1983 in Morrison and Secor 2003, p. 1499), reduced effects from parasites, decreased predation, or decreased intra- or inter-specific competition. Morrison and Secor (2003, p. 1499) hypothesized that the higher brackish-water eel growth measured on the Hudson River is general to most large North American estuaries.

Two other studies became available during our status review, which provided data on use by eels of marine habitats during the eel growth phase (Daverat et al. 2006; Lamson et al. 2006). The first study, by Daverat et al. 2006, looked at habitat plasticity in the American, European, and Japanese eel (*A. japonica;*) the second, by Lamson et al. (2006), at American eel in Canadian waters. In the first study, habitat use consisted of either residency in one habitat (fresh, brackish, or marine) or movements between habitats. Seasonal or minor (1 or 2) movement patterns were seen from brackish water to fresh water and vice versa. Single habitat switch events occurred, usually between 3 and 5 years of age. ''Nomadic'' movement between water masses of different salinity was common; the differences in productivity between freshwater and brackish habitats (and the resulting lower growth of eels in temperate freshwater sites), the authors state, might explain this phenomenon. Occurrence of eels with no freshwater experience was demonstrated, but such eels accounted for a smaller proportion of the overall sample than did eels with some (even brief) freshwater experience. Another interesting result was that eels tend to prefer brackish and marine habitats for feeding at the northern extremes of their range. The authors also suggest that this high degree of habitat use plasticity suggests a remarkable ''bet hedging'' strategy for angullids as a group (Daverat et al. 2006, p. 11). In the second study, conducted on American eels in Canada, marine (saltwater) resident eels were the dominant migratory contingent of eels in saltwater bays (85 percent). Resident eels were established in salt and freshwater habitats by the year after their arrival in continental waters. Eels that shifted between habitats increased their rate of inter-habitat shifting with age. This study also showed that plasticity of habitat usage is the norm among eels, and that the American eel life cycle can be completed in marine waters (Lamson et al. 2006, p. 1572). A study of Japanese eel found that estuarine (43 percent) and marine (40 percent) eels contributed more spawners than did eels from freshwater areas (17 percent), with some seasonal differences. Additionally, the study noted that eels from all three habitats began their marine spawning migration at about the same time. The implication here is that eels from all habitats can mix together during spawning migration and potentially contribute to the next generation (Kotake et al. 2005, p. 220). In Tsukamoto et al's evolutionary perspective, the authors hypothesize, based on Inoue 2001, that molecular evidence might suggest that catadromous Anguillidae come from deep-sea eels, with a migration loop that extended to coastal waters and incidentally visited estuaries; these eels may have eventually obtained a reproductive advantage because of higher food availability in estuaries than in freshwater (Tsukamoto et al. 2002 in Miller 2005, p. 2).

According to Lamson et al. (2006, p. 1568), Édeline and Élie (2004) reported that European glass eels have distinct individual salinity preferences. This implies that young eels separate into migratory contingents upon arrival on the coast, with salt-seeking eels remaining in marine waters while fresh-seekers ascend into fresh waters.

The benefits of facultative catadromy include resource partitioning, by minimizing intra-specific competition between life stages and cannibalism of young by adults. Additionally, there are growth-temperature benefits, as shallow brackish and fresh waters (especially still waters) will heat up faster in the spring and summer than marine waters. Although not tested by any large-scale quantitative distribution data, the effective reproductive contribution of brackish/marine habitats may be substantial (Tsukamoto and Arai 2001, p. 275; Jessop 2002, p. 228; Kotake et al. 2005, p. 220; Knights et al. 2006, pp. 12–13; Cairns 2006a, p. 1). Densities may be relatively low in coastal waters, but for European eel in England and Wales, Knights et al. (2001 in Knights et al. 2006, p. 13) calculated that estuarine and shallow coastal waters (estimated at 5,000 km^2) exceed that of freshwater (1,035 km^2).

Clinal Variations. American eels show clinal variation (gradual changes over a geographic area) in their growth rates and size at maturity between the southern and northern portions of their range. Although mostly a warm water species, Anguillids are eurythermal (tolerant of a wide range of temperatures) and can survive extremes by migratory and cryptic behaviors. Even so, growth seasons inevitably shorten with increasing latitude. This produces clines as you move north of slower growth rates and larger size at maturity, thus retaining relative fecundity with increasing latitude (Knights et al. 2006, p. 6).

Population Status

Typically an evaluation of population status for a 12-month finding would include a rangewide estimate of population size and information on the demographic structure of the population and subpopulations as well as population trend information in context with historical data, and possibly an evaluation of the long-term viability of the current population through a population viability analysis model.

No rangewide estimate of abundance exists for the American eel. Information on demographic structure is lacking and difficult to determine because the American eel is a single population (panmixia) with individuals randomly spread over an extremely large and diverse geographic range, with growth rates and sex ratios environmentally dependent. Because of this unique life history, site-specific information on eels must be evaluated in context with its significance to the entire population. Determining population trends is challenging because the relevant available data is limited to a few locations that may or may not be representative of the species' range and little information exists about key factors such as mortality and recruitment which could be used to develop an assessment model. Furthermore, the ability to make inferences about species' viability based on available trend information is hampered without an overall estimate of eel abundance. Despite these challenges we have determined the species currently appears stable, as we explain below.

The Stock Assessment Committee of the ASMFC recently assessed the ''stock status'' of the American eel (ASMFC 2006a), and this assessment was subsequently reviewed by an independent panel of scientists (ASMFC 2006b). The Stock Assessment Committee concluded that the status of the stock is uncertain as a result of insufficient data. Their conclusion was based on the review of nine indices, two were fisheries-dependent and seven were fisheries-independent. Of these indices, one index shows an upward trend over time, one shows no trend, and the remaining seven show a downward trend (ASMFC 2006a, p. x). The committee hypothesized that the indices exhibiting a downward trend suggest that the stock is at or near documented low levels. The glass eel data from two Atlantic Coast sites were not used, and the panelists who reviewed the stock status felt that these indices were a valuable asset. These panelists interpreted the absence of a declining trend in glass eel abundance in either series over the last 14 to 15 years as the only positive indicator that recruitment, at least to the glass eel stage to these portions of the coast, had not declined in concert with some of the yellow eel indices (ASMFC 2006b, p. 4). The ASMFC stock status assessment has limited value in the 12-month finding because the purpose of the ASMFC stock status assessment is to inform management of the commercial

American eel fishery by determining allowable harvest, not to look specifically at long-term viability of the species.

Recently Canada completed its review of the American eel status within Canadian waters as part of the Committee on the Status of Endangered Wildlife in Canada's (COSEWIC) review for possible listing under their version of the Endangered Species Act, known as Species At Risk Act (SARA). This review also was more similar to a stock status assessment than a population viability analysis. They determined that indicators of the status of the total Canadian component of this species were not available. Their evaluation of the data (indices of abundance in the upper SLR/LO declined by approximately 99 percent since the 1970s and four out of five time series from the lower St. Lawrence River and Gulf of St. Lawrence declined) led them to apply the Special Concern designation (COSEWIC 2006, p. III). Because the COSEWIC review focuses on the status of American eels in Canadian waters, the report also discussed the ''rescue effect.'' In the hypothetical scenario where the American eel became depleted or extirpated within Canadian waters external components would ''rescue'' the species in Canada. These external components refer to the young eels from the Sargasso Sea that are from American eels whose parents originated from U.S. waters, and experience random dispersal due to oceanic currents which would continue to deposit leptocephali into Canadian waters (COSEWIC 2006, p. 43).

Together, however, these reports provide a more recent presentation of the individual data sets than was available in the stock status report by the International Council for the Exploration of the Sea or ICES (2001, pp. 51–52), which was the only stock assessment available at the time of the 90-day finding published on July 6, 2005 (70 FR 38849). As a result of these factors, our assessment of the American eel population status will utilize the available information to: (1) Provide context of historical reports and current landings data as a surrogate for absolute abundance estimates; (2) evaluate the data from each different life stage and the significance of that life stage when evaluating the population status of the species including trend data in specific geographic areas and each area's significance to the population status of the species; and (3) evaluate the data to determine if there is a sustained downward trend in a location or locations that would be considered representative of the entire range. Together these will provide the basis for our assessment of whether the species is currently being impacted by threats to the degree that the American eel meets the definition of threatened or endangered. In addition, in the 12-month finding we also take into account the species' life history characteristics and compensatory mechanisms (see Background and for further discussion).

(1) Historical and Current Information

Historically eels were a significant winter food source for Native Americans (see Casselman 2003, for a compilation of prehistoric and historic information from the United States and Canada) and later for European settlers. However, qualitative rather than quantitative information is all that is available from these early times. In the early 1900s, records from commercial fisheries began to appear. For example, weirs at Oneida Lake, Canada, caught 100 metric tons (220,000 pounds) annually of emigrating eels (Adams and Hankinson 1928 in Casselman 2003, p. 260). Casselman cites the subsequent construction of dams and canals, which restricted access to the lake as the reason for its eventual extirpation from Lake Oneida. Given the size of the harvest, Casselman concludes that recruitment immigration in the past was much more extensive and probably much greater than in recent times.

Although the current status of American eels cannot be described in absolute terms because rangewide estimates of abundance do not exist (ASMFC 2006a, p. viii; ASMFC 2006b, pp. 3, 13), we provide below recent ASMFC and COSEWIC landings data (long-term fishery independent indices do not exist) that indicate that the order of magnitude of yellow and silver phase eel abundance is probably in the many millions. In the past decade, commercial fisheries in the United States and Canada have landed approximately 800 metric tons (1.8 million pounds) of yellow and silver phase American eels annually (ASMFC 2006a, p. 82). These landings data provide a general sense of eel abundance if we make assumptions about the size and relative proportion of eels that are landed. Specific data on the size of eels harvested were not available, but 45 cm was considered a reasonable estimate (Cairns 2006b, p. 1). The average weight of American eels 45 cm long is 156 grams (g) (Cairns 2006b, p. 1), which indicates that 800 metric tons is equivalent to over 5 million eels. Assuming a high capture efficiency of 25 percent for the eel fisheries (Caron et al. 2003, p. 235) suggests that the post-fishery abundance (i.e., 75 percent are not captured) of yellow and silver phase eels is greater than 15 million within the areas fished. Given that not all areas within the range of the eel are fished, this number would represent a minimum. These calculations are not intended to be used as a formal estimate of population size, but simply to provide the context that large American eels, throughout their range, likely number in the many millions.

(2) Trend Data From Different Life Stages and Locations

Trends in American eel abundance from fishery-independent indices (e.g., data from surveys and research) varied among locations and life stages during the past 10–25 years. Data from yellow eels (which may include silver eels) and glass eels (and elvers) are presented below.

Yellow eel. Four indices (including Maritime rivers in Canada and a standardized U.S. coastwide yellow eels abundance index) did not exhibit trends (ASMFC 2006b, p. 3). Indices from freshwater and tidal sites distributed from the mid-Atlantic region north to Canada and the St. Lawrence River indicated a statistically significant declining trend in yellow eel abundance at three sites. Two of these indices, Lake Ontario and the Chesapeake Bay index, had strong and statistically significant declining trends over the recent 1994 to 2004 time period, with 10-year declines in the order of 50 percent in the Chesapeake Bay index to 99 percent in the Lake Ontario indices (ASMFC 2006b, p. 3). Smaller declines (15 percent) were reported in the St. Lawrence estuary (COSEWIC 2006, p. vi). Recent data suggest that declines may have ceased in some Canadian locations; but the positive trends in some indicators for the Gulf of St. Lawrence are, the COSEWIC report states, too short to provide strong evidence of an increasing trend (COSEWIC 2006, p. 58).

It should be mentioned that yellow eel indices may reflect local or regional impacts, such as impacts from harvest or turbine mortality (see Factors B and E for further discussion). Additionally, yellow eels have not yet been subject to mortality that may occur during their oceanic outmigration to the Sargasso Sea. Therefore, yellow eel indices are not the best indicator for estimating annual reproductive success.

Evaluation of the Significance of Upper SLR/LO. The extreme decline in eels migrating up to the upper SLR/LO, as tallied at the Moses-Saunders eel ladder, has focused attention on the potential impact of that decline to the overall status of the American eel;

however, COSEWIC states that a rigorous way to quantify this impact to the overall population has yet to be developed (COSEWIC 2006, p. 35). The suggestion is that the reproductive contribution to the overall American eel population from the upper SLR/LO may be disproportionately larger than from other freshwater portions of the range because the American eels in the upper SLR/LO are almost exclusively female and highly fecund (producing many eggs) due to their large size, and the watershed is of considerable size. Two methods for estimating the relative reproductive contribution were presented in the COSEWIC report (2006, pp. 35–41), but both methods, they state, are based upon questionable assumptions and large uncertainties that reduce confidence in the results. Additionally, contributions from marine and estuarine waters were not considered in the analysis. According to COSEWIC some sources of uncertainty suggest that it is more probable that the methods overestimate, rather than underestimate, the reproductive contribution of the St. Lawrence River basin (COSEWIC 2006, p. 41).

Glass eels. Indices of glass eel recruitment at the only two U.S. sites with long-term data (North Carolina and New Jersey) did not exhibit a declining trend over the last 14–15 years (ASMFC 2006b, p. 4). Recruitment estimates into Canadian rivers are available for two Nova Scotian sites. The East River, Sheet Harbour, abundance series is the longest elver series available for the species. Annual recruitment varied without any upward or downward trend from 0.1 to 0.5 million elvers between 1989 and 1999 (Jessop 2003a in COSEWIC 2006, p. 28). In the East River, Chester, the total run of elvers peaked at 1.7 million in 2002. Since the overlap periods of the two series are strongly correlated, a combined index of 13 years was interpreted in the COSEWIC report. Elver recruitment showed inter-annual variability, but no indication of decline between 1989 and 2002 (COSEWIC 2006, p. 28).

Glass eel counts, also called recruitment indices, are the best measure we have to annual reproductive success (see section immediately below).

(3) Evaluation of Trend Information

Of the available index data for the different American eel life history stages, we have determined that glass eel indices best represents the species status rangewide. Although we do not have glass eel indices from the entire range, the random nature of the leptochephali dispersal allows us to consider these data representative of the reproductive success of the species. As described above, there is not evidence of a sustained downward trend of these glass eel indices; therefore, we conclude that the American eel is not undergoing a sustained downward trend at a population level.

In summary, the best available scientific and commercial information indicates that despite a population reduction over the past century, eels remain very abundant and occupy diverse habitats over an exceptionally broad geographic range. Because of the species' unique life history traits areas which have experienced depletions may experience a ''rescue effect'' allowing for continued occupation of available areas without concern for genetic fitness. Trends in abundance over recent decades vary among locations and life stages, showing decreases in some areas, and increases or no trends in other areas. Limited records of glass eel recruitment do not show declines that would signal recent declines in annual reproductive success or the effect of new or increased threats. Taken as a whole, a clear trend cannot be detected in species-wide abundance during recent decades, and while acknowledging that there have been large declines in abundance from prehistoric and historic times, we have determined the species currently appears stable.

Summary of Background

The American eel is an extremely wide ranging species, continuing to occupy most of its historic range. This species is highly plastic in both its behavior and physiology, being able to occupy habitats ranging from sea water to freshwater lakes. This species also exhibits adaptive behaviors such as switching between habitats and diets. These life history characteristics provide the American eel with the ability to withstand a wide range of, and changing, environmental conditions. The best available scientific and commercial information does not indicate any sustained declining trend in the American eel population.

Previous Federal Actions

On July 6, 2005, we published a 90-day finding (70 FR 38849) which found that the petition to list the American eel presented substantial scientific and commercial information indicating that listing the American eel may be warranted. That document initiated a status review to determine if listing the species was warranted. This 12-month finding provides the results of that status review.

Summary of Factors Affecting the Species

Section 4 of the Act (16 U.S.C. 1533), and implementing regulations at 50 CFR 424, set forth procedures for adding species to the Federal Lists of Endangered and Threatened Wildlife and Plants. In making this finding, information regarding the status and threats to this species in relation to the five factors provided in section 4(a)(1) of the Act is summarized below. We examined each of these factors as they relate to the current distribution of American eel.

