American Eel
Anguilla rostrata

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DESCRIPTION

Taxonomy and Basic Description

The American Eel, *Anguilla rostrata* (Lesueur 1817), belongs to the freshwater eel family, Anguillidae. Related species occur throughout the world, but the American Eel is the only North American anguillid eel. Eels are snake-shaped and covered with a mucous layer that renders them slimy to the touch despite the presence of minute scales. A continuous, low fin runs from the middle of the back, around the tail, and ends behind the vent. Relatively small pectoral fins originate near the animals midline and immediately posterior to the head and gill-covers. Coloration varies with stage of maturity and habitat, but eels are generally dark olive, yellowish, or slate-gray above and light below. Eels from dark, tannic acid streams are darker while those from clear streams and estuaries are lighter (J. W. McCord, pers. obs.).

The American Eel is catadromous; it spawns in oceanic waters but uses freshwater, brackish, and estuarine systems for most of its developmental life. Sexually mature adults, called silver eels, migrate from freshwater to the sea in fall. Their destination for spawning is the Sargasso Sea, an expansive portion of the central North Atlantic Ocean, east of the Bahamas and south of Bermuda. Adults are thought to die after spawning. The largest females produce nearly 20 million eggs (Barbin and McCleave 1997). Mature females in the southern portion of the eel's range are generally smaller and carry as few as 400,000 eggs (Wenner and Musick 1974). Eggs hatch into a brief pre-larval stage before transformation into the active leptocephalus stage.

Leptocephali primarily drift with ocean currents for about a year before metamorphosing into the glass eel stage (Sheldon 1974). Glass eels are shaped like adults, but are transparent and smaller, reaching lengths of 5 to 7 cm (2 to 3 in.) (Hardy 1978). Glass eels actively migrate across the continental shelf and move into estuaries and tidal river reaches in late winter and early spring, apparently by detecting temperature gradients and the scents associated with freshwater (Facey and Van Den Avyle 1987). Glass eels feed little or not at all, but within weeks of entering estuaries and tidal rivers, the small eels begin to feed and become pigmented, at which time they are called elvers and resemble miniature adults in coloration and other physical features.

While some elvers move far into inland habitats, others remain in brackish and estuarine areas. Both glass eels and elvers migrate primarily at night and are able to move beyond obstacles that prevent passage of most aquatic species. Small eels can climb vertical walls, including low dams, as long as surfaces are damp and textured.

The final inland resident stage is called the yellow eel and includes all eels greater than 10 cm (4 in.). Yellow eels may gradually move upstream over many years, with most movement occurring during spring and fall when water temperatures are moderate. However, larger yellow eels may settle in specific areas and have been found to occupy distinct home ranges (Gunning and Shoop 1962). Adult females are larger than males and may grow to lengths of nearly 1.0 m (40 in.), but most adults are 0.6 m (24 in.) or less. Maturation occurs from 3 to 24 years of age (ASMFC 2000), with males generally maturing at a younger age and remaining smaller in size than females. Eels as old as age 15 have been recorded in South Carolina (Harrell and Loyacano 1980).

American Eels are opportunistic carnivores, feeding on a vast array of animal life, depending on the size of the eel and the availability of prey within a given habitat. Larger eels feed primarily on small fishes and benthic invertebrates, including crustaceans, aquatic insects, worms, and mollusks. Elvers and small yellow eels feed primarily on aquatic insects, small crustaceans and worms. Elvers collected from the Cooper River consumed mostly midge larvae, cladocerans (zooplankton), amphipods (small crustaceans) and fish parts (McCord 1977). Adults taken from the same study area fed primarily on fish parts, elvers (eels can be highly cannibalistic), and terrestrial isopods (McCord 1977). In estuaries, eels often feed on blue crab (*Callinectes sapidus*) and polychaete worms (Wenner and Musick 1975). Both blue crab and horseshoe crab (*Limulus polyphemus*) are used as bait in trap fisheries for American Eel in the Chesapeake Bay and elsewhere.

Elvers are not only preyed upon by larger eels but are also eaten by many fishes, both game and non-game species. Small yellow eels up to 46 cm (18 in.) in length are used as bait for striped bass and cobia. Eels are also consumed by other predatory fishes such as Largemouth Bass (*Micropterus salmoides*) and Bowfin (*Amia calva*) (J. W. McCord, pers. obs.) and are likely preyed upon by opportunistic predatory fish like non-native Flathead Catfish (*Pylodictis olivaris*). American Eels are also included in the diets of fish-eating birds and mammals, such as mink (*Mustela vison*) (Sinha and Jones 1967, Seymour 1974). American Eels are a valuable part of the many ecosystems they inhabit during various growth stages. Dams and other impediments to migration have eliminated the American Eel from many historical habitats in South Carolina (USFWS 2001). The effects of the loss of American Eels from aquatic food webs, though not quantified, may be substantial (Freeman et al. 2003).

