Eel Fortunes

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When it comes to adaptability, few species can top the American eel (*Anguilla rostrata*). They turn up in more habitats than any other fish. After spawning in the open ocean, they can be found in coastal estuaries, rivers, trout streams, farm ponds—even wet caves. Eels are found in so many places that in the 4th century B.C., Aristotle once concluded that they must arise spontaneously from the mud. Other ancients thought they originated from small worms or even horsehair dropped into water.

To this day, no one has ever seen one spawn. The drifting patterns of their eggs and larvae leads scientists to believe it takes place about 1,000 feet deep in the Sargasso Sea. But someplace between there and the headwaters of East Coast streams, scientists say something has gone terribly wrong.

Eel numbers have dropped so precipitously that leading eel scientists last fall issued an unprecedented "declaration of concern" about American eels, as well as European and Japanese eels, which are also in sharp decline.

In Canada, the Ontario government in April 2004 announced it was closing its eel fishery. The fish has nearly disappeared from Lake Ontario, which once boasted millions of the largest eels on the continent. Not long ago, eels were the province's third most valuable fishery.

Also in April 2004, the Atlantic States Marine Fisheries Commission—which represents all East Coast states—said it would amend its eel management plan to reduce catches. The commission also suggested that the U.S. Fish and Wildlife Service and the National Marine Fisheries Service explore whether the eel should be considered a candidate species under the federal Endangered Species Act—in effect, a "watch list" for getting formal protection under the act.

The Chesapeake Bay, where the American eel is a $1 million-a-year fishery and accounts for nearly half of the total U.S. landings, is thought to boast the largest eel population. "The Bay is considered the cradle of abundance for the American eel," said Lewis Gillingham, of the Virginia Marine Fisheries Commission, and a member of the ASMFC's American Eel Technical Committee.

Virginia catches have trended downward. Maryland catches have been steady over the past decade, but reports from the state's Department of Natural Resources suggest that eels have, on average, been getting smaller and younger —a possible sign of overfishing.

In fact, an analysis by Julie Weeder, a former Maryland DNR biologist now working for the National Marine Fisheries Service, shows that reproduction from adult eels leaving Chesapeake Bay would be too little to replace the Bay's population. Rather than being the "cradle" of the eel population, Weeder said, the Chesapeake now depends on reproduction by eels elsewhere. "It produces a lot, but it has a potential to produce even more," Weeder said.

Nowhere is the decline more obvious than in the St. Lawrence River. Since the early 1980s, biologists have counted the number of young eels moving up an "eel ladder" that zigzags its way over the 90-foot-high Moses Saunders Hydroelectric Dam in Ontario.

In the mid 1980s, between 25,000 and 30,000 pencil-sized eels a day slithered up the ladder and over the dam on

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This article is reprinted from the Nov. 2003 issue of Bay Journal, *newsletter of the Alliance for the Chesapeake Bay, a coalition of enviromentalists, business representatives, government officials, and others who are working together to protect the Chesapeake Bay. The Alliance is a non-advocacy organization that seeks to help protect the Bay through education and by providing the public, as well as decision-makers, with information and opportunities to become involved in Bay activities. For more information, visit www.acb-online.org.*

their upstream migration. "It was just seething with eels," said John Casselman, an eel expert with the Ontario Ministry of Natural Resources.

Today, peak numbers are only 20 or 30 a day, Casselman said, and those eels are not young eels moving upstream, but larger ones simply moving back and forth on the river.

Upstream, Lake Ontario was once home to 5 million to 10 million eels as recently as two decades ago. That number has declined to several tens of thousands as old eels migrate out and are not replaced by young eels. "It is like our passenger pigeon," Casselman said.

Such a decline in Canada might not raise a major concern for East Coast states if eels were anadromous fish, such as shad or striped bass. Those species live most of their lives in the ocean, but return to their river of birth to spawn. As a result, each major river has its own unique stock of anadromous fish. If they are wiped out in one river, the population may still be fine in the next river up the coast.

Eels, though, are exactly the opposite. They are a catadromous species, which means they spawn together in the ocean as one common stock, but live in estuaries or freshwater rivers for most of their lives. After spawning, currents disperse eel larvae along the coasts of South, Central and North America, although the vast majority end up in an area from North Carolina to the St. Lawrence.