Regional information was more obtainable from the Atlantic coast, likely due to the economic interest in the American eel. We have divided the range of the American eel into seven areas for purposes of discussion: (1) The Gulf of Mexico (from south Texas to the southern tip of Florida); (2) The Mississippi watershed (Lake Itasca in Minnesota to the Gulf of Mexico); (3) The U.S. Atlantic coast (the southern tip of Florida north to Maine's border with Canada); (4) The Canadian Atlantic coast (Canadian border north to Labrador, and including the Gulf of the St. Lawrence); (5) The St. Lawrence River and Lake Ontario (from the Gulf of the St. Lawrence River to and including Lake Ontario, abbreviated as SLR/LO); (6) The Caribbean Islands (Antigua, Barbuda, Bahamas, Cuba, Dominica, the Dominican Republic, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, and Bermuda); and (7) Central/South America (Atlantic coasts of northern Mexico; south through Guyana, Suriname, and Venezuela; to northern Brazil).

Addressing Uncertainties

The life history of American eels presents unique challenges to understanding the biological and environmental processes influencing eels at the species level. The eel's panmictic nature, wide geographic range, oceanic spawning, and segregation into freshwater, estuarine, and marine environments all contribute to the complexity of assessing status, threats, and whether listing is warranted. With many species, population dynamics modeling can inform listing determinations, but the current understanding of American eel population dynamics is rudimentary due to its complex life history and the paucity of data available for many key parameters, such as recruitment, growth, and mortality. A useful conceptual framework for a population dynamics model has recently been developed by a group of eel experts (Angermeier 2005), but quantitative analysis has been precluded due to a lack of data.

As discussed below in the five factor analysis, much speculation exists on factors that could negatively affect eels, often based on effects seen on other species but with little supporting data for eels. Much of the uncertainty exists because decreased fitness would be realized during life stages that are currently not possible to assess, specifically, the time between adult spawning migration and the return of glass eels to coastal streams. For example, contaminants and swim-bladder parasites may compromise the health of silver eels during migration. Contaminants could also contribute to significant early life history mortality, but these effects are not directly observable.

We considered a number of questions when reviewing the available information and potential threats to American eel. What is the population status of American eel and how much caution is warranted? What is the species' ability to withstand threats and changing environmental conditions? Would all eels throughout the widely distributed range of the panmictic population be affected by a given threat? Is there evidence that indicates a threat has caused significant population effects, or are effects only speculative? Has there been a reduction in juvenile (glass eel) recruitment (which would signal population-level effects)? And if so, does it correlate in time (temporal correlation) to the appearance of a particular threat or threats? Answers to these and other questions are important to making a listing determination.

When addressing uncertainty (not having complete, or in some cases any, data on one or more of the questions listed above), we employed a multi-step approach. The first step was to review all available data on the American eel with regard to uncertainty and determine, for example, if the data we have regarding an impact at a local or regional level implies an impact at a population level, and if so, what the likely response of the population is and in what given time period. If data for American eel is lacking, then we reviewed data for other Anguillid species, such as the European and Japanese eel, and determined if the application of that data was appropriate to the analysis. If uncertainty still remained high, then we requested individual assessments from experts regarding the probable implications to the species given the uncertainties.

In making this finding we examined all the relevant data on threats, life history characteristics (such as resiliency and vulnerabilities), and distribution information. We explored all reasonable conclusions and examined information to support and refute theories on population level effects, looking at whether the species was currently showing the effects of any population level threats. A population level effect is defined for purposes of this finding as an effect that is acting in a way which puts the persistence of the entire species at risk. Population-level effects would be demonstrated by a sustained downward trend in glass eel abundance (recruitment) observed at index sites that represent a substantial portion of the range. *Our five-factor analysis follows.*

Factor A. The Present or Threatened Destruction, Modification, or Curtailment of the Species' Habitat or Range

In analyzing these threats we assessed: (1) The relative importance to reproductive contribution of the various habitats occupied by the American eel during its life stages (such as spawning habitat in the Sargasso Sea, oceanic migration habitats, fresh water, estuarine and marine habitats), including which habitats are more likely to produce males or females, various growth rates, and levels of fecundity; (2) the threats to these habitats; and (3) the availability of that habitat to the American eel. Much of the information on the habitats other than freshwater was not available for the 90-day finding, and the new information has had a significant effect on our assessment of the status of the American eel.

Spawning and Ocean Migration Habitat

American eels spawn only in the Sargasso Sea, and the young produced from that spawning utilize ocean currents to migrate to continental habitats where they will grow to maturity before again entering oceanic habitats to migrate back to the Sargasso Sea to spawn. Therefore, the spawning and ocean migration habitats are of vital importance to the persistence of this species.

Seaweed harvest was indicated as a possible threat to the American eel in the ASMFC's Interstate Fisheries Management Plan for the American eel (FMP) (2000, pp. 6, 34). The seaweed *Sargassum* is commonly found floating in the Sargasso Sea and drifting with currents along the Atlantic coast from Florida to Massachusetts. Harvesting *Sargassum,* it was proposed, would affect eggs and leptocephali, if harvesting occurs where eggs and leptocephali are present.

After analysis of the available data, we conclude that *Sargassum* harvest is not a threat to American eel either in the Gulf Stream current or in the Sargasso Sea because first, studies of larval and juvenile fishes associated with *Sargassum* found no American eel larvae (Settle 1993 in SAFMC 2002, pp. 20–23), and second, according to the South Atlantic Fishery Management Council (SAFMC), there has been no commercial harvest of *Sargassum* reported in U.S. waters since 1997. Any future *Sargassum* harvest will be highly regulated because in November 2002, the SAFMC finalized the revised Fishery Management Plan (FMP) for Pelagic *Sargassum* Habitat of the South Atlantic Region. This plan specifies maximum and optimum sustainable *Sargassum* yield and sets total allowable catch limits, which severely limit *Sargassum* harvest (SAFMC 2002, pp. vi, viii). As such, we have concluded that U.S. commercial *Sargassum* harvest is not a threat to the American eel. Furthermore, there is no information indicating any other threat to the Sargasso Sea or ocean migration habitats (see Factor E for *Oceanic Conditions*), and these habitats remain abundantly available to the American eel.

Estuarine and Marine Habitat

Estuarine. The importance of estuarine habitat is described by Helfman *et al.* (1984, p. 135), Jessop et al. (2002, pp. 84, 228), Morrison et al. (2003, pp. 93–95, 97), and Knights et al. (2006, pp. 12–13). An estuary is a semi-enclosed coastal body of water which has a free connection with the open sea and within which sea water is measurably diluted with fresh water derived from land drainage tributaries. Estuarine habitat appears to not only be habitat in which eels may choose to remain during their continental phase, but it is used by freshwater residents for weight gain. According to Knights et al. (2006, p. 25), inshore coastal and estuarine mean net primary productivity (the transformation of chemical or solar energy to biomass) is greater than that of rivers and lakes. Females inhabiting estuarine waters, therefore, can provide a greater reproductive contribution. Estuarine habitat includes a mix of males and females. Because eels grow faster in estuarine waters than fresh water, the average age of a female within estuarine waters preparing to spawn is much younger (9 years of age) than females leaving lake habitats (24 years of age in Lake Ontario). Variation in maturation age benefits the population by allowing different individuals of a given year class to reproduce over a period of many years, which increases the chances of encountering environmental conditions favorable to spawning success and offspring survival. Jessop et al. (2002, p. 228) provides an interesting perspective on the relative production of silver eels by comparing elvers that spend 1 to 4 years in the estuary versus elvers that entered the river shortly after continental arrival. The authors suggested that the relative production of silver eels was 380 times higher for juvenile eels that spent 1 or more years in estuarine water, due possibly to lower mortality rates in the estuary than in fresh water (see Background, *Facultative Catadromy*). Helfman et al. (1984, p. 135), even as early as 1984, recognized the value of estuarine habitat where annual growing conditions were more favorable. Maximum size was greater in fresh water, but lengths at a given age were greater in estuaries. Morrison et al. (2003, pp. 94–95) found that annual growth rates were approximately 2 fold higher in brackish water when compared to annual growth rates in fresh water. The theory is that eels which grow faster, emigrate to spawn earlier.

Although there have been historic losses and degradation of estuarine habitat (from, e.g., contaminants, low dissolved oxygen, etc.), current rates of estuarine habitat loss (nationwide) are now estimated at 0.9 percent (averaging 5,540 acres annually) (Dahl 2006, p. 16). The results of the most recent Status and Trends of Wetlands in the Conterminous United States from 1998–2004 became available during the status review. In summary, coastal wetlands are still being lost but at a slower rate than in prior reports. Human-caused loss of deep salt water in coastal Louisiana accounts for much of the recent coastal wetland loss (Dahl 2006, p. 16). Hurricanes can also transform coastal habitats, but the effects of this transformation of habitats on the American eel have not been studied. A U.S. Geological Service (USGS 2006, pp. 1–2) preliminary wetland loss estimate for southeastern Louisiana from hurricanes Katrina and Rita, which is not included in the status and trends report, is the transformation of some 64,000 acres of marsh to open water.

From the 1950s to 1970s, substantial amounts of estuarine wetlands were dredged and filled extensively for residential and commercial development and for navigation (Hefner 1986 in Dahl 2006, p. 48). Since the mid 1970s, however, many of the nation's shoreline habitats have been protected either by State or Federal regulations or public ownership (Dahl 2006, p. 48).

Channel dredging and overboard spoil disposal are common throughout the Atlantic coast, and changes in salinity as a result of dredging projects could alter the distribution of American eels. Additionally, dredging associated with whelk and other fisheries may damage benthic habitat for this species (ASMFC 2000, p. 42). Although it is likely that dredging and overboard spoil disposal at least temporarily degrade benthic habitat, we were not aware of any analysis indicating that these activities are a threat to the American eel.

The two largest estuaries in North America are both on the eastern seaboard and support American eels: The Chesapeake Bay and the Albemarle-Pamlico Sound. The Chesapeake Bay and its tidal tributaries have over 11,000 miles of shoreline; this is more than the entire West coast. The Albemarle-Pamlico Sound, located in North Carolina, is the second largest estuary with 1.5 million acres of brackish estuarine waters (EPA 2006, pp. 3–4).

Although there are limitations to the following data, as they include areas outside the range of the American eel, the status and trends report estimated that in 2004, there were slightly more than 5.3 million acres (2.1 million hectares) of marine and estuarine wetlands in the conterminous United States. Eighty-six percent of that total area was vegetated wetland (Dahl 2006, p. 48).

Significant estuarine areas remain from Maine to Texas. Therefore, this important habitat remains available to American eels, and there is documentation of distribution of the yellow stage of American eels within estuarine areas from commercial harvest data (Weeder and Hammond, in press, pp. 1, 6), surveys, and research data (Helfman et al. 1984, p. 135; Morrison et al. 2003, pp. 91–92).

Marine. New information on marine or saltwater habitat became available during the status review (Daverat et al. 2006, see Background, *Facultative Catadromy*). The relative importance of marine habitat is not well understood, and the use of marine habitat by American eel for growth and maturity has only been recently confirmed. There was earlier confirmation in Japanese and European eel. We do not know what percent of the eel population inhabits strictly marine habitats, but eels in this habitat have high growth potential (Knights et al. 2006, pp. 6, 10–11), there is a predominance of females, and extensive habitat is available. Sasal et al. (2001 in Knights et al. 2006, p. 12) found the female–male ratio to be 4:1 for Japanese eel caught in the East China Sea from 1952–1999. Knights et al. (2006, p. 13) calculates that for the European eel in England and Wales the combined estuarine and marine contribution to reproduction probably exceeds that of fresh water. Others have also suggested that the percent of the American eel population living in estuarine and marine waters, particularly those that will contribute to future generations, may be quite high (Cairns 2006a, p. 1). Although there is no available data on the distribution of the American eels in marine waters throughout their range, the estimated totaled nearshore habitats (tidal fresh areas, through mixing areas, to seawater) are substantial. In the United States nearshore habitats have been estimated at 5,379 km^2 for the North Atlantic, 20,298 km^2 for the Mid Atlantic, 12,172 km^2 for the South Atlantic, and 30,604 km^2 for the Gulf of Mexico (ASMFC 2000, p. 35; NOAA 2006, pp. 1–3); this amounts to a total of 68,453 km^2. No threats to the American eel in marine habitats are known to exist.

Freshwater Habitat

Lacustrine Habitat. Lacustrine, or lake, habitat has historically been considered among the most important habitats for eel because some very well-known lake habitats, such as Lake Ontario, produce exclusively large, highly fecund females (Castonguay et al. 1994a, p. 481; Casselman 2003, p. 255). Studies by Oliveira et al. (2001, pp. 947–948) showed that the greater the amount of lake habitat within a watershed, the more the sex ratio favors females. There are numerous lakes within the distribution of the American eel, many of which have likely been impacted by water quality issues or exotic species invasions, and American eels have been denied access to some historical lake habitats due to barriers (see *Riverine Habitat* below for more discussion of barrier impacts) such as dams constructed in the past. We are not aware of new dam construction activities that are likely to threaten the American eel. Below we will present the information on two lakes, Lake Champlain and Lake Ontario that are in the Saint Lawrence River drainage. It has been suggested in the literature that a cause of declines of American eels in these lakes was barriers.

The significance of Lake Ontario's reproductive contribution to the American eel was presented and discussed at a workshop (Casselman 2006, pp. 1–8 in USFWS 2006, pp. 8–10) and presented in the recently released COSEWIC Assessment and Status Report on the American Eel

(2006, pp. 35–41) (see Background, *Population Status* for further discussion).

Access to Lake Ontario and other Great Lakes by American eel was restricted to a degree by the building of hydroelectric facilities on the St. Lawrence River; however, the building of canals also opened new avenues and even provided passage past the natural barrier of Niagara Falls. Eels migrating into the Great Lakes and Finger Lakes basin in New York historically had one route through the Gulf of St. Lawrence and up the St. Lawrence River to Lake Ontario. Once in Lake Ontario, the eels could access a large number of tributaries in the United States or Canada, but were blocked from Lake Erie and the upper Great Lakes by the natural barrier at Niagara Falls. With the opening of the Erie Canal in 1825, and later, the New York State Barge Canal in 1928, a second route up the Hudson River and through the canal system was created, allowing eels another access route to Lake Ontario and the Finger Lakes (Patch 2006, p. 2).

Although the building of the Beauharnois Dam blocked American eels from passing directly up the St. Lawrence River for 70 years, many eels were able to continue their migration through the adjacent canal—the St. Lawrence Seaway. Two ladders were recently constructed on the Beauharnois Dam, increasing the opportunities for upstream eel passage at that site. A second large hydroelectric dam, the Moses-Saunders Dam, is located 40 miles upstream from the Beauharnois Dam. From 1959 until 1974, eels were able to pass upstream of the Moses-Saunders dam only through the Wiley-Dondero Canal (Verdon and Desrochers 2003, p. 140–141). In 1974, an eel ladder was constructed on the Canadian side of the Moses-Saunders Dam, allowing American eels to again migrate directly up the St. Lawrence to Lake Ontario (Casselman et al. 1997, p. 163), and a ladder on the U.S. side of the Moses-Saunders Dam was completed in 2006. These historical and recently constructed fish ladders are likely to benefit American eels in the SLR/LO by providing them with multiple opportunities to access to this drainage.

Lake Champlain also produces predominately female eels. Declines in Lake Champlain were noted in the fishery in the Richelieu River (the river carrying about 3 percent of the fresh water from the lake to the St. Lawrence River). The decline has been mainly related to the rebuilding of two old cribwork dams on the Richelieu River in the 1960s (Verdon et al. 2002, p. 2) that impeded access to Lake Champlain by young up-migrating eels. In 1997, a ladder was retrofitted on the Chambly Dam to enhance eel recruitment, and in 2001, the Saint-Ours dam, downstream, was retrofitted with a similar eel ladder (Verdon et al. 2002, p. 11–12). In 1997, the total population at the foot of the dam was estimated at 19,650 individuals, and minimum ladder efficiency was estimated at approximately 57 to 68 percent. Access to Lake Champlain, having been reestablished, now allows American eel access to 1,200 km^2 of habitat (Verreault et al. 2004, p. 5).