Status

The American Eel currently has no special status under state or federal regulations; however, a petition was filed in late 2004 with the United States Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) to have the American Eel listed as an Endangered species. The US Fish and Wildlife Service and the National Marine Fisheries Service reviewed the status of the American Eel in 2007 and found at that time that Endangered Species Act protection for the American Eel was not warranted. However, The US Fish and Wildlife Service received another petition in 2010 seeking to extend federal protection to the American Eel. The Service found that this petition, from the Council for Endangered Species Act Reliability, presents substantial information that warrants the initiation of a more extensive status review of the species. The Atlantic States Marine Fisheries Commission (ASMFC) has published a

management plan for the conservation of this species in response to perceived declines (ASMFC 2000), and is currently conducting a stock assessment which will be complete in 2012.

POPULATION SIZE AND DISTRIBUTION

One genetically similar population of eels is thought to occur along the Atlantic Coast (Williams and Koehn 1984). However, eels become resident as sub-populations in drainage basins throughout the range of the species until they become sexually mature. Accordingly, many sub-populations by drainage basin and region collectively comprise the North American population. The complex life cycle contributes to the difficulty in determining the population status of this species. Furthermore, the American Eel has been poorly studied through much of its range. Historical data are scant for most areas of the Atlantic coast; no such information exists for South Carolina. Long-term data sets collected in the northeastern United States and southeastern Canada indicate declines in both recruitment of juveniles and in adult populations (ASMFC 2000). Directed fisheries for silver eels have shown precipitous declines in catch per unit of effort (ASMFC 2000). Long-term data for elvers at Conowingo Dam fish lift on the Susquehanna River, Maryland indicate a declining trend from 1974 through 1996 (ASMFC 2000). Eel migration data from 1984 to 1995 indicates significant negative trends for yellow and/or silver eels in Ontario, Quebec, New York, and Virginia (Richkus and Whalen 2000). Since there is likely a single genetic stock throughout the range, sub-population declines in any region or drainage basin can impact the entire population. The largest declines have been indicated over the past two decades. Dramatic declines in the northern portion of the American Eel's range are important since sub-populations in this region carry the highest reproductive potential (Casselman 2003).

The American Eel occurs along the Atlantic coast from Canada to Central and South America. Within South Carolina, eels occur from estuaries to the headwaters of coastal streams and at least as far inland as the Fall Line in longer river basins, including the Savannah, Santee and Pee Dee. Although the American Eel is capable of traversing obstacles that may completely restrict dispersal of other fishes, both eel distribution and population size may be limited by dams and other impediments to migration. Historical records show that American Eels occur in the Santee basin well inland of the fall line and into North Carolina (USFWS 2001). Similar historical distributions occurred for the Waccamaw-Pee Dee Basin and are likely to be present in the Savannah River Basin.

American Eel populations within the Santee-Cooper River watershed inland of Pinopolis, St. Stephen, and Wilson Dams are likely well below numbers present prior to impoundment of the Santee-Cooper lakes in the 1940s. Observations from St. Stephen Dam indicate rather poor passage success for the American Eel (D. Cooke, SCDNR, pers. comm. 2004). Fish passage at Pinopolis Dam on the Cooper River is provided by navigational lock. Such passage systems are not considered to be particularly effective for American Eels because of great fluctuations in water flow that occur during lock operations (Lary and Busch 1997). Dams on the Savannah and Waccamaw-Pee Dee drainages are well inland and probably do not significantly restrict eel distribution.

HABITAT AND NATURAL COMMUNITY REQUIREMENTS

The American Eel is widely distributed in many aquatic habitats including estuarine, brackish and freshwater tidal channels; tidal creeks; coastal impoundments; ponds; lakes; and nearly all accessible freshwater habitats associated within river basins as far inland as the Fall Line and beyond. Males are generally restricted to estuarine and brackish habitats while females are more often found in freshwaters. Among freshwater habitats, eels seem to be most abundant in streams, but occupy all habitats having sufficient food resources and well-oxygenated water. A high density of yellow eels has been observed in the upper South Edisto River, where single channels branch into a braided or intertwined network of small creeks within swamp forest. Yellow eels are also present in high densities in the middle Savannah River in relatively shallow, non-navigable reaches characterized by riffles and pools with rocks and submerged aquatic vegetation (J. W. McCord, pers. obs.). American Eels are dependent upon access to such diverse habitats for growth and maturation, as well as free downstream passage for spawning migration. Sexually mature adults are dependent upon the vast expanses of the North Atlantic Ocean and the Sargasso Sea.