"It's almost like you take a handful of darts and throw it at a dart board," Gillingham said. "There is absolutely no fidelity." That means even if every last eel were fished out of a particular river, the next spring should still bring a new wave of young "recruits" into the river.

When a species declines, the first signs of trouble are often at the edge of its distribution range, which explains why the near total disappearance of eels in the Upper St. Lawrence has been so alarming.

"We're all in this together," Casselman said. "This stock, at the extremity of its range, is endangered."

Other surveys have shown downward trends as well. Trawl surveys by the Virginia Institute of Marine Science show an adult eel decline over the past decade. At the Conowingo Dam on the lower Susquehanna River in Maryland, more than 60,000 young eels were counted in 1975 and 1976. Only 23 were counted last year.

Extrapolating from some of those surveys is difficult because—unlike the Canadian survey—they were not designed to monitor eels and no one knows how reflective they are of the overall population. Some other random surveys along the East Coast have not shown sharp declines.

In fact, the overall status of the population is unknown; no stock assessment of the entire American eel population has ever been completed. "Data is really very limited," Gillingham said. Some landings data, he said, may only reflect changes in the demand. Still, he said, "it sounds like there are not as many eels around, but I don't know what I can tell you I base that on."

For most people, the decline of eels would have gone unnoticed. They are nocturnal, bottom-dwelling predators. Anglers who spend a lifetime fishing in the region's rivers may never see an eel. "They live under a rock in the daytime, and only come out at night, so our society doesn't associate with them," Casselman said.

If they did see them, most would not be impressed. "Most people's encounters with eels are negative," Weeder said. "People really do not like them at all. It looks like a snake."

To most people, the best thing about an eel is it makes good bait. It's much different in Japan and Europe, where eels are considered a delicacy. "We just don't eat eels, so people don't care about them," said Dave Secor, a scientist with the University of Maryland's Center for Environmental Science, who has studied eels. By Secor's calculation, every man, woman and child in Japan eats an average of two eel meals a month.

Yet some of the earliest drawings from the Sir Walter Raleigh's failed Roanoke Colony (20 years before Jamestown) depict Native Americans eeling. It was an important food for natives, who caught and smoked the fish, because it was far more calorie-dense than other fish—about three times greater.

In the 1700s, colonists reported Onondagas roasting eels in the headwaters of the Susquehanna River. A study conducted a century ago by the Pennsylvania Department of Fisheries concluded that the number of eels migrating up the state's rivers each spring was "simply enormous."

At first glance, the eel would seem an unlikely candidate for a major decline because it can adapt to more aquatic habitats than perhaps any other fish species in the world—from the ocean to the furthest headwater streams.

But eels also grow slowly, especially in colder climates like Canada where it can take females up to 25 years to mature. In Chesapeake Bay, it takes females about eight years to mature, although studies indicate some males may be ready to spawn in as little as four.

They spawn only once. In fact, on their way back to the ocean, the females absorb their own digestive tracts to give them extra energy for the journey. That means all fishing—and other mortality—on the species takes place before they have a chance to spawn.

Journeys of a Lifetime

Eels are thought to have originated in a small sea hundreds of millions of years ago, before the continents drifted apart.

At that time, it's speculated the eels could not find enough food in their spawning areas, and began making their journeys to freshwater streams.

Today, it just takes them longer to make the trip, which starts in the Sargasso Sea, an area of relatively still water covered by seaweed that floats over its surface.

Adult eels spawn in the winter and early spring in the Sargasso. After spawning, the adults die. The eggs hatch into larvae, which are transported by ocean currents, mostly in a northwesterly direction, although some end up in rivers in South and Central America, and the Gulf Coast.

During the trip, the larvae develop into transparent "glass" eels, which are just a few inches long, and so clear it is possible to read type through their bodies. Reaching coastal waters can take anywhere from a few months (in the case of the Mid-Atlantic) to two or three years for Canada and other far-flung parts of its range.

As the glass eels begin moving up the estuaries, they become pigmented with gray or brown tint as they reach a size of about 6 inches, and are known as "elvers." Elvers become yellow eels—because of their yellow-green tint. They spend most of their lives as yellow eels, and early in that stage, eels—in an unusual trait—select their sex. Where populations are dense, males predominate, but where numbers are less dense, the population is overwhelmingly female.