Although we are not aware of a rangewide analysis of the remaining amount of lacustrine habitat available to the American eel, according to the NatureServe data a significant amount of lacustrine habitat remains available to the American eel. A survey of 203 randomly selected lakes in eight states in the northeast United States showed American eel as being present in at least 20 percent of the lakes sampled (Wittier et al. 2001, p. 1).

Also, efforts are being undertaken in the two large lake systems described above to increase American eel densities. A 10-year annual transfer to Lake Champlain of 0.5 to 1 million elvers from the Bay of Fundy (New Brunswick, Canada) is underway as an effort to improve abundance within Lake Champlain (Dumont et al. 2006, pp. 1–2). In Lake Ontario, 50,000 young eels were recently stocked as a first step in a Canadian multi-year plan to restore the American eel to greater numbers in Lake Ontario (CNEWS 2006, p. 1).

Riverine Habitat. Riverine habitat within the range of the American eel is highly variable with respect to water depth, temperature, and flow, and habitats available. Therefore, yearly reproductive contributions vary among river systems. The amount of habitat, rather than specific types of habitat within the river, primarily determines how many eels a river can support (Oliveira and McCleave 2000, p. 148–149). Both males and females are produced; densities of eels apparently determine the sex of individual eels, rather than habitat type (see Background, *Sex Determination*).

Loss of access to riverine habitat has been put forward as a threat to the American eel (ASMFC 2000, pp. 35–39) by both decreasing distribution and abundance. However, most of the loss of access to riverine habitat occurred prior to 1960 and we have no information of future water development projects that threaten the American eel. Below we will discuss effects of the construction of dams to the eel's distribution first. Busch et al. (1998, pp. 1–3) conducted a preliminary analysis of stream habitat availability for diadromous fish in Atlantic coast watersheds. They reported that from Maine to Florida, 15,115 dams have the potential to hinder or prevent upstream and downstream movement of fish such as eels, resulting in a restriction or loss of access to 84 percent of the stream habitat within the Atlantic coastal historic range. This constituted a potential reduction from 345,359 miles (556,801 kilometers) to 56,393 miles (90,755 kilometers) of stream habitat. However, only 35 percent (5,387) of the dams from Maine to Florida are over 25 feet in height. The majority (65 percent or 9,728) are, therefore, less than 25 feet in height. Regional analysis of two watersheds in the South Atlantic area noted that eels remained present over many barriers, until those barriers reached 50 feet in height (Cantrell 2006, pp. 4–5). Of the 15,115 dams, only 7 percent are for hydroelectric power (Busch et al. 1998, p. 3).

Most barriers are thought to have been in place before the 1960s. Castonguay et al. (1994a, p. 484) reviewed major habitat modifications as a potential cause for the extreme decline of American eels in the Lake Ontario and Gulf of St. Lawrence ecosystems. Anthropogenic (human-caused) habitat modifications in the Lake Ontario and St. Lawrence River ecosystem occurred mostly before the 1960s, whereas the eel upstream migration decline noted at the Moses-Saunders Dam started only in the early to mid 1980s. Castonguay et al. (1994a, pp. 484, 486) proposed that the lack of temporal correspondence between permanent habitat modifications and the start of the regional decline evident in the SLR/LO argues against the role of habitat loss in the decline, as the decline should have been evident earlier than the 1980s. This assessment was tempered by the brief mention that American eels may be slower to respond to impacts than other fish species.

Riverine habitats within the range of the eel can be highly degraded through contaminants (see Factor E, *Contaminants*) and changes in temperature, pH, and biological communities. The effect, if any, on eel is an increase in susceptibility in eels to disease, likely decreased growth (Machut 2006, p. 152; USFWS 2006, p. 27), increased elver mortality (Jessop 2000, pp. 523–524), and changes in behavior (USFWS 2006, pp. 9–10). Stream flow velocities can affect the upstream migration of elvers (Jessop 2000, pp. 515, 520) due to their weak swimming ability. However, reduced velocities due to seasonal or operational changes of managed flows have likely provided periods when velocities are passable for migration. The elver's ability to find paths around these velocity barriers has also been documented (elvers have strong climbing abilities and can negotiate vertical barriers) (Jessop 2000, p. 520; Craig 2006, pp. 2–4).

Impacts of barriers on distribution: When discussing impacts of barriers on distribution, we will cover impacts at three levels: (1) Rivers, (2) watersheds, and (3) the American eel's entire range.

At the level of individual rivers, the impact of barriers can range from very little impact to local or regional extirpation. This is because the effect of barriers on eel upstream migration appears to be site-specific. For example, a steep vertical barrier has a different effect on elvers, which can climb, than on yellow eel, which do not have the same climbing ability. Therefore, the location of the barrier along the river and in the watershed will dictate its impact (USFWS 2005b, p. 16). Additionally, the level of impact is also affected by the type of barrier (i.e., hydroelectric dam, weir, old mill dam, or dam for recreation, water supply, or navigation), as well as how the barrier is operated (if there is spill water), its general condition (those in poor repair are more likely to have rough areas or spillage, both better for eel), whether it was equipped with eel or other fish passage, and other site specific conditions (Goodwin and Angermeier 2003, pp. 532–533; USFWS 2005b, pp. 16–19). Indeed Busch et al. (1998, p. 3) originally suggested that site-specific assessments would be required when further analyzing the impacts of barriers to the American eel, and that their estimate of 84 percent loss of freshwater habitat for the American eel was a gross estimate, provided as a starting point for future scientific studies.

Our additional research into eel distribution shows that eels remain widely distributed within most of the watersheds historically inhabited by the American eel. For example, Jacobs et al. (2004, pp. 325, 330), in a Connecticut watershed survey, verifies the presence of American eel above barriers and a current extensive distribution. American eel were the most ubiquitous species of all fish species sampled in the Connecticut River drainage, present in 97 percent of all sites sampled and common in both the main stem rivers and tributary streams (Jacobs et al. 2004, p. 325). Machut (2006, p. 49), in his study of Hudson River tributaries, found that American eels are the most numerous fish within the tributaries surveyed.

To better understand the impacts of historically constructed barriers on eel upstream migration and potential loss of habitat we analyzed three watersheds we think are representative of the U.S. range of the species.

The Mississippi Watershed. The American eel persists in the Mississippi watershed (Mississippi River and the tributaries of the Missouri, Arkansas, Ohio, and Tennessee Rivers), albeit having likely declined in abundance during the past half century (Becker 1983, p. 258). Very little data exists on the abundance of the American eel within the Mississippi watershed (Ickes et al. 2005, p. 4), both historically and currently, as eels are not typically targeted during studies and are likely underestimated. The Long-Term Resource Monitoring Program (LTRMP) conducted by the Upper Mississippi Environmental Sciences Center (UMESC) observed 75 eels out of nearly four million fish collected from 1993–2002 (Ickes et al. 2005, p. 9).

The distribution of the American eel remains widespread in the Mississippi watershed even though it was anticipated by Coker (1929, p. 173) that the American eel, in time, would cease to exist in areas of Minnesota, Wisconsin, and Iowa, due to the construction in 1913 of the Keokuk Dam, or Lock and Dam 19, in Keokuk, Iowa (River Mile 364). The barriers on the Mississippi River mainstem are mainly navigation locks and dams in the upper portion of the river. These navigation locks and dams were built to hold back water and form deeper navigation ''pools'' while allowing for barge passage through the locks. Presumably, these lock and dam complexes allow for eel passage when barges pass (Cochran 2005, p. 2) or eels pass during high water stages, as American eel are still found above Keokuk Dam today. The Keokuk Dam is currently the tenth dam eel encounter during their upstream migration on the Mississippi River.

South Atlantic-Pee Dee River and Santee River Basins, North Carolina and South Carolina. American eels continue to be distributed throughout the lower areas of these watersheds, indicating they are able to negotiate certain barriers and persist within this historic habitat. Of the six dams in the Santee and Pee Dee River basin, eels are able to pass four (Cantrell 2006, p. 3). They are prevented from reaching their extreme headwaters where they had historically been reported as ''everywhere common'' by Jordan (1889, p. 139). Large (over 50 feet) hydroelectric and other dams likely impede upstream movements of elvers and subadult eels to these historic habitats.

Androscoggin and Kennebec River Basins, Maine and New Hampshire. Our knowledge of current distribution of American eel for the Androscoggin and Kennebec watersheds of Maine and New Hampshire is based on a systematic survey in 2002 and 2003, and supplemental electrofishing survey data (Yoder et al. in preparation, pp. 1–7). Presence of fishways on dams; dam leakage, height, configuration, materials, and location up the river relative to the size of eel; water quality issues; and presence of lakes (which may be of more interest to eels due to odor cues) are thought, by Wippelhauser, to play a role in the distribution differences within the two watersheds and explain why eels are more abundant in the Kennebec watershed (2006a, p. 1).

The American eel remains present above the first dams encountered inland, as well as subsequent barriers, up to the Gulf Island Dam on the Androscoggin (approximately 52 river miles) and the Wyman Dam on the Kennebec (approximately 122 river miles), with anecdotal information indicating that abundance has decreased (Adams 1992, p. 86).

Rangewide our analysis of the impacts of barriers was limited to the information available, that of North America. An update of NatureServe's distribution map (Figure 2) includes the American eel freshwater distribution information we received from most States within the species' historic range as well as from Canada and a few of the Caribbean Islands, along with NatureServe's existing database.

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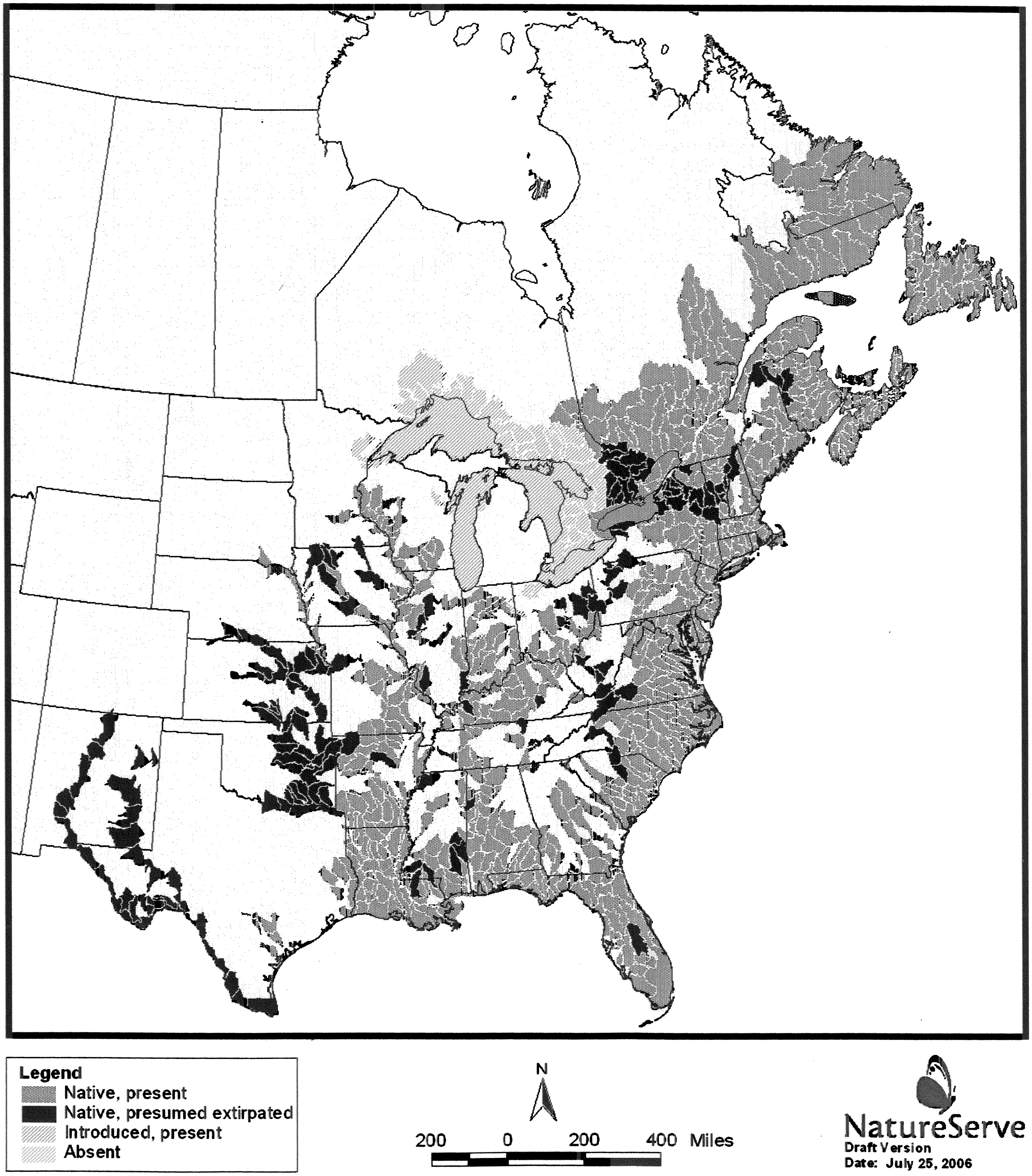
Watershed Distribution of American Eel (Anguilla rostrata) in the U.S. and Canada



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At the scale analyzed, the American eel remains distributed over roughly 75 percent of its historic native range within U.S. watersheds (Castiglione 2006, pp. 1–5). Figure 2 represents the historic (291,416,355 hectares) and current distribution (163,781,049 hectares) of the American eel within its native freshwater habitat in the United States. Additionally, Figure 2 identifies the area where the eel was introduced and is considered currently present, an addition of 2,921,343 hectares (Castiglione 2006, pp. 1–5).

The watershed examples provided earlier are indicative of the relationship of barriers and eel distribution throughout the species' range in North America. From these examples, and the data from NatureServe, we conclude that not all structures (natural or human-made) considered barriers to other fish species should be thought of as barriers to the eel. We also conclude that there are dams, other human-made structures, and some natural features that are complete barriers to American eel. In the case of human-made structures, those structures have reduced the historical range of the American eel.

The fate of eels that are unsuccessful in passing a barrier is unknown, but it has been speculated that eels may find alternative habitat, that overcrowding below the barrier may increase the likelihood the eels will become male, and that below the dams there is likely increased competition, reduced food availability negatively affecting growth rates, and predation (USFWS 2005b, p. 19; Machut 2006, p. 53).

Impacts of barriers on density: Whereas general fish surveys can provide American eel distribution data, few studies address the changes in eel density (also called abundance) due to barriers. Goodwin and Angermeier (2003, p. 533) found that dams can exacerbate the decline in eel density; however, this is clearly the case for only one in three dams within their study area. Machut (2006, p. 51) found in the Hudson River watershed, where there are almost 800 barriers, that the first barrier encountered dramatically reduces eel densities, but did not necessarily result in local extirpation. Densities were highest below barriers, while age, growth (in length), and the number of females increased above barriers.

Two aspects of the eel's life history add complexity to understanding the true impact that decreased density may have on eel reproductive contribution. Densities decrease naturally with distance from the Continental Shelf (see Background), while relative female fecundity increases with lower density (see Background). Based on these factors, we conclude that low upstream abundance is a natural phenomenon exacerbated to varying degrees geographically by human-made structures and natural barriers, but that relative reproductive contribution is not lost in direct proportion to the decrease in density (see Background, *Distribution Clines*). Additionally, we conclude that when taking into consideration or trying to quantify the impact of barriers on the American eel, site-specific information on the barrier is critical, as is analyzing the historic sex ratio of an area, the dynamic between lower abundance and the higher probability that females will be produced, density-dependant growth relationships, and length-fecundity relationships. Unfortunately, the information to conduct this comprehensive analysis is not available.

The availability of riverine habitat can be seen in Figure 2, and also be looked at in terms of kilometers of riverine habitat unimpeded. Unimpeded freshwater habitat (riverine kilometers downstream of terminal dams, the dams closest to the ocean) in each river also remains available to the American eel. In the United States alone, from Texas to Maine (not including the Great Lakes), there remains over 590,000 km of freshwater habitat available to American eels downstream of terminal dams or within rivers that do not have significant barriers (such as the Delaware River). An example of this downstream available habitat on a watershed basis is the 1,153 river miles available on the Connecticut River downstream of the terminal dam, including both the mainstem and tributaries (Castiglione 2006, p. 1–2).