CHALLENGES

Because of its complicated life cycle, the American Eel population faces a broad range of challenges, some of which are specific to a particular growth stage. Since males and females largely utilize separate habitats, impacts in a given region may affect the sex ratio of the eel population. Dams and causeways obstruct access to a diversity of habitats, which may limit basin-specific and statewide populations. The Pee Dee, Edisto, and Santee coastal drainages have suffered an 83% reduction in unobstructed stream habitat (Busch et al. 1998). Impingement (entrapment in) and entrainment (being carried through) water intakes and turbines are sources of mortality on seaward-migrating eels.

The American Eel is sensitive to low dissolved oxygen levels (Hill 1969, Sheldon 1974) in water typically found below dams. Logging in swamp forests may also cause lowered dissolved oxygen by increasing siltation and water temperature. Contaminants such as heavy metals, dioxin, chlordane and polychlorinated biphenyls (PCBs) can bioaccumulate and cause acute toxicity or reduced productivity (Hodson et al. 1994).

Dredging can result in many negative affects to American Eels. Physical injury or mortality may result from entrainment of seaward-migrating adults. Increased turbidity or suspended sediments may negatively affect migration of adults, glass eels and elvers. Dredging may also cause changes in salinity regimens that could impact eel distribution and prey availability.

Spawning habitat may be adversely affected due to seaweed (*Sargassum* sp.) harvest in the Sargasso Sea. Spawning habitat and success is also likely to be affected by pollution like oil spills.

Dewatering freshwater streams for irrigation and other water removal projects decreases habitat availability for American Eels and exacerbates any existing areas of poor water quality.

Nonpoint source runoff from residential areas, roads, and golf courses can have a negative impact on floodplain ecosystems and impact water quality. Potential overfishing or excessive harvest of juveniles (glass eels and elvers) could negatively impact localized populations. Competition and predation from non-native species, particularly Flathead Catfish (*Pylodictis olivaris*) and Blue Catfish (*Ictalurus furcatus*), is also a problem for American Eels. Both of these catfish are piscivorous and opportunistic; they will feed on any fish that can fit in their mouths. Because both of these species are found in habitats frequented by elvers (J. W. McCord, pers. obs.), predation on eels by these catfish is a concern. Additionally, non-indigenous pathogens or parasites such as the Asian swimbladder nematode (*Anguillicola crassus*), has been shown to have significant negative impacts on the European Eel (*Anguilla anguilla*) and on captive American Eels in South Carolina and Texas (ASMFC 2000).

Changes in oceanographic conditions may alter oceanic currents, thereby potentially altering larval transport and recruitment of juveniles across the continental shelf. The cause of these changes is unknown, but global warming may play a part (ASMFC 2000).

CONSERVATION ACCOMPLISHMENTS

An interstate fisheries management plan (IFMP) has been developed for the American Eel under the auspices of the ASMFC. The original IFMP for the American Eel was completed in 2000 and is currently in the process of being amended. The plan established a framework of recommendations for protecting or enhancing eel sub-populations by state and region.

The IFMP required the states to control and limit directed effort in both bait and commercial eel fisheries in South Carolina. Beginning in 2001, states were required to collect and monitor catch and effort statistics for American Eel commercial fisheries and to limit effort at levels achieved in 2000. As a result, SCDNR capped participation at 10 license holders and capped gear use as well. The permitting system that emerged from the IFMP mandate has greatly enhanced SCDNR's ability to initiate proactive controls over American Eel fisheries. In addition, the plan required states to limit recreational harvest through the establishment of several regulations: the possession limit is not to exceed 50 eels; the minimum size limit is 15 cm (6 in.); and sale of American Eels is prohibited without a license.

SCDNR and Duke Energy partnered to study American Eel movement and growth throughout the Santee Basin beginning in 2009. Other partners include SCANA, NWRC, and USFWS. Analysis of annual glass eel migrations in Goose Creek, elver use of the St. Stephen eel ramps, and eel occurrence at a trap in the Wateree Dam provided incentive to gather more detailed data on eel movement rates. As of April 2013, 7,469 eels have been marked.

