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Eels and Their Utilization

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INTRODUCTION

To the average American, the image of the common eel conjures up a picture of a snake-like creature slithering through brooks and rivers. The mental picture is often accompanied by an inward shudder of revulsion. This unfortunate association of eels with snakes has deprived most Americans from enjoying a fish that has been considered a gourmet delicacy for thousands of years in many parts of the world. Not only that, but the reptilian association of eels is completely erroneous. The American eel, *Anguilla rostrata*, is a true fish with gills and scales.

The eel itself is a fascinating creature and was, and still is to some extent, the object of one of the greatest biological detective studies of all times. Since the time of the ancient Greeks, man has wondered where the eels came from—where they spawned. For hundreds of years, no one had seen an eel with eggs or milt. Did they really originate from horse hairs dropped into streams as was once believed?

As a food, the eel is consumed in many ways; and in parts of Europe and particularly in Japan, demand has so outstripped supply that young eels—or elvers—have brought several hundred dollars a pound. The Netherlands has sent a specially designed ship with live wells to the United States and Canada to collect mature eels and transport them alive to Europe. The lucrative foreign market for eels has promoted the establishment or expansion of eel fisheries in several eastern States, notably, Maine, Massachusetts, New York, New Jersey, Maryland, Virginia, North Carolina, and Florida, with varying amounts from other States. In 1970 from recreational fishing alone, it was estimated (Statistics and Market News Division, 1975a) that over 4 million pounds (1,814 metric tons) of eels were taken from the Atlantic coastal States, while another 1½ million pounds (680 metric tons) were taken commercially in 1972 (Statistics and Market News Division, 1975b). Eels are usually caught with traps, but otter trawls, hand lines, long lines, fyke and hoop nets, floating traps, spears, haul seines, and pound nets have also been used. Most of this gear was used in some form by the early settlers along the eastern coast, particularly in New England.

With the worldwide interest in eels and the fact that eel fisheries in the United States go back to the time of the Pilgrims, why have eels been shunned by most of the citizens of the United States? Why are they still largely underutilized here, particularly in light of the present shortage of so many of our more established marine food fish? Perhaps part of the reason is that the public is so unfamiliar with eels, except for the vague misconception mentioned earlier. This paper presents some basic information on the eel, its life history, the various methods of catching and preparing them, and some indication of world demand.

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DESCRIPTION

Eels are found worldwide and there are a number of different species. In the United States, when the word "eel" is used alone, one can be quite certain that the fish referred to is the so-called common or American eel, *Anguilla rostrata*. Other names used in this country are the yellow eel, silver eel, and freshwater eel. Young eels are called elvers after they acquire pigment and "glass" eels when colorless. The American eel is found along the coast and in freshwater streams and rivers from Greenland to the Gulf of Mexico and as far south as Panama, the West Indies, and rarely to the northern coast of South America.

The taxonomic or biological classification of eels is as follows:

Kingdom: Animalia
Phylum: Chordata
Class: Osteichthyes
Order: Anguilliformes
Family: Anguillidae
Genus: Anguilla

There have been about 17 species found of the *Anguilla* genus. These are identified in Table 1 along with the parts of the world where they normally occur.

Other eels resemble the American eel to varying degrees. The conger or sea eel has the same serpentine body but grows to a larger size. The conger eel has more vertebrae than the American eel, and the dorsal fin begins just behind the pectoral or side fins, whereas the dorsal fin of the American eel originates much farther back. The conger eel does not enter fresh water. Another fish that might be confused with the American eel is the sea lamprey, *Petromyzon marinus*. This species is parasitic and was responsible for nearly wiping out the lake trout population in the Great Lakes. It has almost no jaws but rather an oval-shaped mouth with many

Table 1.—Distribution of species of the genus *Anguilla* (Eales, 1968).

Species	Distribution
A. anguilla	Europe, Iceland, and North Africa
A. australis	Australia, Aukland Island, and New Zealand
A. bengalensis	Indian Ocean
A. bicolor	Indian Ocean to Malayan Islands, Philippines, and New Guinea
A. borneensis	Borneo
A. celebesensis	Indo-Malaya, Philippines, and western New Guinea
A. dieffenbachi	Australia, Aukland Islands, and New Zealand
A. japonica	China and Japan
A. marmorata	Indian Ocean, most oceanic islands north to the Marianas and south to New Guinea, New Caledonia and Society Islands as eastern limit
A. mauritania	Central Pacific
A. megastomata	New Caledonia, Solomon Islands, eastern Polynesia, Fiji, Tonga, Samoa, Marquesas, Tuamotu, and Tahiti
A. mossambica	Indian Ocean
A. nebulora	Indian Ocean
A. obscura	Australia, New Guinea, East Indies, eastern Polynesia, Fiji, Tonga, Samoa, Marquesas, Tuamotu, and Tahiti
A. pacifica	East Pacific
A. reinhardi	Australia and New Caledonia
A. rostrata	North America and Greenland

hooked teeth which it uses to fasten onto other fish, rasp a hole in their side, and draw out blood which seems to be their main food.