In our analysis, we found that the distribution of the American eels has not been significantly reduced by barriers, as many barriers do not preclude upstream migration of the American eel. Some dams appear to form a complete barrier to upstream migration, potentially responsible for the reduction in available freshwater habitat of approximately 25 percent. Further, distribution is far less affected by barriers than is density. If there were population level effects from this decrease in American eel distribution or density in maturation habitats, there would be corresponding declines in the recruitment of juvenile eels; however, this is not the case (see Background, *Population Status*).

Summary of Factor A

Spawning and ocean migration habitats are essential to the persistence of the American eel; there are no apparent human-caused or significant threats to these habitats; and, they remain available and occupied by the American eel.

Estuarine, marine, and freshwater habitats provide maturation habitat for the American eel, and new information verifies that some portion of the American eel population completes its lifecycle without ever entering fresh water. Of these maturation habitats, freshwater habitat has been the most impacted by human-caused actions such as barriers (i.e., dams constructed for hydroelectric, water supply, and recreation purposes), most of which we would consider historic losses; in which case population level impacts have likely been mostly realized. We are not aware of future dam construction which is likely to cause significant impact to the American eel. We have concluded that although some dams appear to form a complete barrier to upstream migration and likely caused the regional extirpations seen in 25 percent of the eel's historic freshwater habitat, American eels are able to negotiate many barriers. This has allowed the American eel to remain well-distributed throughout roughly 75 percent of its historic freshwater range, mainly in the lower reaches of watersheds. American eel abundance has been affected by barriers to a greater degree than has distribution; however, there is no evidence that the reduction in densities has resulted in a population level effect, such as a reduction in glass eel recruitment. Analyses of local and regional declines in abundance do not temporally correlate with the loss of access to habitat.

The status of the American eel and the effects of freshwater habitat loss must be examined in light of the American eel's habitation in fresh, estuarine, and marine habitats. Highly fecund females continue to be present in extensive areas of fresh water (lacustrine and riverine) and estuarine and marine habitats; males also continue to be present in these habitats. Recruitment of glass eels continues to occur in these habitats with no evidence in reduction in glass eel recruitment. For these reasons, we believe the available freshwater, estuarine, and marine habitats are sufficient to sustain the American eel population.

Factor B. Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

In analyzing the threat of overutilization, we focused primarily on recreational and commercial fisheries on the U.S. Atlantic coast and in Canada because these fisheries are the most active. We will briefly characterize these two fisheries and discuss recent changes, summarizing the pertinent scientific and commercial information. For detailed descriptions of United States and Canadian fisheries (e.g., harvest restrictions by State), see the 90-day finding (July 6, 2005, 70 FR 38849) or ASMFC 2006a (pp. 11–20) and for Canada's fishery, see the COSEWIC report (2006, pp. 46–48). We will begin, however, with a short discussion of the factors that drive the commercial harvest of Anguillid eel.

Commercial Fishery (Including Bait Fishery)

Eels (most notably Japanese and European eels) are popular seafood in Europe and Asia, particularly Japan, and to a much lesser degree in North America. At this time, fish culturists have not been able to provide the conditions necessary for eels to reproduce and mature in captivity; therefore all eels consumed or used as bait are taken from the wild. Some of the eels taken from the wild as glass eels or elvers are grown out to maturity in aquaculture facilities.

The commercial eel harvest both here or in other countries is driven in large part by the international demand for eel (see Pawson et al. 2005 for discussion of international eel market), yet American eel represent but a fraction of the total international trade in eels. China appears to be setting the world price by both buying eels on the international market and producing eels in extensive aquaculture facilities (Dekker 2005, p. 2). According to TRAFFIC, a joint program of the World Wildlife Fund and the World Conservation Union (IUCN), over 90 percent of the world's eel aquaculture yield takes place in the Asian countries of Japan, Taiwan, and mainland China (TRAFFIC 2002, pp. 11–12). Between 1998 and 2004, China supplied two-thirds (i.e., approximately 130,000 metric tons) of the world's cultured eel production. The species used in aquaculture in Asian countries consists primarily of European and Japanese eel. According to the United Nations' Food and Agriculture Organization (FAO), even with increasing dependence on European and American glass eels for aquaculture purposes with the decline of Japanese eels (TRAFFIC 2002, pp. 13–14), American eels represent only about 5 percent of the overall worldwide yield of Anguillid eels (OLE 2004, p. 1; FAO in Dekker 2005, p. 3). The insignificant contribution to the worldwide eel trade indicates that the American eel harvest is unlikely to be appreciably affected by changes in international markets.

Commercial harvest of the American eel in North America occurs mostly along the Atlantic coast of the United States and Canada. In the United States, the commercial fishery occurs mainly in the Chesapeake Bay with smaller fisheries scattered throughout other States. All continental life stages are harvested commercially, but regulations restrict harvest so that exploitation of life stages differs geographically. American eel fisheries are unevenly distributed within Canada. In some regions, there are intensive fisheries, while in other regions, eels are unexploited. All continental stages are harvested commercially in Canada, but the stages that are exploited vary geographically (COSEWIC 2006, pp. 46–47). Limited commercial fisheries exist in Mexico and some Caribbean islands (ASMFC 2006a, p. 14). No glass eel or elver fishery exists in the Gulf of Mexico (ASMFC 2000, p. 18).

Exploitation rates (the percent of mortality associated with harvest) vary with the life stage, fishing gear, and other factors. Glass eels and elvers are typically harvested as they ascend rivers and estuaries. One study suggests an exploitation rate of 30–50 percent of arriving elvers (Jessop 2000, p. 523). If there was no density-dependent change in sex ratio, growth, survival, or emigration rate in subsequent stages, the reduction in egg production due to the elver fishery would be equivalent to the percent elver exploitation described above. However, such density-dependent effects are believed to occur (ICES 2001, p. 34). In other words, the relatively high exploitation rate for glass eels and elvers does not translate to that level of reproduction loss because the glass eels and elvers that are not harvested have a greater potential for survival and, therefore, reproduction. Elver fisheries, it has been suggested by Jessop (2000, p. 523), may be biologically justified to a greater degree in Nova Scotian streams with low pH, given the abundance of elvers entering these streams and the high mortalities that occur during their first summer in fresh water (rather than in more productive streams with higher pH values).

Silver eels are exploited in rivers mainly in weir fisheries and in coastal waters with eel pots. In the St. Lawrence estuary silver eel fishery, mark-recapture experiments estimated exploitation rates of 19 percent in 1996, and 24 percent in 1997 (Caron et al. 2003, p. 239).

In the Chesapeake Bay, the estimated exploitation rate is something less than 25 percent. The data collected did not separate exploitation rates for yellow eels harvested in the pot fishery from eels that naturally emigrated from the area. This combined fishing mortality and emigration was estimated at 25 percent, significantly lower than the Prince Edward Island fishery presented below (ICES 2001, p. 34).

Data from Prince Edward Island, Canada, were used by the authors of the ICES report (2001) to calculate yellow eel exploitation rates. They estimated an approximately 50 percent rate of exploitation in estuary and tidal waters (ICES 2001, p. 41). The authors also estimated how this rate of exploitation would be expressed in loss of reproductive contribution, but based on some significant assumptions, they consider the estimate preliminary. They suggest the effect on reproduction would be a decrease of approximately 90 percent, based on the premise that the largest, and hence most fecund, females are targeted. However, they also note that the estimated reduction in reproduction for the entire Prince Edward Island area would be less than this value, because there is no eel fishery in non-tidal waters, and there is minimal fishing effort in the central and western portions of the Northumberland Strait, which amount to about one third of the Prince Edward Island coastline (ICES 2001, pp. 34–35).

Exploitation rates are lacking for most of the range where the American eel is harvested, but the above examples show how complex estimating exploitation rates is, given that factors, such as areas unfished, need to be accounted for when evaluating harvest effects on a species rangewide.

The American eel fishery has changed over time. Harvest, or landings, were significantly higher in the 1970s (Figure 3), presumably as a result of demand for glass eels for the newly emerging aquaculture industry in China (St. Pierre 1998, p. 1), which inflated prices and made eel fishery profitable. Landings have declined in the United States and Canada since then; however, the reason for the decline in landings appears multifaceted.

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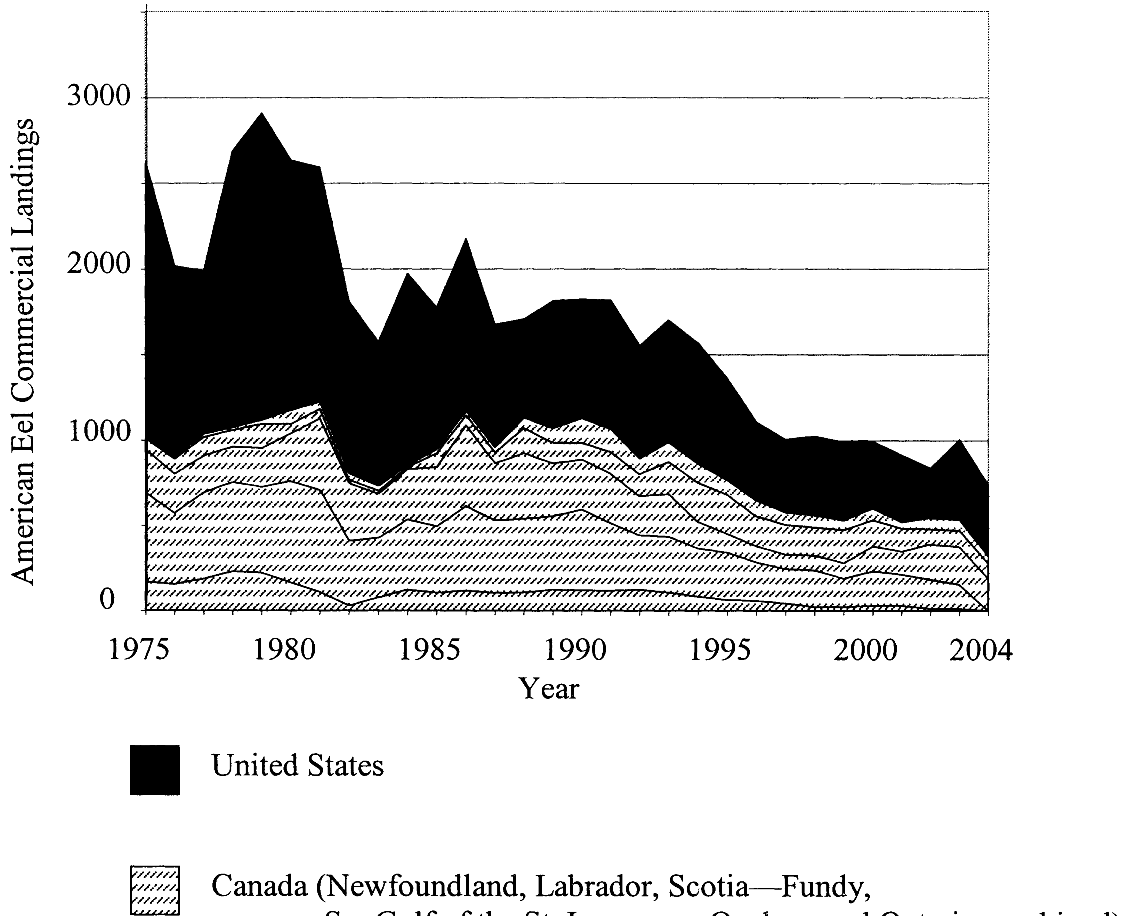

Figure 3-Commercial American Eel Landings in Metric Tons in the United States and Canada

(NMFS 2005; Canadian Department of Fisheries and Oceans 2005 in NMFS 2005).

The price per pound fluctuates considerably for American eel, thereby affecting landings. For instance, the Chinese aquaculture market still requires glass eels to maintain the established aquaculture business (Moriarty and Dekker 1997 in ASMFC 2006a, p. 6), but when available, the Chinese buy Japanese glass eel, which is the eel preferred by Asians. Consequently, the price for American eel has dropped. ASMFC (2006, p. 7, 12–13, 43) also lists poor market conditions as likely responsible for more recent reductions in all commercial eel fisheries. Since 1998, glass eel market prices have fluctuated from $300 per pound (1998), to $10–$15 per pound in 1999, to $105–300 per pound in 2005, to $60 per pound in 2006 (Wippelhauser 2006b, p. 1).

License requirements and State-regulated size and catch limits have also played a role in the decline seen in landings (ASMFC 2006, p. 43). In 2000, the ASMFC (the agency regulating harvest along the U.S. Atlantic coast), responding to the concerns of fishers, scientists, and resource managers that American eel had declined from historic levels and that assessment data was limited, implemented a Fishery Management Plan that required States to establish minimum size limits for commercial eel fisheries.

Trends in Canadian eel fishery. In Canada, there has been a trend towards increasingly restrictive fishing regulations in the last several decades, especially in the Atlantic Provinces, and especially since 2000 (Cairns et al. 2005 submitted in COSEWIC 2006, p. 48). This could translate, we believe, to a decline seen in Canadian landings data. Changes include shortening of seasons, increases of minimum size, caps on the number of fishing gear that can be deployed, and freezes on development of any new American eel fisheries (COSEWIC 2006, p. 48). There was a buy-out of 50 percent of commercial licenses at Lake St. Pierre, the fishery in the Richelieu River was closed in 1998, and the fishery in the upper SLR/LO was closed in 2004 (OMNR 2004, p. 1). Glass eel and elver fishery only exists in the Scotia-Fundy area of the Maritime Provinces and occurs during narrow time windows (COSEWIC 2006, pp. 46–47).

Trends in United States glass eel and elver eel fishery. During the lucrative early 1970s, Florida, North Carolina, South Carolina, Virginia, Massachusetts, and Maine developed glass eel and elver fisheries. By 2002, all Atlantic coast States except Maine and South Carolina had restrictions on harvestable eel size or fishing gear that restricted glass eel and elver fishery (ASMFC 2006a, pp. 12–18). One of those remaining States, Maine, began in 1999 to limit glass eel and elver harvest through emergency legislation with a limited entry system, restrictions in fishing gear, restrictions on locations, and a reduced length of the season (March 15–June 15). This later requirement allows for one or more months in winter when glass/elvers are not harvested. The emergency legislation reduced fishing effort in Maine by at least 79 percent (ASMFC 2005, p. 18), ensuring that a significant run remains in Maine waters. Maine was the only State reporting glass eel and elver landings in 2004, at approximately 0.5 metric tons, down from 7.53 metric tons in 1995, and 9.98 metric tons in 1977. South Carolina and Florida permit glass eel fishery, but it is not active (ASMFC 2005, pp. 5, 14).

Trends in United States yellow and silver eel fishery. Currently a yellow and silver eel fishery exists to varying degrees in all States and jurisdictions along the Atlantic coast except Pennsylvania and the District of Columbia. South of Maine, the yellow and silver eel fishery seems to be primarily coastal pot fisheries, and different States have varying regulations, if any, imposed on this fishery. In Maine, the yellow and silver fishery occurs in both inland and tidal waters (ASMFC 2006a, pp. 19–20). The Maine fishery has declined since 1998 because of legislation and poor market conditions, with prices paid declining from $3–$4 per pound to $1.25–$1.75 per pound. Harvesters report that the low prices are due to eels being grown out in aquaculture facilities in Canada (Knights 2003, p. 242). Eels grown out in an aquaculture facility, a fish company representative suggests, are better suited to smoking, due to their high fat content and uniform size and shape. The uniform size is better suited for the current mechanized processing (Feigenbaum 2005, p. 12). The decline in effort may encompass other areas along the Atlantic coast as well (ASMFC 2006a, pp. 13–14). For example, on the northern shores of New Jersey, the number of active fishers has declined from 16 in 1980s to 0 in 2004 (Feigenbaum 2005, p. 6).

In characterizing the future impact of harvest, the literature supports the prediction that 1970s harvest levels are unlikely to occur again due to the changes in the market (Pawson et al. 2005, p. 6; Dekker 2005, p. 2), including the interest in eels raised in aquaculture facilities rather than wild caught eel, due to ease of processing (Feigenbaum 2005, p. 12); the implementation of harvest regulations (ASMFC 2006a, p. 43); and the retirement of eel fishers (Wippelhauser 2006b, p. 1).