The question was whether eels passing St. Stephen in April make it through the Santee-Cooper lakes and arrive at the Wateree Dam in the subsequent month of May, or does it take longer periods. The only real way to verify movement speed was to implant uniquely colored elastomer tags under the skin of elvers at St.Stephen, release them upstream into Lake Moultrie, and look for their arrival at the Wateree Dam. Elvers marked with yellow (2010), blue (2011), orange (2012), and white (2013) elastomer tags have been released annually into Lake Moultrie. For

example, in April and June of 2012, SCDNR, along with the USFWS, Duke Energy, and others, tagged 3,377 elvers (young eels) with orange elastomer.

Many dams in South Carolina are currently, or are soon to be, undergoing Federal Energy Regulatory Commission (FERC) re-licensing, which includes considerations for improved access by and migration of aquatic species. Therefore, increasing opportunities for passage are possible in the future.

CONSERVATION RECOMMENDATIONS

- Conduct statewide eel distribution and population surveys to make prioritized decisions for restoration and passage.
- Inventory sources of American Eel mortality and formulate remedies where practical.
- Determine contaminant levels in eel tissues and relate those to mortality and reproductive success.
- Investigate impacts of logging in swamp forests on water quality and habitat. Work with municipalities and landowners to direct forestry activities away from floodplain areas.
- Determine impacts to American Eel populations of dewatering freshwater streams.
- Determine size, sex, and age structures for each sub-population of American Eels.
- Determine potential presence and distribution of the Asian swimbladder nematode (*Anguillicola crassus*).
- Determine potential impacts to American Eels from competition and predation by non-native species and, to the extent possible, control and prevent further distribution of non-native blue and flathead catfish populations.
- Determine the scope and impact of American Eel harvest on sub-populations, and revise South Carolina eel regulations to limit harvest of any eel life stage or sub-population.
- Conduct genetics studies to document sub-populations by region or river basin.
- Investigate opportunities to provide passage at dams and other obstructions that are not under FERC authority, and develop more cost-effective and efficient techniques for providing both upstream and downstream passage of American Eels at migration barriers. Partner with NMFS, USFWS, United States Army Corps of Engineers (USACE) and non-governmental organizations (NGOs) to promote the inclusion of fish passage designs, wherever prescribed, that can successfully provide two-way passage of American Eels.
- Build partnerships with NGOs, permitting authorities and county and local governments to improve and implement the use of Best Management Practices (BMPs) in agriculture and urban development activities to reduce siltation and contaminant input.
- Partner with the Department of Health and Environmental Control to develop or improve water removal guidelines for agricultural, civil, or industrial purposes that protect American Eels.
- Work with the USACE to identify dredging protocols that consider the timing of eel migration.
- Form an alliance with other state and federal agencies as well as NGOs to implement range-wide conservation and management of the American Eel as described in the ASMFC IFMP.

- Partner with the South Atlantic Fishery Management Council (SAFMC) to promote implementation of the Fishery Management Plan for Pelagic Sargassum Habitat of the South Atlantic Region.
- Promote changes in water release protocols for dams that will restore or approximate natural flow regimens and increase minimum flows.
- Institute permitting protocols for aquaculture and pet fish industries that require certification of the absence of diseases and parasites for all *Anguilla* species.
- Participate in interstate research examining the effects of oceanic changes on distribution of larval American Eel and how these changes may be related to global warming.
- Develop education and outreach programs that distribute information to governments, civic groups, educational systems and NGOs about critical habitat needs, threats, and potential conservation actions for the American Eel.

MEASURES OF SUCCESS

One measure of success would be to expand SCDNR's American Eel monitoring program to more areas over a more appropriate time period (as outlined in ASMFC plans) to document distribution and population trends. Another measure of success would be to document stable to increasing American Eel population trends in response to improved conditions in aquatic ecosystems and improved access to suitable habitats, as outlined in the 'recommendations' section.

On May 24, 2013, the first tag from the elastomer tagging effort was recovered at the Wateree Hydro eel trap. The elver was 132 mm (5.2 in.). Notes indicate the average length of these 2012 eels was 93 mm (3.7 in.) at tagging so that's almost 40 mm (1.2 in.) of growth. A second orange VIE tagged eel was caught on June 6, 2013 that measured 175 mm (6.9 in.) in length.

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