The American eel has an elongated serpentine body that tapers to a point at the tail. It is closely related to the European eel but has a lesser number of vertebrae—about 107 as compared with 114. There are a pair of pectoral fins just behind the head with a small gill opening in front of each pectoral fin. The dorsal fin originates far behind the pectorals, back about a quarter to one-third the length of the body. The dorsal fin runs into and is continuous with the caudal and anal fins. The lower jaw at least equals the upper jaw in length and sometimes projects slightly beyond the upper. Both jaws are lined with many needle-like teeth (Bigelow and Schroeder, 1953).

The color of eels varies widely, depending on the stage of maturity and their habitat. Prior to sexual maturity, they are usually a dark muddy brown or olive brown to black above, yellowish along the sides, and light yellow or dirty yellow-white on the belly. It is in this stage that they are referred to as yellow eels and can be found in fresh water, estuaries, or the sea. Their color can change, depending on the type bottom where they are found and changes in illumination. They can alter their skin color within a matter of hours by redistributing pigments. When these eels reach maturity, the yellow gradually changes to a silvery white, and they are known as silver eels.

Female eels grow to a larger size than males. A mature female will vary from 30 to 42 inches (76.2-106.7 cm) in length and weigh from about 2½ to 3½ pounds (1.1-1.6 kg). Females up to 4 feet (1.22 m) and weighing over 16 pounds (7.3 kg) have been reported. The male can mature at 12 inches (30.5 cm) and usually does not go much over 18 inches (45.7 cm) in length. Any eel over 18 inches (45.7 cm) would probably be a female, and any over 24 inches (61 cm) would certainly be a female.

LIFE HISTORY

Historical Background

The eel was prized as a delicacy by the ancient Romans and was widely observed throughout the waterways of Europe. In fact, the origins of the eel have fascinated people since the beginning of European civilization. They noted that the eels never contained roe or milt as did other fish and this gave rise to a variety of strange myths as to their origin. Some thought they developed from horse hairs falling into streams or rivers or from water beetles. Aristotle, in 350 B.C. in "Historia Animalium," gave his views and observations to support his theory of spontaneous generation. He observed that eels had no seminal fluid or eggs and when dissected showed no seminal canal or womb; therefore, no eels are born from mating or from eggs.

The eel goes from fresh water to salt water and not vice versa, as do other fish (apparently the migration from salt water to fresh water of the young glass eels and elvers was not observed). Aristotle further observed that in pools that had been drained, eels could be found "reforming" themselves after a rain. (Actually, the eels were simply buried in the mud and reemerged when the pool again had water.) Finally, he pointed out that eels come from the "entrails of the earth" where there were places with rotting material such as in the sea where seaweed accumulates, in rivers and at the water's edge, for it was there that the heat of the sun develops and produces putrefaction. By "entrails of the earth," Aristotle may have meant that eels were born from worms or larvae. The idea of spontaneous generation was common in Europe for hundreds of years after Aristotle, of course, and thought to be the way maggots arose from rotting flesh.

Pliny, in his "Natural History," had a unique explanation as to the reproductive process of eels. He said, "to reproduce themselves, eels rub their bodies against the rocks; from the shreds of skin thus detached come new ones." Oppian, in the second century in Sicily, had an equally unique explanation. His theory was that eels mate with snakes. The female eel takes the snake's head in her mouth. Following this union, the eel went to sea and the snake to land.

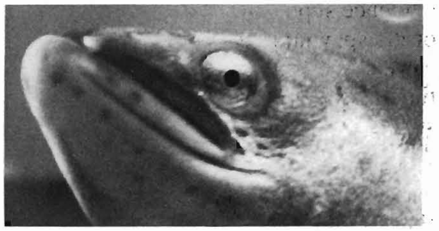
There was no further scientific enlightenment of the origin of eels throughout the Middle Ages. Scholars of that time mainly reflected the views of earlier philosophers such as Aristotle. It was not until the 17th century that Francesco Redi of Tuscany observed that eels leave fresh water around August and go to sea where, he concluded, the female dropped her eggs. Later the young eels, or elvers, returned to fresh water. This was the first time the small elvers were observed entering fresh water and correctly identified as young eels.