Population level impacts. In assessing population level impacts of commercial fishing on American eels, we took into account both the species' resiliencies and vulnerabilities, and levels of exploitation, including a review of fished versus unfished areas in the species' range, and whether there is evidence of a population level impact.

Resiliencies include the following: (1) The wide range of the species, which leaves many areas without fishing pressure (USFWS 2005b, pp. 69–70, 76; COSEWIC 2006, pp. 46–47, 53; Cairns 2006c, pp. 1–3); (2) harvesting within an area is unlikely to substantially affect the replenishment of the area through recruitment (to the degree it might with fish species that have river specific stocks) because of the random nature of recruitment (see Background section and Factor E Ocean Conditions); (3) harvesting will not affect genetic variability because the species is a single population; (4) eels have relatively high fecundity rates; and (5) the species possesses general plasticity and robustness (Knights 2005 in USFWS 2005b, pp. 50–59); also see Background for further explanation and citations). Conversely, vulnerabilities include the following: (1) All eel harvest takes place before the species has had an opportunity to spawn, and American eel only spawn once; (2) all continental life stages and multiple year classes are subjected to harvest in some portions of the species' range; and (3) harvest of large individuals unequally affects females (eels below 40 cm in length are either male or female, but almost all eels greater than 40 cm are female) (ASMFC 2000, p. 2; USFWS 2005b, p. 75).

Although we have data on landings (harvest) of American eel, we lack specific data on fished versus unfished areas over the range of the American eel. Recent mapping by Cairns and others (2006c, p. 3) has begun to identify (but not yet quantify) fished versus unfished areas in Canada, but initial results suggest that much of the Canadian range of the American eel is unfished (COSEWIC 2006, pp. 46–47, 53). In Canada, there is little eel fishing effort in the Gulf of Nova Scotia, and none in most fresh waters of the southern Gulf of the St. Lawrence River. Many rivers and coastal areas in the Scotia-Fundy area of the Maritime Provinces are unfished and Newfoundland and Labrador have rivers which are not exploited. Additionally, there are the areas of harvest closure including the Richelieu River and Lake Ontario (Cairns 2006c, pp. 1–3).

Although we do not have similar mapping in the United States, there are considerable areas within the species' range that are not subject to harvest. Commercial eel harvest is either prohibited (such as in Tennessee, Todd 2006, p. 1) or at low levels in States within the Mississippi watershed (Keuler 2006, p. 1) and the U.S. portion of the Great Lakes (Lutz 2006, p. 1). Although the ASMFC was unable to provide fished versus unfished areas along the Atlantic coast, a fish company representative who works with the fishers was able to confirm that there are areas along the Atlantic coast which support eels and are not now being exploited (Feigenbaum 2006, p. 6).

Modeling exercises have indicated that harvest has depleted the abundance of eels in the Chesapeake Bay, where approximately 50 percent of the U.S. yellow eel landings occur (Weeder and Uphoff, in press, pp. 6–7). Modeling conducted by BEAK (2001, pp. 31, 5.1, 5.7) for the purposes of prioritizing factors influencing eel abundance, ranked fishing mortality on yellow and silver eels as the number one factor with regards to American eel abundance in the upper SLR/LO. The upper SLR/LO was an area of substantial harvest beginning in the 1970's, with a peak in 1978 of 230 metric tons (Robitaille et al. 2003, p. 258). Commercial harvest in the upper SLR/LO closed in 2004.

At a population level, however, one must take into account existing regulations and exploitation rates that allow for: (1) A level of individuals who are not subjected to fishing pressure; (2) the theory that fishing of glass eels and elvers does not necessarily represent a substantial loss to reproductive capacity of the species; (3) the vast areas that remain unfished; and, (4) the lack of evidence that there is a reduction in glass and elver recruitment rangewide (which would be the indicator of overharvest) (see Background, *Population Status*). Taking all these factors into account, we have determined that commercial harvest currently affects the American eel only at a local or regional level.

Recreational Fishery

Recreational harvest is either limited or nonexistent throughout most of the range of American eel. Eels are likely purchased or caught by recreational fishermen for use as bait for larger gamefish such as striped bass (USFWS 2005b, p. 74; ASMFC 2005, p. 6), and the remainder is mostly catch and release (ASMFC 2005, pp. 5–6). The NMFS Marine Recreational Fisheries Statistics Survey (MRFSS), which has surveyed recreational catch in ocean and coastal waters since 1981, shows a declining trend in the recreational catch of eels during the latter part of the

1990s. In 2003, total recreational catch was 156,381 eels, and in 2004, 112,001 eels. In 2004, the combined catch from New Jersey and Delaware represented 40 percent of the recreational American eel catch, and the combined catch from New York and Delaware represented 62 percent of the recreational American eel harvest. About 79 percent of the eels caught were released alive by the anglers in 2004 (ASMFC 2005, p. 6).

To protect American eel from unregulated recreational harvest, all ASMFC member States were required to establish uniform size (6 inches) and possession limits (maximum 50 eels per person per day) for recreational fisheries, and recreational fishermen are not permitted to sell eels without a State license that specifically authorizes this activity (ASMFC 2006a, p. 17). After a review of the best available scientific and commercial information, it does not appear that recreational harvest poses a significant threat to American eel.

There is little information in the literature on subsistence harvest and bycatch. But according to Laney (2006, p. 1) and others (USFWS 2005b, p. 14, 79), bycatch of eels in marine waters, during harvest for other targeted fish species, does not appear to be of concern for the American eel. This is likely due to the fishing gear used in these other fisheries (Laney 2006, p. 1). Fisheries utilizing trawl gear may catch eels, depending on the size of the netting. Netting of a ½ inch and 1 inch used in the late 1960s did catch eel, but only a handful (Wenner 1973, p. 1). Modern netting size is more specific to the targeted fish species in an attempt to limit bycatch.

Summary of Factor B

In conclusion, there are no data to suggest that subsistence harvest, bycatch, and recreational harvest are having a significant impact on American eel regionally or rangewide. Future commercial harvest of American eel is not anticipated to reach 1970s levels, and we find it unlikely that American eel landings will increase significantly by future changes in the international market.

Commercial harvest has had a strong influence on eel densities in some local and regional areas, but we see no evidence that commercial harvest is having an effect at a population level. A population level impact would be seen in declines in juvenile recruitment rangewide, yet this is not in evidence. It is probable that: (1) The random dispersal of the larval stage enables the species to successfully recruit to other areas, including extensive unfished areas, throughout its range, thereby buffering the effects of harvest; (2) the compensatory mechanism of the increasing probability of glass eel and elver survival, or of undifferentiated eels becoming female, as densities decrease provide this species with some level of resilience; and, (3) current exploitation rates and regulations insure that substantial numbers of eels remain unfished. These factors are likely sufficient enough to maintain the species as a whole even under foreseeable fishing pressure. As such, we have determined that harvest is not a significant threat to the American eel at a population level.

Factor C. Disease or Predation

In our analysis of diseases and predation, we focused on the diseases and types of predation that were most likely to affect the American eel at a population level.

Predation

We evaluated changes in predation as a result of human-caused activities. It had been suggested in the 90-day finding that American eels blocked or delayed at upstream barriers could experience higher than normal mortality rates due to predation, because birds of prey and piscivorous fish often congregate at the base of dams to prey on other fish species (USFWS 2005b, p. 20). However, we found nothing more than anecdotal information on this topic, and therefore we were unable to quantify the impact of predation as a result of barriers. Natural predation rates are likely very high for elvers upon entering freshwater (see Background, *Juvenille Mortaltiy* and Jessop 2000, p. 522), but there is no evidence to indicate that natural rates of predation have risen, or that eel population numbers are approaching a diminished level where natural predation rates pose an increased risk to the eel rangewide (USFWS 2005b and 2006).

Disease

We analyzed whether the spread of fish diseases, and in particular parasites, has accelerated due to human activities, including global transport of fish for aquaculture, and whether the threat of disease presented a risk to the American eel at a population level.

Parasites. The parasite of most concern is the nonindigenous nematode *Anguillicolla crassus,* a parasite with five life stages that becomes sexually mature in the swimbladder of the eel. The only other parasite found in the eel swimbladder is another nematode, *Daniconema anguillae* (Moravec and Køie 1987 in Kirk 2003, p. 387), but it rarely occurs in high numbers (Kirk, unpublished observations in Kirk 2003, p. 387).

Although there is no direct evidence that *A. crassus* prevents Anguilled eels from completing their spawning migration or influencing the silvering process, hypotheses, such as those of Kirk 2003, have suggested that *A. crassus* may impair the capacity of the eel to undertake the migration to the Sargasso Sea. Presented below is the history of invasion by *A. crassus*, percentage of American eels infected, the known physiological effects on Anguilled eels from *A. crassus*, hypotheses regarding impacts to outmigrating silver eels, and our analysis of the data.

Native to Japanese eel, *A. crassus* invaded wild populations in Europe, most likely through aquaculture, around 1982, and in North America (Texas) about 1995, again likely a result of transported eels. Since then, the U.S. invasion by *A. crassus* has spread north along the Atlantic coast. By 1997, 10 to 29 percent of the American eels in the Chesapeake Bay were infected by *A. crassus*, and by the year 2000, greater than 60 percent of the American eels in the freshwater portions of the Hudson River, New York, were infected. The known northern extent of the parasite at this time is the Sedgeunkedunk Stream in Maine (USFWS 2006, p. 2). Although it has not yet been detected in Canadian waters, it is believed that *A. crassus* is likely to spread to Canada in the future, potentially through aquaculture, because there do not appear to be limiting factors for the parasite spreading farther north (USFWS 2006, p. 2, 7). Temperature is apparently not a limiting factor (although temperatures at or below 4 °C slow infection rates), nor is salinity (although rates of infection have been shown to be lower in brackish waters), and the parasite has now been found in all size classes of eel (Oliviera 2006, pp. 1–20, in USFWS 2006, p. 2).

An aspect that may aid in the spread of the parasite is the number and variety of intermediate hosts (currently 12 families, both fish and invertebrates, are known to serve as intermediate hosts). However, physical barriers, such as dams and natural waterfalls, which likely preclude movement of intermediate hosts, have been shown to significantly reduce infections of eels upstream beyond the second barrier (Machut 2006, pp. 75, 81–82). Also the expulsion of ballast waters may be providing transport for the parasite. Recent research indicates rivers with large ports have the highest rates of infection, leading researchers to the conclusion that ballast water may explain continued invasion (Oliveira 2006, p. 19 in USFWS 2006, p. 2). Another recent finding is that urbanization may increase susceptibility to infection. Elevated infection rates were present when urbanized lands exceeded 15 percent (Machut 2006, p. 82).

The percentage of American eels infected by *A. crassus* can vary significantly. In one North Carolina study the percentage of American eels infected ranged from 10 to 100 percent, between sites studied (Moser et al. 2001, p. 1). Hypotheses suggested to explain this wide range in American eel infection rates include: (1) Eels occurring near large shipping ports will have more exposure to exotic parasites, possibly as a result of infected intermediate hosts being transported by ballast water; (2) warmer waters are equated with higher prevalence of parasitic infection; and, (3) the longer a watershed has been infected, the higher the anticipated infection rate (USFWS 2006, p. 1–8).

Although *A. crassus* infection causes physiological damage to the swimbladder, this damage is not much of a concern except for silver eels during outmigration. There is no apparent detrimental effect on eel weight and length in the yellow eel stage, but the demands on the swimbladder, which assists in buoyancy and depth control, would be greatest during outmigration because the eel may use deeper waters on its trip back to the Sargasso Sea to spawn. The parasite typically lives for several months and therefore likely persists during outmigration (van den Thillart et al. 2005, pp. 7, 233; USFWS 2006, p. 2). According to Knopf and Mahnke (2004, p. 494), Japanese eel are not affected by *A. crassus* to the degree that a non-adapted host, such as the European eel (and presumably American eel) is because the Japanese eel possesses more effective defense mechanisms against *A. crassus*, likely due to the co-evolution process which resulted in a balanced host–parasite system without significant harm to the host. Kirk (2003, pp. 390, 391) presents studies suggesting there may be a level of immunity that develops in the non-adapted hosts.

Laboratory studies in the European eel, have shown that light (approximately 5 nematodes per eel) and moderate infections can reduce eels' swim capacity, perhaps by as much as 10 percent (Sprengel and Luchtenberg 1991 in Moser et al., 2001, p. 851). Würtz et al. (1996 in Kirk 2003, p. 390) demonstrated that adult parasite intensities of greater than 10 adult parasites per eel can reduce the proportion of oxygen in the swimbladder of adult eels by approximately 60 percent when compared to uninfected eels. Simulated swimming experiments in European eel indicate the impact of heavily parasitized eels (20 or more parasites) results in a decrease in swim efficiency and possibly reduced buoyancy. Heavily infected eels were not able to swim longer than a few months. Parasites cause the swimbladder to shrink, resulting in higher costs of transport (van den Thillart et al. 2005, p. 105). In addition, heavy infection causes deterioration of the swimbladder function due to severe permanent damage.

According to van den Thillart et al. (2005, pp. 233, 236) a damaged swimbladder interferes with the buoyancy control, resulting in poor or absent vertical navigation capacity in the open ocean and a decrease in swim efficiency which, they hypothesize, prevents the completion of the spawning migration. The likely result is death en route to the spawning grounds in the Sargasso Sea.

There is a significant level of speculation about the impact of *A. crassus* on the American eel during outmigration and spawning, neither of which can be easily studied under natural conditions. A level of uncertainty is therefore, inherent in our analysis. Also unknown is whether contaminants may act synergistically with parasites, possibly magnifying the impact on the species (USFWS 2006, pp. 7, 26).

For the American eel, the number of nematodes per infected eel (mean intensities) is an important aspect in evaluating the potential impact of this nematode on American eel, as is understanding the depths at which American eels outmigrate back to the Sargasso Sea, the length of that migration, and further understanding of what proportion of the American eel completes its life cycle in salt and brackish water where infection rates may be significantly lower. Unfortunately much of this information is not available.

Mean intensities in American eels have been found to be significantly different among sites, including being significantly lower in brackish water when compared to fresh water, (Morrison and Secor 2003, p. 1492). The majority of studies of American eels have shown fairly moderate levels of intensity of infection. North Carolina had a mean ranging from 2.0 to 12.3 nematodes per eel, depending on the river (Moser et al. 2001, p. 851). Mean intensities of infection of eels from the Hudson River in early studies were 1.0 to 1.7, increasing over time to 3.2 and 23.7, depending on the site (Morrison and Secor 2003, p. 1491). Low to moderate mean intensities of 2.6 to 9.0 were reported in the Chesapeake Bay (Barse et al. 2001, p. 1366). It is unknown if these relatively moderate mean intensities would have the same impact on American eels under natural conditions as was reported by the recent laboratory research by van den Thillart et al. (2005, p. 105) on European eels where higher densities of parasites caused a decrease of the optimal swim speed and increased the energetic cost of swimming.

We remain cautious in extrapolation of these preliminary laboratory studies with regard to rangewide implications given the absence of evidence for population-level effects, such as reduced recruitment of glass eels (which would be an indicator of decreased outmigration survival). This being said, we acknowledge the statement by the International Council for the Exploration of the Sea (ICES 2001, p. 6) that due to the fairly recent invasion of the U.S. by *A. crassus* and the long-lived nature of at least a portion of the American eel population, the impact of *A. crassus* on American eel may not yet have been fully realized. ICES (2001, p. 6) concluded that, for the European eel, the occurrence of this parasite does not match the timeline for when the decline in recruitment for European eel occurred. Given the extensive research on the European eel and the reasons for its apparent decline this statement should be given due consideration.

In summary, indigenous parasites are not known to be of significant concern to American eel at a population level. During the status review, we were provided with new information on the nonindigenous parasite *A. crassus*, including the northern extent of invasion. The literature details the impacts to individual European eels by *A. crassus* in a laboratory setting, and puts forward the hypothesis that these impacts reduce an individual's chance of successful spawning. However, similar research in the American eels has yet to be undertaken and several factors pertaining to the American eel may indicate less potential impact from *A. crassus:* (1) The mean intensities reported for American eels appear to be moderate; (2) the American eel has a shorter outmigration distance to the Sargasso Sea than European eels; (3) some areas currently are free from *A. crassus* infection (Canada, and possibly Central and South American and the Caribbean Islands); and (4) areas remain where *A. crassus* is found, that are still producing uninfected outmigrating individuals.