Arrows represent the ocean currents that carry eel larvae back to freshwater streams. Map courtesy of MD Sea Grant.

Females tend to continue their migrations up freshwater rivers in the spring, while males may remain in brackish coastal waters for almost all of their lives.

When eels mature, which generally takes eight years or less in warm climates, but 25 years or more in colder areas, they turn a bronze-black sheen, and are known as silver eels.

Their skin thickens, they store body fat and absorb their own digestive systems to make the long swim back to the Sargasso, a journey that begins in the autumn.

"Fishing pressure is a huge factor," Weeder said. "There is a higher stake for the ones that are left. Not only do they have to replace themselves, but they have to replace all the other ones that died."

Eel harvests peaked at an estimated 3.5 million pounds a year along the U.S. East Coast in the late 1970s, as demand increased in both Europe and Japan after the declines of their own eel fisheries. Harvests stayed high through the early 1980s but have fallen to less than a million pounds in recent years, with nearly half of that coming from the Chesapeake.

Until recently, American and Canadian eel harvests were about equal. But the Canadian catch has fallen so much that U.S. landings—though declining—now account for 80 percent of the catch.

Weeder's conclusion that the Maryland population is overfished is a concern because Chesapeake Bay is considered to have the densest eel population along the East Coast. Further, because eels in the Bay mature relatively quickly, they return to the Sargasso Sea more rapidly than those from rivers farther to the north, where it takes longer to reach maturity.

On the other hand, almost all of the eels in Canada are females. And because it takes them longer to reach maturity, they grow to larger sizes—up to eight pounds—and produce anywhere from 13 million to 50 million eggs each. (An eel from Chesapeake Bay would produce about one million eggs.)

That has led some to believe that eels from the St. Lawrence may be disproportionately important to the population, and creating something of a chicken-or-the-egg type question. It's possible that very large "pulses" of recruitment are needed to send eels to the farthest extent of their range, Casselman said. But it's possible that the egg-rich females from those areas are needed to produce those recruitment pulses.

"It's very difficult trying to find a cause-and-effect," he said. "Our big agony here is they are leaving us, and they are not coming back."

But many scientists doubt that fishing pressure alone explains the decline of the eel. While pressure has been in high in important areas such as Chesapeake Bay and in

American Eels Get a Passage of Their Own on the Shenandoah

Small American eels trying to make their way up the Potomac River drainage in 2003 found something unique in the Chesapeake Bay watershed—a fish passage of their very own.

While dozens of fish passages have been constructed on Chesapeake Bay tributaries, the movable aluminum structure over the Millville Dam on the Shenandoah watershed is the first "eelway" constructed in the Chesapeake watershed. It may be the first eelway built in North America outside Canada.

The $75,000 structure was built and installed after officials with Allegheny Energy Supply, which owns the dam, learned of the success of similar devices in Canada. "We decided, let's give it a try," said Charles Simons, a biologist with the utility.

After the device was installed in the spring of 2003, more than 300 eels were observed passing the dam, Simons said, and more likely went unseen.

The Millville Dam is the first blockage on the Shenandoah upstream of the Potomac. The utility is planning a passage at the next upstream dam, at Warren, in about two years. "We will just keep working our way up the Shenandoah," Simons said.

The nontidal portion of the Potomac River has not been a major target for fish passages because Great Falls, just north of Washington, created a natural barrier to fish migration. Eels, though, have always been able to slither around the falls as they move upstream. Colonial reports show the presence of eel fisheries in the Potomac beyond the falls.

Some eels have been able to get around the dams on the Potomac, although biologists believe the obstructions also prevent many from moving upstream. "This just offers them an easier passage to find their way upstream," Simons said.

Allegheny Energy this year is planning to pay for eelways at two downstream dams on the Potomac as part of a relicensing agreement with the Federal Energy Regulatory Commission.

Compared to traditional fish passages, which can cost hundreds of thousands of dollars—and in the case of large dams, millions—to build, eelways are relatively inexpensive. "You don't have to get into concrete," Simons noted.

The Millville eelway is a simple, covered aluminum trough about two feet wide. Inside are a series of vertical PVC pipes, which allow the small eels to slither up the slope. The eelway is placed over the top of the dam to the river below, and is removable.