Pathogens. Viruses such as EVA (Eel Virus—America) and bacteria are present in the American eel, and periods of stress, such as metamorphosis, may activate viruses and bacteria. Although mortality from viruses may occur, there is no information available about virus prevalence and impact on American eel at a population level.

Van den Thillart et al. (2005, p. 7) found that European eels infected with the rhabdovirus EVEX (Eel Virus European X), a virus widely spread in the European eel population, developed hemorrhage and anemia during simulated migration in large swim tunnels and died after swimming for 1,000 to 1,500 km (estimated European eel outmigration to the Sargasso Sea is 5,500 km). The resting group of eels did not develop the disease, although they were also infected with the virus. This supports the theory that stress, such as completing metamorphosis and migrating, may activate the virus. Because none of the infected swimming eels survived the swim test, the authors concluded that virus infections may adversely affect the spawning migration of eels. The virus infection appeared more severe than the infection with the swimbladder parasite, *A. crassus* (van den Thillart et al. 2005, p. 7). In a report on the presence of viruses in eel populations from various geographic regions and countries, the samples taken from the United States (Virginia) and Canada (St. Lawrence River) were negative for EVEX virus (van Ginneken et al. 2004, p. 270). Disease screening for glass eels used in recent stocking programs have also been free of EVEX virus. Other pathogens, such as *Aeromonas salmonicida,* a bacterium known to cause furunculous lesions, exist in cultured American eel (Hayasaka and Sullivan 1981, p. 658), but neither rates of infection in the wild nor population level impacts have been established.

In summary, pathogens such as EVEX virus appear to have a significant impact on eels in a laboratory setting; however, the prevalence of this virus, or any other virus or bacteria, in the American eel population is not documented.

Summary of Factor C

We conclude that predation is not a threat to the American eel at the population level, nor are disease and pathogens. We acknowledge that there is a high level of uncertainty with regards to the impacts on individual silver American eels infested with *A. crassus* during outmigration. However, given the absence of information for population-level effects, such as reduced recruitment of glass eels, and given that there remain uninfected eels for spawning and extensive areas of the species range which are not currently invaded by *A. crassus* or infection levels are low to moderate, we have determined that the current information does not indicate that *A. crassus* is a threat to the American eel at a population level.

Because outmigration occurs in the open ocean, direct study of the effect of *A. crassus* under natural conditions will continue to be difficult. This emphasizes the need for data collection and analysis designed to differentiate between population fluctuations responding to natural phenomena, such as oceanic conditions, and those that are human-caused. We support the continuation and expansion of the coastwide monitoring program started several years ago, and the ongoing research being conducted by the scientific community.

Factor D. Inadequacy of Existing Regulatory Mechanisms

Under this factor we will briefly describe and address whether existing regulatory mechanisms are adequate or inadequate to conclude that the American eel is not endangered or threatened. As part of our analysis of threats under Factors A, B, and E, we describe how certain existing regulatory mechanisms directly or indirectly reduce these threats (we are unaware of regulatory mechanisms that would directly reduce the threats discussed in factor C). Based on this analysis, we conclude that *Sargassum* harvest, freshwater and estuarine benthic habitat destruction, streamflow alteration, harvest, passage barriers, turbines, and contaminants are not significant threats to the American eel at the population level and that additional protection is not necessary to determine that listing the species is not warranted. Because we found no threat that, individually or in combination with other threats, is significant at a population level, there is no instance in which the protections provided by existing regulatory mechanisms are inadequate such that listing as endangered or threatened would be necessary.

Seaweed Harvest

The status of the American eel with regard to *Sargassum* harvest is influenced by the effect of the following regulation, and therefore, we describe in this section how the existing regulatory mechanisms directly or indirectly reduces this threat. During the status review, we evaluated the harvest restrictions outlined in the second revised Fishery Management Plan for Pelagic *Sargassum* Habitat of the South Atlantic Region. The specified maximum and optimum harvest of *Sargassum* severely limit *Sargassum* harvest, and American eel larvae have not been found in the *Sargassum.* We concluded during the status review that the commercial harvest of *Sargassum* is not a threat to the American eel (see Factor A), and therefore we find that the regulations governing *Sargassum* harvest are more than adequate for the protection of American eel larvae.

Habitat Degradation

The status of the American eel with regard to habitat degradation is influenced by the effect of the following regulations, and therefore, we describe in this section how certain existing regulatory mechanisms directly or indirectly reduce this threat.

Stream Flow and Benthic Habitat. During the status review, we evaluated Federal and State and local regulations that afford levels of protection and regulate benthic habitat destruction and stream flow alteration. The Clean Water Act (33 U.S.C. 1251 *et seq.*) is the primary Federal law, enacted at Federal and State levels that restricts the degradation of benthic habitats and flow alteration. The Fish and Wildlife Coordination Act, as amended (16 U.S.C. 661 *et seq.*), has been the principal authority for incorporating fish and wildlife conservation measures into water development projects. The River and Harbors Act of 1938 (Pub. L. 75–685) provided for wildlife conservation to be given ''due regard'' in planning Federal water resources projects. The Federal Power Act, as amended (16 U.S.C. 791a *et seq.*), contains requirements to incorporate fish and wildlife concerns into licensing, relicensing, and exemption procedures. The original Federal Power Act provides for cooperation between the Federal Energy Regulation Commission (FERC) and other Federal agencies, including resource agencies, in licensing and relicensing power projects.

Many States have specific laws and regulations that limit benthic habitat destruction and flow alterations. Some mirror or implement Federal clean water law regarding water quality standards, including designated uses, criteria, and an antidegradation policy, which can provide a sound legal basis for protecting wetland resources, including benthic habitats for American eels, through State water quality management programs. In most of the eastern United States and Canada, the riparian doctrine provides some protection for maintenance of instream flows. The riparian doctrine generally affords some protection for off-stream uses of water, while flow alterations usually must conform to some minimum standard.

Estuarine habitat. Laws, such as the Estuary Protection Act (16 U.S.C. 1221 *et seq.*), the Estuaries and Clean Waters Act of 2000 (33 U.S.C. 2901 *et seq.*), and the Coastal Barrier Resources Act (16 U.S.C. 3501 *et seq.*), provide financial incentives for estuary habitat protection and restoration. Additionally, the Rivers and Harbors and the Federal Power Act described above would also address impacts within estuarine waters.

During the status review, we concluded that habitat degradation is not a significant threat to the American eel (see Factor A) and therefore we find that the regulations governing activities such as estuarine and benthic habitat degradation and stream flow alteration are adequate for the protection of American eel.

Contaminants

In general, before the 1960s there were no Federal environmental laws regulating pollution. Concerns began to mount with regard to the threat of pollution to environmental resources and were first addressed in 1965 with the Solid Waste Disposal Act and the Water Resources Planning Act. In 1970 the U.S. Environmental Protection Agency (US EPA) was established to ''protect human health and safeguard the natural environment''. Currently there are numerous International, Federal, and State regulations that reduce the threats of contaminants to environmental resources such as the American eel. The 1972 Great Lakes Water Quality Agreement was signed between the U.S. and Canada to ''restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem''. In addition, Canada also has authority to manage water resources and control pollution under two primary acts, the Ontario Water Resources Act and the Environmental Protection Act. Federal regulations that address environmental contaminants include the Water Pollution Control Act and the Federal Insecticide, Fungicide and Rodenticide Act of 1972, Safe Drinking Water Act of 1974, Resource Conservation and Recovery Act of 1976, Clean Water Act and the Soil and Water Resources Conservation Act of 1977, Comprehensive Environmental Response Compensation and Liability Act of 1980, and the Oil Pollution Act of 1990. Under the Clean Water Act, the U.S. EPA can delegate many of the permitting and regulatory aspects of the law to state governments. In accordance with the Clean Water Act and state statutory authority, individual states have developed water quality regulations that are comparable to and often more stringent than the Federal regulations.

We concluded during the status review that contaminants are not a significant threat to the American eel (see Factor E), and therefore we find that the regulations governing contaminants are adequate for the protection of the American eel.

Fish Passage

The status of the American eel with regard to barriers and turbines are influenced by the effect of the following regulations, and therefore, we describe in this section how certain existing regulatory mechanisms directly or indirectly reduce these threats.

During the status review, we evaluated section 18 of the Federal Power Act (16 U.S.C. 791a *et seq.*). Section 18 is the regulatory mechanism that specifically provides for fish passage prescriptions by the Secretary of Interior (as exercised by the USFWS) and the Secretary of Commerce (as exercised by NMFS) for dams regulated by FERC. Most States within the range of the American eel in the United States have specific fish passage laws, and those State resource agencies often work closely with the USFWS or NMFS when creating fish passage facilities. Sometimes fish passage is incorporated in the 401 Water Quality Certificate issued by the States under the Clean Water Act (33 U.S.C 1251 *et seq.*).

Along the Atlantic coast, most fish passage facilities are prescribed under section 18 of the Federal Power Act or recommended under section 10(j) of the Federal Power Act administered through FERC at hydroelectric facilities. On the mainstem of the upper Mississippi River /Illinois Waterway, the Army Corp of Engineers (ACOE) owns and operates a series of navigation locks and dams for the Federal 9-Foot Channel Project. However, other than recommendations made by resource agencies under provisions of the Fish and Wildlife Coordination Act (16 U.S.C. 661 *et seq.*), there is no specific regulatory mechanism requiring the ACOE to provide fish passage (Wege 2006, p. 6). There may be opportunities in the future for fish passage under the proposed Federal Navigation and Ecological Sustainability Program, which requires Congressional authorization and funding. Many of the large reservoirs in the Midwest were constructed by the ACOE and remain under its jurisdiction. In the Tennessee River Valley, the Tennessee Valley Authority owns and operates 49 developments for flood control, navigation, and hydroelectric development; none of these facilities is operated specifically for fish passage, although some upstream and downstream passage is likely through those mainstem dams with locks (Wege 2006, pp. 5–6). Recent records of American eels from the Tennessee and Cumberland River are few (Etnier and Starnes 1993, p. 120).

Thousands of small dams that were constructed over the last several hundred years for water power to run grist mills, saw mills, and textile mills, as well as for water storage for drinking water and other industrial and municipal purposes, are exempted from most modern regulatory mechanisms except for State dam safety codes. Thousands of dams in the Mississippi River watershed and along the Atlantic coast fall under this category. However, as these structures age, funding is often not available to bring them up to State dam safety codes, which provides an opportunity for their removal (Wege 2006, p. 5).

The Energy Policy Act of 2005 (Pub. L. 109–58) amended the Federal Power Act amended section 18 of the Federal Power Act and calls for administrative hearings when the material facts of an agency-prescribed fishway measure can be challenged by the dam owner or other party to the proceeding. The alternative fishway measure presented by the dam owner or other party can be adopted if it is as effective in purpose and economically beneficial to the dam owner. The burden of proof, of both the benefit and need for the fish passage, has been somewhat shifted from the private sector (i.e., dam owner) to the public sector (i.e., agency personnel). Additionally, the agency is now to consider the economic impact of a fishway prescription to the dam owner. While the process to consider alternative fishways is new, the agencies (USFWS and NMFS) have received and considered alternatives from license parties as a regular practice, and have revised preliminary conditions and prescriptions as new information was received (Hoar 2006, p. 2; DOI 2005, p. 69808). It is yet to be seen whether these amendments to the Federal Power Act will have an effect on eel passage implementation.

In Canada, there is no licensing or regulatory system comparable to FERC for hydroelectric dams. Canadian resource agencies must rely on various fisheries laws that can be invoked, and they must often negotiate the construction of fishway facilities rather than require them.

We have concluded that barriers limit, and in some watersheds eliminate, access to inland portions of the American eel's range in North America, but that there is no indication that the roughly 25 percent restriction of access to historic freshwater areas is significantly impacting the American eel at a population level (see Factor A). We have also concluded that turbines can cause regional impacts to abundance of American eels within the watershed, but there is no evidence that turbines are affecting the species at a population level (for full discussion of turbine impacts see Factor E). Therefore we find that the regulations governing fish passage are adequate for the protection of American eel.

Harvest and Trade

The status of the American eel with regard to harvest and trade are influenced by the effect of the following regulations, and therefore, we describe in this section how certain existing regulatory mechanisms directly or indirectly reduce these threats.

During the status review, we reexamined the ASMFC's mechanism for regulating the commercial and recreational harvest of American eel along the Atlantic coast States (see Factor B. *Overutilization*) and ASMFC's flexibility in responding to changing stock status. The American Eel Fisheries Management Plan (FMP) requires that member States establish uniform size limits and other regulations for commercial harvest. In 2005 and 2006, the ASMFC underwent a public process for potential changes to the FMP. In 2006, the ASMFC adopted Addendum I to their American Eel FMP (ASMFC 2006c, p. 1; ASMFC 2006d, pp. 1–3) which requires a reporting system. Addendum 1 recommends the implementation of a specific eel harvester permit or license for each State. Under this addendum, each license requires reporting of trip-level catch and effort, or States can choose to implement an eel dealer permit and reporting system. The American Eel Technical Committee under the ASMFC stated that this improved monitoring system will assist in future stock assessments. The permit or license should be required for all eel harvesters, including those who harvest eels for use as bait. The American Eel Technical Committee also recommended a specific eel report from dealers and a license or permit for dealers, including bait dealers. Harvester and dealer reports must differentiate between the amount of eels used or sold for food and the amount of eels used or sold for bait. The Addendum responds to concerns regarding the lack of accurate catch and effort data, and the critical need for these data for stock assessment purposes (ASMFC 2006a, p. 2). Although silver eel fishery and seasonal closures were options presented during the public process (ASMFC 2004b, p. 7), no further harvest restrictions, other than those already laid out in the ASMFC's FMP in 2000, have been implemented at this time.

In Canada, harvest restrictions are under the purview of the federal government unless the authority has been passed to the Provinces. Restrictions and closures are already in effect for certain areas in response to the decline in the upper SLR/LO (see Factor B. Overutilization). Provincial management programs in Ontario and Quebec have imposed license and season restrictions, and reduced quotas, in some cases to zero catch (Mathers and Stewart 2005, p. 1). The federal government of Canada retains authority within the Maritime Provinces.

New information was gained on the lack of restrictions in harvest from responding countries outside U.S. and Canadian waters, and the lack of import restrictions in the responding European countries (see Factor B). Our determination, based on the analysis of commercial harvest during the status review, is that although abundance of eels is likely affected locally and regionally by commercial harvest, commercial harvest is not a significant threat to the American eel (see Factor B).

To protect American eel from unregulated recreational harvest, all ASMFC member States were required to establish uniform size (6 inches) and possession limits (maximum 50 eels per person per day) for recreational fisheries, and recreational fishermen are not permitted to sell eels without a State license that specifically authorizes this activity (ASMFC 2006a, p. 17). During the status review recreational harvest was determined not to be a significant threat to the American eel at a population level (see Factor B).

In summary, because we conclude that *Sargassum* harvest is not a threat to the American eel, and habitat degradation, harvest, and fish passage, including turbines, were not significant threats to the American eel at the population level, it is reasonable to conclude that current regulatory mechanisms governing habitat degradation, harvest and fish passage, including turbines, are adequate to the extent that listing under the Act is not necessary.

Factor E. Other Natural or Manmade Factors Affecting the Species' Continued Existence

Hydropower Turbines

During the status review, we examined the extensive body of literature on the impacts of turbines to eels. Specifically, we looked at: (1) Types of turbine impacts; (2) variations in mortality and injury rates and possible causes; (3) uncertainties and information gaps; and, (4) impacts of turbines on the American eel at a population level.

During outmigration, as eels swim downriver, where hydroelectric facilities are present, some eels become entrained and enter the turbines. Of the eels that enter the turbines, some survive and others are injured or die (EPRI 2001, p. 3–1). Smaller turbines and turbines that rotate faster pose the greatest threat to eels. The degree of injury and mortality increases with larger eels (EPRI 2001, p. 3–8), suggesting that mortality rates of large female eels may be disproportionately higher than mortality rates of males. Turbine mortality to eels has also been shown to be affected by dam size, turbine type, load, and specific operating conditions (including nighttime versus daytime operation, because eels tend to outmigrate during the night; peak versus off peak power production, and level of spill), and the behavior of the eels (EPRI 2001, pp. 3–4—3–10; USFWS 2005b, pp. 30–33). There is only limited data on sublethal effects to eels and their impact on outmigration and reproductive viability of the population. Sublethal effects include injuries that may result in loss of fitness (USFWS 2005b, pp. 34–36), increased risk of predation, and delayed migration (as observed in Anguillid species native to New Zealand) (Watene et al. 2002 in EPRI 2001, pp. 2–18).

The Electric Power Research Institute report compiled data on eel mortality through turbines and found that not all, but most, eels go through turbines due to migration behavior. For eels that go through the turbines, the mortality level was highly variable, depending on turbine design, size of eels, and operational conditions. For example, for survival rates estimated at Moses—Saunders and Beauharnois hydropower facilities on the St. Lawrence River, Francis turbines were found to result in mortality rates of approximately 15 percent (85 percent survival), and fixed-blade propeller turbines were found to result in mortality rates of approximately 25 percent (75 percent survival) (COSEWIC 2006, pp. 45–46; see EPRI 2001, pp. 3–1—3–11 for more details on the impacts to eels from turbines). Higher mortality rates have also been reported. Montên (1985 in McCleave 2001b, p. 593) reviewed literature through the early 1970s on injury and mortality on European eel during turbine passage. He reported injury rates, where injury likely resulted in death, of 40 to 100 percent in 73-cm eels passing through Kaplan turbines under various operating conditions. According to Hadderingh (1990 in ASMFC 2000, p. 40) and McCleave (2001b, p. 611), if American eels have to pass through turbines in their downstream migration, mortality rates range from 5 to 60 percent.

Cumulative mortality refers to the estimated combined mortality within a watershed, and is thought to cause significant reductions in that watersheds' eel reproductive contribution to the population. Verreault and Dumont (2003, p. 247) estimated combined mortality rates of 40 percent for Lake Ontario s outmigrating female eels from the Moses—Saunders and Beauharnois hydroelectric facilities on the St. Lawrence River. The cumulative impact of multiple hydroelectric projects within a watershed, as simulated by McCleave (2001b, p. 602), indicates substantial decrease in overall eel reproductive contribution from a watershed, even when survival rates of eel passage were high through each successive turbine or dam project. The simulated cumulative mortality within the watershed was approximately 60 percent (40 percent survival) of overall reproductive contribution when mortality per dam was 20 percent (80 percent survival). McCleave states, however, that his model is meant as a tool to compare results based on different inputs, not a definitive statement about cumulative mortality within the watershed. Based on the data available, we can reasonably assume that where American eels encounter one hydropower facility during outmigration, there is a typical mortality rate in the range of 25 to 50 percent, and when one or more turbines are encountered, the range of mortality rate increases to 40 to 60 percent for that watershed. This still leaves escapement values (the percent of individuals who survive to continue outmigration) of a minimum of 40 percent and a maximum of 75 percent. Even if the mortality rate has been underestimated, there are still eels in freshwater areas that are unaffected by turbines, and eels that survive passage in spillover.

We have updated Busch et al.'s (1998) data on the percentage of dams with turbines on the Atlantic coast and have added the Gulf Coast. Out of the 33,663 dams, 1,511 (or 4.5 percent) are for hydropower and, we assume, are fitted with turbines. Of these only a small percentage (2.06 percent) are on terminal dams (Castiglione 2006, p. 1). Terminal dams (dams closest to the ocean) fitted with turbines affect American eels throughout the watershed as they outmigrate, but dams fitted with turbines farther up in the watershed impact only eels outmigrating from tributaries and the mainstem of the river above the dam, not outmigrating eels from tributaries or mainstem river habitats below the dam. Mapping also showed that hydroelectric facilities appear clustered in the Northeast and Great Lakes area (Castiglione 2006, p. 2). Still, we do not have the percent of eels subject to turbines. This number could be relatively small given that: (1) The species' range is extensive (see Background, *Range*); (2) not all Atlantic coast watersheds have multiple hydroelectric turbines (USFWS 2005b, p. 31); (3) dams that have turbines are likely large dams (more then 50 feet high), which often limit upstream passage of eels in these watersheds because of their height, and therefore limit the risk of turbine mortality or injury at maturity (see Factor A); and, (4) there are tributaries to the Gulf of Mexico that have limited impacts from hydroelectric turbines, including the Mississippi watershed (which has few hydroelectric facilities) (Wege 2006, pp. 5–6).

The impacts from turbines to the American eel, experts have suggested, could result in a decrease in local or regional abundance, as well as a population skewed toward smaller and younger females and more males, and together these changes in the population could ultimately result in a decline in recruitment (USFWS 2005b, p. 34). In analyzing the effects of turbines on the American eel, however, we also took into account that turbines principally affect freshwater inhabitants, leaving the portion of the population that inhabits estuarine and marine waters largely unaffected (USFWS 2005b, p. 3). As a consequence, a decline resulting specifically from turbine mortality may be buffered by the spawning input from eels residing in unaffected freshwater habitats, or the estuarine or marine habitats throughout its wide range.

It was also suggested by experts that the importance of turbines as a population threat can be assessed only in the context of a general understanding of distribution and dispersal patterns of the eel. Specifically, a watershed's specific reproductive contribution rates and size distribution of females needs to be accounted for in determining the impact of turbines on anything larger than a watershed level basis (USFWS 2005b, p. 31). Currently there is no such rangewide estimate.

In lieu of this rangewide estimate, we can look at whether there has been an impact to the American eel population, and if so, if it relates to the construction of hydropower facilities. As is discussed under Population Status, there does not appear to be a rangewide decline in recruitment of juvenile eels; therefore, we can draw no connection between turbine mortality and population level impacts. Additionally, according to Castonguay et al. (1994a, p. 486), the timing of the 1980s decline of the American eel in the upper SLR/LO does not correlate with the human-caused changes that occurred on the St. Lawrence River prior to 1965.

In summary, turbines, particularly multiple turbines within a watershed or turbines on terminal dams, can cause substantial mortality within those watersheds. However, turbines are present on a small portion of the dams within the Atlantic coast and are absent from most of the barriers encountered in the Mississippi Watershed, and there remains a percentage of successful eel passage through turbines or with spill over the top of dams. Additionally, there is no evidence of a population level effect from turbine mortality. We conclude that turbines are responsible for decreases in abundance on a local or regional scale, but turbine mortality is not a significant threat to the American eel at a population level.

Contaminants

During the status review, we developed a summary of the current American eel contaminant literature (Roe 2006, pp. 1–26), and analyzed the impacts of: (1) Existing contaminants on the American eel life cycle, including levels of uncertainty, and particularly the inability to successfully raise eels and consequently study the impacts of contaminants on any of the eel life stages; (2) new and emergent contaminants; (3) other persistent contaminants, such as genotoxic polycyclic aromatic hydrocarbons (PAHs); (4) non-persistent contaminants, such as pharmaceutical chemicals and pesticides; (5) complex mixtures of contaminants; (6) vitamin deficiency related to diet; and (7) combined threats, such as disease, parasites, and contaminants, on eel health.

(1) Existing Contaminants

Concentrations of polychlorinated biphenyls (PCBs), PAHs, polychlorinated diphenyldioxins/ polychlorinated diphenyl furans (PCDDs/PCDFs), pesticides such as mirex and dichlorodiphenyltrichloroethane (DDT), and metals such as mercury were reported in yellow and silver American eel tissues from eastern U.S. and Canadian waters. However, much uncertainty exists with regard to the population's rangewide contaminant load since environmental contaminant data were only available from a small portion of the species' range; therefore, the contaminant loads within American eel throughout its entire population range are unknown.

The contaminant concentrations reported in American eel tissues are within the range of concentrations associated with impacts that have been documented in other fish species. These environmental contaminants have been shown to have biochemical, immunological, genotoxic (chemicals toxic to DNA), growth, survival, and reproductive impacts on various fish species. We believe that contaminants therefore have the potential to also impact the American eel (Roe 2006, pp. 5–8). Interestingly, American eels survive with these contaminant loads at concentrations that would be toxic to other fish species. There is, however, a potential for the impacts to be fully expressed during critical periods of their life cycle such as metamorphosis, hatching, and larval development (Robinet and Feunteun 2002, pp. 267, 270–272), all of which occur at sea and therefore are currently impossible to research under natural conditions (USFWS 2006, p. 24–27). Because of this species' unique life history, caution was suggested in utilizing surrogate species data in determining impacts of contaminants on eels (USFWS 2006, p. 24).

Inability to successfully study contaminants on all American eel life stages. To date, researchers have not been able to successfully complete the eel life cycle in the laboratory (Penderson 2003 pp. 324, 336–337; Palstra et al. 2005, pp. 533–534). Research has also not been conducted on the impacts of contaminants on eel embryos and leptocephali, or during metamorphosis from the yellow to silver eel stage, or during outmigration and reproduction. Two recent laboratory studies on the reproductive capacity of European eels by van den Thillart et al. (2005, pp. 110, 169) and Palstra et al. (2006, pp. 147–148) indicated that preliminary studies of PCB and dioxin-like contaminant impacts to maturation and fertilization showed negative impacts on egg quality and embryonic development. However, artificial hormone inducement of maturation in European eels is complicated by high female adult mortality rates and high rates of embryo death after fertilization (Pedersen 2003, pp. 336–337; Knights submitted, pp. 1–2). Therefore, it is difficult to be certain whether the mortality rates are associated with artificial maturation or fertilization techniques or with exposure to contaminants (Knights submitted, p. 2). Unless or until the issue of embryo death can be attributed exclusively to the presence of contaminants, the data is still inconclusive with regard to the determination of the impacts of PCB and dioxin-like contaminants at a population level in the American eel.

(2) New and Emergent Contaminants

The impacts of new and emergent chemical contaminants in fish are unclear and not available for the American eel. An example of new and emergent contaminants presented during the workshop (USFWS 2006) was polybrominated diphenyl ethers (PBDEs), a group of chemicals used as flame retardants in a multitude of consumer products (Agency for Toxic Substances and Disease Registry or ATSDR 2004, pp. 11–12). PBDEs are similar to PCBs in that they are lipophilic, persistent in the environment, and bioaccumulate in organisms. However, the impacts to fish and other aquatic organisms have not been completely defined in the scientific literature. There is evidence that PBDEs cause enzyme activity alterations and delayed embryonic hatching in fish, and they result in behavioral alterations (Timme-Laragy et al. 2006, pp. 1098–1103). Concentrations of PBDEs have been measured in European eels (de Boer 1990, pp. 315–318; Covaci et al. 2004, pp. 3851–3855) and in other species (Lebeuf et al. 2004, pp. 2973–2976); however, the impacts of PBDEs to eels were not discussed. Therefore any impacts to the American eel at a population level would be purely speculative.

(3) Impacts of Genotoxic Contaminants

The impacts of genotoxic PAHs on the eel remain uncertain. There is considerable evidence that indicates a causal relationship between exposure to PAHs and genotoxic impacts such as tumor frequency, deformities, and other lesions in fish, particularly bottom feeding fish (Black 1983, pp. 328–333; Metcalfe et al. 1990, pp. 133–139; Baumann and Harshbarger 1995, pp. 168–170; Baumann et al. 1996, pp. 131–149; Johnson et al. 1998, pp. 125–134). Couillard et al. (1997, pp. 1918–1926) documented the occurrence of precancerous lesions in liver tissues from migrating American eels from the St. Lawrence River. The prevalence of the lesions in the eel liver tissue was reported to be correlated with increasing contamination in eels, and the authors concluded that PAHs may have been the cause (Couillard et al. 1997, p. 1924). Recent research in American eels (Schlezinger and Stegeman 2000, pp. 378–384) and European eels (Doyotte et al. 2001, pp 1317–1320; Bonacci et al. 2003, pp. 470–472; Mariottini et al. 2003, pp. 94–97) has shown that induction of enzyme activity has also been used as a biomarker for exposure to PAHs and similar contaminants. Genotoxic PAHs may be impacting successful outmigration, but impacts of lesions and tumors have not been researched under natural conditions or within the laboratory.

(4) Non-Persistent Contaminants

Short-term exposure to non-persistent contaminants during critical American eel life stages may be of concern (USFWS 2006, p. 25), but uncertainty remains. The literature has shown that endocrine disrupting environmental contaminants such as 4-nonylphenol (which is formed during the industrial synthesis of detergents), and pesticides such as atrazine and diazinon, cause physiological changes, inhibit growth, and therefore inhibit the survival of wild Atlantic salmon (*Salmo salar*) along the Canadian Atlantic coast (Moore and Waring 1996, p. 758; Fairchild et al. 1999, p. 349; Brown and Fairchild 2003, p. 146; Arsenault et al. 2004, p. 255; Waring and Moore 2004, p. 93). American eels are sporadically exposed to relatively high concentrations of non-persistent contaminants during their migration through the St. Lawrence River to the Sargasso Sea (Pham et al. 2000, p. 78). For example, the largest primary physio-chemical municipal sewage treatment plant in North America is located in Montreal, and treated effluent is discharged to the St. Lawrence River (Environment Canada 2006, pp. 1–3; USFWS 2006, p. 25). At this location, there is evidence of endocrine disruption in other aquatic organisms exposed to the effluent from 50 km upstream to 50 km downstream of the plant (Aravindakshan et al. 2004, pp. 156–164; Gagné et al. 2004, pp. 33–43).

However, currently there is no information within the literature on the sensitivity of eels to short-term exposure to these potentially endocrine disrupting non-persistent contaminants.

(5) Exposure to Complex Mixtures of Contaminants

The cumulative impacts of complex mixtures of contaminants on eel species are unknown. Fish and other wildlife are not exposed to just one single contaminant in the aquatic environment. Contaminants mixed together may interact and have additive (Dioxin-like contaminants: Safe 1990, pp. 71–73; Van den Berg et al. 1998, pp. 775–776) or synergistic (PAHs: Wassenberg and Di Giulio 2004, p. 1662) effects.

(6) Vitamin Deficiency Related To Diet

In addition to contaminant-induced impacts discussed above, decreased concentrations of antioxidant vitamins may also be impacting American eel survival, but this remains uncertain. Deficiences of antioxidant vitamins, such as thiamine, vitamin B1, and astaxanthin (a precursor to vitamin A), have been associated with increased early mortality in salmon and trout species (Fitzsimons 1995a, p. 267; Fitzsimons 1995b, pp. 286–288; Vuorinen et al. 1997, pp. 1151–1163; Fitzsimons et al. 2001, p. 229). It has been suggested that the occurrence of the early mortality syndrome in Lake Ontario lake trout is related to alewife (*Alosa pseudoharengus*) and their high thiaminase content (Fitzsimons 1995b, p. 288). Thiaminase are a group of enzymes that break down thiamine in the body and Alewife is a common food item for young trout. Because alewife are also consumed by American eels it has been hypothesized that American eels in Lake Ontario may be experiencing effects from reduced levels of thiamine. However, because this hypothesis has yet to be tested this theory remains speculative.

(7) Impacts of Combined Threats

Finally, contaminants can impact the immune system and therefore increase the organism's susceptibility to other threats such as diseases, parasites, and bacterial and viral infections (Arkoosh et al. 1996, pp. 1154–1161, Arkoosh et al. 1998, p. 182; Grassman et al. 1996, p. 829; Couillard et al. 1997, p. 1916; Johnson et al. 1998, p. 125; Van Loveren et al. 2000, p. 319; Zelikoff et al. 2000, p. 325), but the effect on the American eel remains uncertain. The cumulative stress of the complex mixtures of environmental contaminants and other threats may potentially lead to increased mortality. Field studies have documented susceptibility to infections in European and North American fish species (Arkoosh et al. 1998, pp. 188–189; Van Loveren et al. 2000, pp. 322–323; Zelikoff et al. 2000, pp. 325–330), which would make these fish more susceptible to disease. Bacterial pathogens have been isolated in American eels, and the authors suggested that increased prevalence of these pathogens may potentially be related to stress and subsequent decreased immune resistance (Hayasaka and Sullivan 1981, p. 658; Davis and Hayasaka 1983, pp. 559, 561; see Factor C).