While the Potomac watershed is the first in the Bay region to get eelways, they may be appropriate in other areas as well, said David Sutherland, a biologist with the U.S. Fish and Wildlife Service's Annapolis Field Office. He said it's unknown how effective traditional fish passages are in passing eels upstream, but eels would probably need to be 2-3 years old to get up a traditional fish ladder.

Also, the ideal placement for an eelway may be different from that for a fish passage. Migrating fish are attracted to strong flows as they swim upstream, but eels seek the easiest way over an obstacle. The entrance to the Millville eelway, for instance, is placed in a pool of relatively calm water.

"There is a need for this specialized passage," Sutherland said.

And while eels can slither around some smaller dams, larger structures may close rivers altogether.

The Maryland Department of Natural Resources' Biological Stream Survey found that the average density of American eels in the Susquehanna River basin below the 100-foot-high Conowingo Dam was about 500 per square mile. Above the dam, the survey found only one eel at 11 sites surveyed in Maryland.

Extrapolating those figures for the entire upstream habitat, the survey made a "conservative estimate" that the upstream watershed would have supported at least 13 million eels without the dam.

Canada, eels are ubiquitous along the East Coast—they swim all the way up the Mississippi to Minnesota.

"I just can't believe it is overexploitation," Secor said. "I think regionally you can find it, absolutely. But there are just too many places for an eel to be where there is no harvesting. You need the effects of exploitation to be systematic throughout the species range to drive down the entire species. That's a tall order."

He believes that some type of climate or oceanographic change may be affecting the eels. American, European and Japanese eels all are in decline.

A weakening of the Gulf Stream since the 1980s, which some have attributed to global climate change, may be affecting their distribution. The closely related European eels also spawn in the Sargasso Sea, and ride the same Gulf currents all the way past the North Atlantic coast and back to Europe. Recruitment of European eels has also declined by about 99 percent since the 1970s.

A long-term regional climate pattern known as the North Atlantic Oscillation—a mathematical index of ocean level and temperature—has been in a phase that appears to negatively affect eel recruitment, Casselman said.

But there are other suspects for the decline as well.

Eels historically were incredibly abundant in freshwater streams, by some estimates accounting for half of the biomass in many streams.

By some estimates, up to 85 percent of the eels' habitat has been entirely, or partially restricted by dams—even though young eels can slither out of the river and crawl around some smaller dams. The 100-foot-high Conowingo Dam in Maryland, for instance, blocks almost the entire river to eels.

"It's true that eels can climb over dams, but not all dams," Weeder said. "But you have to think that the abundance of eels getting over the dam is not the same as if it were not there at all."

Another problem is that when adult females more than four feet in length migrate downstream in the fall, they can be big targets for turbines in hydroelectric dams. In recent decades many older dams built for other purposes have been retrofitted to produce electricity, possibly making downstream migrations more hazardous.

Exotic parasites could be a problem as well. In the late 1990s, Secor discovered the blood-feeding worm, *Anguillicola crassus*, which historically was found in the Japanese eel, in American eels in Chesapeake Bay.

The parasite reproduces in the eel's swim bladder, a large organ critical to the eel's ability to move in the water. The worms chew the walls of the swim bladder and lay their eggs. After they hatch, the young parasites leave the eel, sometimes by boring holes through the swim bladder.

Though not fatal, the damage done to the swim bladder may cause long-range problems for the eel. It could harm their ability to elude trawl nets, escape predators and feed. Perhaps even more importantly, it may affect their ability to make the lengthy migration to spawning grounds in the Sargasso Sea.

Because of their long lifespan and high fat content, eels have a high potential to accumulate toxic contaminants in many areas. High levels of contaminants have caused health advisories to be issued for eel consumption in some states, although it's unknown whether the chemicals are affecting their ability to reproduce or return to spawning sites.

Some even suggest that harvests of seaweed from the Sargasso Sea may in some way be degrading the eels' spawning habitat.

It may be a case of more changes than the adaptable eel can adjust to. Today's harvests are not high by historic standards, but it's possible, some say, that overfishing in the 1970s and 1980s decreased the population to the point where it could no longer sustain previous levels of recruitment especially given the added pressures from climate change, pollution, habitat loss and parasites.

"It's never one single factor," Casselman said. "If it was, we could understand it." But of those factors, he said, the ones that people can immediately affect are fishing and turbine mortality. "It may be too late to worry about the cause. We need action."