In summary, contaminants may impact early life stages of the American eel, but we remain cautious in extrapolation of these preliminary laboratory studies with regard to rangewide implications without specific information. A correlation between the contamination of the upper SLR/LO and the timing of the 1980s decline of American eel in the upper SLR/LO is not evident (Castonguay et al. 1994a, pp. 482–483), and current environmental laws and regulations have significantly decreased the discharge of many persistent environmental contaminants. Given the absence of evidence for population-level effects, such as reduced recruitment of glass eels (which would be an indicator of decreased outmigration survival, or egg or leptochephali survival as a result of the impacts of contamination), we believe that the available information on contaminants does not indicate a significant threat to the American eel at a population level.

Because spawning and egg and leptochephali maturation occurs in the open ocean, directly study of the effects of contaminants under natural conditions will continue to be difficult. This emphasizes the need for data collection and analysis designed to differentiate between population fluctuations responding to natural phenomena such as oceanic conditions and those that are human-caused. We support the continuation and expansion of the coastwide monitoring program started several years ago, and the ongoing research being conducted by the scientific community.

Oceanic Conditions

During the status review, we explored the relationship between oceanic conditions and the recruitment of leptocephali to coastal and riverine habitats both hypothetically and through correlative data. Additionally, we investigated and describe briefly here the types of oceanic conditions that have the potential to impact American eels. Finally, we analyzed the potential for oceanic conditions to impact the American eel at a population level.

Variations in oceanic conditions have been linked to wide-ranging and long-term changes in many fish, invertebrate, and zooplankton species. General ecological responses to oceanic variations encompass changes in timing of reproduction, egg viability, timing of food availability, larval growth and mortality, population sizes, spatial distribution, and inter-specific relationships (such as competition and predator-prey relationships), by affecting temperature, salinity, vertical mixing, circulation patterns, and ice formation. However, the relationships are complex, usually non-linear, and operate through complex mechanisms through several trophic levels over the ecosystem, and over a broad range of time and spatial scales (Colbourne 2004, p. 16). Further, a population's response is likely to vary in different regions (Ottersen et al. 2001, pp. 1–14; Attrill and Power 2002, pp. 275–278; Hurrell et al. preprint, p. 10, 22–25, 38; Perry et al. 2005, p. 1–4; Weijerman et al. 2005 abstract and appendix 2, p. 3).

Oceanic conditions likely play a significant role in the population dynamics of American eel (Knights et al. 2006, p. 2), but the relationships between specific oceanic conditions and eel recruitment remain almost entirely hypothetical. Changes in oceanic conditions have previously been thought not to be correlated with the decline in the upper SLR/LO (Castonguay et al. 1994b, p. 6; ICES 2001, p. 5). To better understand this complex relationship given the scant available literature, we requested assistance from oceanic and eel experts. Part of the assistance was a summary of all available literature, entitled *American Eel Leptocephali-Larval Ecology and Possible Vulnerability to Changes in Oceanographic Conditions,* by M. Miller of the Ocean Research Institute at the University of Tokyo (cited as Miller 2005). Additionally, we examined published and unpublished data on the topic (Knights, Friedland, Casselman, Miller, Kritzer, and Govoni in USFWS 2005b, pp. 50–65).

The types of oceanic conditions that have the potential to affect eels in the North Atlantic include: (1) Changes to sea surface temperatures (SSTs); (2) changes to mixed layer depth (MLD); (3) deflections of the Gulf Stream at the Charleston Bump and Cape Hatteras; and (4) other changes. Changes of SSTs include inhibition of spring mixing, and nutrient recirculation and productivity, which may influence leptocephali food abundance. MLD (the depth to which mixing is complete, relative to the layer of ocean water beneath it) changes include changes in size and depth of leptocephali habitat, which would affect leptocephali abundance, survival, or transport. Changes in the Gulf Stream could interrupt migration by slowing or removing leptocephali from the Gulf Stream, and any transport and subsequent recruitment problems might be accentuated at the extremes of the species' range. The ''other'' category included changes to other aspects of the Gulf Stream, such as the formation of eddies, which may spin leptocephali off of the main current (USFWS 2005b, p. 53).

Variation in oceanic conditions is often depicted by the North Atlantic Oscillation Index (NAOI). The NAOI is a measure of oceanic-climate changes, expressed as the difference in atmospheric pressure measured between Greenland and the Azores. The NAOI has phases (positive and negative) that have important oceanographic effects. For example, a positive (high) NAOI is indicated by periods of stronger winds, greater surface-water mixing, reduction of the Gulf Stream, shift of the Gulf Stream in a northeast direction, and increases in deep water formation and water mass formation in the Labrador Sea (and, it is hypothesized, weak eel recruitment); a negative NAOI shifts the Gulf Stream south and increases the transport in the Labrador Current (the western boundary current of the North Atlantic subpolar gyre) (and it is hypothesized, a strong eel recruitment). These oscillations correlate with other oceanic factors such as MLD, SST anomalies, and position of the North Wall (a steep water temperature gradient) of the Gulf Stream (for further discussion of NAOI see Weijerman et al. Appendix 2, pp. 3, 9).

The NAOI has received considerable attention because of its strong negative correlation with recruitment of European eels (glass eels recruited to den Oever, Netherlands) (ICES 2001, p. 5) and a similar, but weaker, negative correlation with recruitment of American eels (juvenile eels recruited to the St. Lawrence River) (ICES 2001, p. 5; Cairns et al. 2005, Table 9.2, p. 66). From the mid 1950s to 1978/1979 winter the NAOI was in a 24 year negative phase. From 1979/1980 winter to 1994/1995 winter the NAOI was in a positive phase (Weijerman et al. Appendix 2, pp. 3, 9) and this positive phase may have continued until recently. During this prolonged positive (high) phase European eel recruitment had been correspondingly low (ICES 2002, p. 2). The last few winters, however, have not been strongly positive (Hurrell et al. preprint, p. 4), which may indicate that the NAOI is beginning to shift to a negative phase, which would benefit eels (USFWS 2005b, p. 66). A shift to a negative phase would be consistent with the observation that the NAOI seems to follow 7- to 8-year cycles, superimposed on 20- to 30-year cycles (Knights 2003, p. 238).

The correlation between NAOI and recruitment suggests that oceanic conditions are currently the most influential variable affecting recruitment. As noted earlier, efforts to model the population dynamics of American eel are inherently limited by sparse or nonexistent data. Nonetheless, sensitivity analysis of one modeling effort indicated that oceanic conditions had greater eel population effects than fishing, dams, or other habitat impacts (BEAK 2001, pp. 5.10–5.11).

In summary, oceanic conditions influence growth, recruitment, and distribution of many marine species. The interactions between the marine environment and production of marine species, however, are exceedingly complex. Although the interactions are not completely understood, the success of early eel life stages and subsequent recruitment to fresh water is dependant on oceanic conditions, which are subject to natural variation. Natural conditions can, when a species is significantly reduced in range or abundance, be considered a threat. However, there is no indication that the American eel is suffering this level of reduction in either abundance or range. Therefore, because oceanic conditions are within normal variations, the American eel is evolutionarily adapted to oceanic variations, and there is no indication that the American eel is at a reduced level where this natural oceanic variation would significantly affect the species, we have concluded that oceanic conditions are not now, and there is no information indicating oceanic conditions should be in the future, a significant threat to the American eel at a population level.

Summary of Factor E

In conclusion, hydropower turbines are a source of ongoing mortality. This mortality has affected, and will continue to affect, regional presence and abundance of eels. However, the current information does not provide evidence to support turbines as a significant threat to the American eel at a population level. There is substantial uncertainty on the effects of contaminants on the American eel and more research is needed. However, after examination, the literature does not support a population level impact from contaminants. Oceanic conditions are highly variable and cyclical. They determine recruitment to the continent, and therefore they have a substantial influence on the presence and abundance of eels on the continent, particularly in freshwater habitats. Oceanic conditions are a naturally occurring influence on the American eel during its early life history, and are not a significant threat to the American eel. In sum, given the absence of evidence for population-level effects, such as reduced recruitment of glass eels, we have concluded that there is not supporting data to indicate other natural or manmade factors as a significant threat to the American eel.

Finding

The Act defines the term ''threatened species'' as any species (or subspecies or, for vertebrates, distinct population segment) that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range. The term ''endangered species'' is defined as any species that is in danger of extinction throughout all or a significant portion of its range. The principal considerations in the determination of whether a species does or does not warrant listing as a threatened or endangered species under the Act are the threats that confront the species, as discussed in the five factor analysis above.

In reviewing the status of the American eel, we make the following findings. The species has been extirpated from some portions of its historical freshwater habitat over the last 100 years or so, mostly as a result of dams built by the late 1960s. There is also evidence that the species' abundance within freshwater habitats, and to some degree estuarine habitats, has declined in some areas (e.g., upper SLR/LO and the Chesapeake Bay) likely as a result of harvest or turbine mortality, or a combination of factors. However, the species remains widely distributed over the majority of its historical range. Based on information from the ASMFC stock assessment and peer review and the COSEWIC Assessment and Status Report, an indication of decline exists in yellow eel abundance, but recent glass eel recruitment trends, although variable from year to year, appear stable over the past 15 years. The American eel is a highly resilient species, with the ability to occupy the broadest range of habitats within freshwater, as well as estuarine and marine waters, and it remains a widely distributed fish species. The lack of population subdivision (i.e., panmixia) in the American eel provides resilience to genetic problems that can result from decline and isolation of subpopulations.

Although roughly 25 percent of the American eel's historical freshwater habitat is now inaccessible due to dams, the loss of this habitat does not threaten the species' long-term persistence. This is because a large amount of freshwater habitat still remains (roughly 75 percent of historic freshwater habitat in the United States remains available and occupied by the American eel), from which both males and females outmigrate, and because a portion of American eels complete their life cycle in estuarine and marine waters without entry into freshwater. Although the significance of the estuarine and marine eel contribution to reproduction is considered speculative by some, a growing number of researchers think the contribution could be substantial (Tsukamoto and Arai 2001, p. 275; Jessop 2002, p. 228; Kotake et al. 2005, p. 220; Cairns 2006a, p. 1; Knights et al. 2006, pp. 12–13), and there is no doubt that substantial amounts of estuarine and marine waters remain available to and are occupied by the American eel throughout its range.

The threat of *Sargassum* harvest is no longer considered a threat due to new information indicating that the American eel larvae do not utilize *Sargassum,* and due to regulations restricting its harvest. Recreational and commercial eel harvests are no longer factors of concern at a population level due to economics, the species' resilience, and existing regulatory mechanisms. Although mortality during outmigration due to parasites and contaminants, and the potential effects of contaminants on early life stages, remain a concern, we have no information indicating that these threats are currently causing or are likely to cause population level effects to the American eel. We have no information indicating that predation or competition with nonnatives or mortality from turbines are causing population-level effects. Recruitment success of the American eel is dependent on ocean conditions, and variation in ocean conditions causes fluctuation in recruitment. However, because the available information indicates that the species remains widely distributed and glass eel recruitment trends appear stable over the past 15 years, observed ocean conditions do not threaten the current population status of the American eel. Also, we have no information to indicate that ocean conditions are likely to threaten the American eel at a population level in the future.

In reviewing the status of the American eel, we also considered whether there was any area where the species is threatened or endangered throughout a significant portion of its range. We considered threats to its spawning, migratory, and growth habitats (see discussion under Factor A and Ocean Conditions in Factor E) and found no area where the species is threatened or endangered throughout a significant portion of its range. The Sargasso Sea, where the American eel spawns, is for that reason a significant portion of the range, but we identified no threats to this habitat. Similarly, the open ocean migratory habitat of the American eel is also a significant portion of the range, but we identified no threats to this habitat either.

The American eel's growth habitat consists of those areas, apart from its spawning and migratory habitats, where the species' growth primarily takes place. We evaluated whether the upper SLR/LO, an area of the American eel's growth habitat that has experienced an extreme decline in American eel abundance, is a significant portion of the range. The American eel is panmictic, genetically homogeneous, and capable of occupying a diversity of growth habitats. It currently occupies a number of growth habitats, each of which is similar in habitat characteristics. Therefore no one growth habitat would be a significant portion of the range unless it was significant in terms of eel reproductive contribution. Although it has been suggested that the upper SLR/LO historically contributed a disproportionately larger amount of reproduction than other freshwater areas of similar size, significant uncertainties have been identified regarding this analysis (COSEWIC 2006, pp. 35–41). Even if the upper SLR/LO had historically contributed a disproportionately larger amount of reproduction than other freshwater areas of similar size (see Population Status in Background section), our consideration of the data on facultative catadromy (the ability to grow and become sexually mature in estuarine and marine waters in addition to freshwater) suggests that the total reproductive contribution from the rest of the range (including other freshwater and all estuarine and marine waters) outside the upper SLR/LO is substantially greater than the historical reproductive contribution from the upper SLR/LO (see Population Status in Background section). Consequently, any historical additional reproductive contribution from the upper SLR/LO does not make this area significantly more important than if its historical reproductive contribution was similar to that of other similarly sized areas within the range of the species. Because the upper SLR/LO area does not contain any unique or particularly high-quality habitat, does not contribute to any genetic differences, contains substantially less than 50 percent of the growth habitat for the eel, and does not appear to contribute greatly to the long-term persistence of the species, we have determined that it is not a significant portion of the range. In addition, even if the SLR/LO were to be considered a significant portion of the range we find from the record before us that the eel is not threatened or endangered in the SLR/LO because eels will likely persist there into the foreseeable future (for discussion of this ''rescue effect'' see Background, *Population Status*). The American eel is panmictic and substantial reproductive contribution comes from outside the upper SLR/LO. We believe that the upper SLR/LO will likely continue to receive eels and, therefore, extirpation of eels from the upper SLR/LO is unlikely.

In addition, we considered whether there are any segments of the population of American eel that would qualify as distinct population segments (DPSs) under the USFWS's Policy Regarding the Recognition of Distinct Vertebrate Population Segments Under the Endangered Species Act (DPS Policy) (USFWS 1996). To be identified as a DPS, a population must satisfy both the discreteness and significance tests of the DPS Policy. Because the species is panmictic (a single inter-breeding population), no part of the species' population meets the discreteness test of the DPS policy. Because no discrete populations can be identified, there are no populations for which we could evaluate significance. Therefore, no American eel DPSs can be recognized.

Due to the concerns about the status of the American eel in Canada, we considered delineation of a Canadian DPS using the international border. However, we determined that the Canadian population of American eels would not satisfy the significance test. There is no evidence to suggest that eels in Canada are genetically different from eels in other parts of the species' range, that eels in Canada inhabit a unique ecological setting, that loss of eels in Canada would result in a significant gap in the range of the species, or that the Canada population of eels otherwise could be considered significant under the DPS policy. Also, because the species is panmictic and juveniles are distributed randomly over a wide range, and because substantial reproductive contribution occurs over most of the range, Canada will likely continue to receive eels despite any reduction in yellow eel abundance in Canada. Therefore, the Canadian population would not be considered endangered or threatened and as a result would not qualify as a DPS under the DPS policy.

In summary, we find that the American eel remains widely distributed over their vast range including most of their historic freshwater habitat, eels are not solely dependent on freshwater habitat to complete their lifecycle utilizing marine and estuarine habitats as well, they remain in the millions, that recruitment trends appear variable but stable, and that threats acting individually or in combination do not threaten the species at a population level. On the basis of the best available scientific and commercial information, we conclude that the American eel is not likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range and is not in danger of extinction throughout all or a significant portion of its range. Therefore, listing of the American eel as threatened or endangered under the Act is not warranted.

Author

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References Cited

A complete list of all references cited is available on request from the U.S. Fish and Wildlife Service's Region 5 Regional Office (see **ADDRESSES** section above).

Authority: The authority for this action is the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 *et seq.*).

Dated: January 23, 2007.

Kevin Adams,

Acting Director, U.S. Fish and Wildlife Service.

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