Redi was the first person to refute the theory that eels were born alive. Others had found parasites in mature eels and assumed they were young eels waiting to be born. Leeuwenhoek in 1692 had described the eel's bladder as the womb and the parasitic worms found there as young eels. Others, including Linnaeus in the 1700's, made this same mistake. It was not until 1777 that Mondini in Italy discovered an ovary in an eel, and another hundred years, 1874, passed before an eel testis was discovered. This was done by finally looking at the smaller eels rather than the largest, which were females. In 1896, two Italians proved that the small leptocephali is the larval stage of the eel by watching it change in an aquarium.

With this basis of information concerning the European eel at the beginning of the 20th century, it was the remarkable work of a Danish oceanographer, Johannes Schmidt, that finally traced the origin of the spawning area of the European eel and also tentatively identified the spawning grounds of the American eel. His work covered a period of nearly 20 years from 1904 to 1922. He observed that eels from all over Europe had, on the average, the same number of vertebrae, around 114 to 115. This led to the conclusion in 1907 that all eels found in Europe belonged to the same species. This launched Schmidt on his search for the common spawning ground of these eels. This search was to take another 15 years and cover a good portion of the North Atlantic from Greenland along the coast of Europe and North America to the Caribbean and Mediterranean Seas.

He took samples from various depths over a large part of the North Atlantic Ocean and followed the trail of young eels of decreasing size until he identified the Sargasso Sea in the southwest part of the North Atlantic, generally between Puerto Rico and Bermuda, as the common spawning ground of all European eels. During his studies, he also took a relatively few specimens of the larvae of American eels and identified their spawning area as somewhat to the west of the European eel, but still in the general area of the Sargasso Sea. Schmidt defined the European eel's spawning area as being between lat. 22°-30°N and between long. 48°-65°W. The dividing line between the spawning area of American and European eels is considered to be long. 50°W.

American eels, *Anguilla rostrata*. Photographs courtesy of John J. Poluhowich, Research Director, Institute for Anguilliform Research, Department of Biology, University of Bridgeport, Bridgeport, CN 06602.



Life Cycle

The description of the life cycle which follows applies to both the European eel, *A. anguilla,* and the American eel, except where specific differences are noted. Léon Bertin (1956), from which most of the information on life cycle is drawn, said that "there can hardly in the whole of natural history be a more remarkable example of response to environment, to temperature, to salinity, to light, and to current," than that exhibited by the eel during the course of its life.

The European eel spawns at a depth of about 400 m (437 yards) inside a 17°C (63°F) isotherm. Each species of eel seems to have a definite temperature preference for spawning, and this seems to be the best evidence for the location of the spawning area of the European eel in the Sargasso Sea. The evidence supporting the actual location of the spawning grounds of the American eel is not as clear cut. The spawning time for the European eel is during the spring, with most spawning occurring in May and June. The American eel spawns over a longer period from February to July (Bertin, 1956). Each female is capable of producing as many as 15-20 million eggs about 1 mm (0.04 inch) in diameter.

No spawning eels have been taken nor have any mature eels been seen after they have spawned. It therefore appears that the adult eels die after spawning so that the Sargasso Sea becomes at the same time the nursery of young eels and the graveyard of adults. After the larvae are hatched, they go through an embryonic phase lasting a few days. During this time, they derive their nourishment from the yolk sac. They next enter the larval stage and gradually rise to the surface. During the larvae stage, the young eels are known as leptocephali. These are transparent and ribbon-like and are said to resemble willow leaves. They have small pointed heads and long teeth. They join drifting plankton on which they feed and travel under the influence of the ocean currents towards continental water. These flat and glassy leptocephali are so unlike mature eels that it is not surprising it took so long to identify them as young eels. In fact, the name leptocephalus means flat head.

One of the major differences between American and European eels is the length of time they remain in the leptocephali stage and the time it takes them to reach the continent. For the small leptocephali that are carried north or south into cold currents from Labrador or into the warm ones from the equator, there is death. Only those that reach the proper currents to carry them toward Europe or North America survive. It takes the European eel from 2½ to 3 years to make the long migration; whereas, the American eels make their journey in about 1 year. During their transatlantic migration, the eel larvae travel on the surface at night and descend into deep water during the day.

The leptocephali of the American eel with a shorter distance to travel reach the freshwater streams of North America by the spring of the year after they were spawned. The European leptocephali take about 2½ to 3 years as was noted above. During this time, the transformation or metamorphosis to young eels or elvers is accomplished. This is probably the most significant difference between the European and American eels; that is, the time spent in migration from the spawning ground to their respective continental waters and the timing of their metamorphosis to coincide with this journey.

Before describing this change in the young eels, it should be pointed out that there has been some question as to the accuracy of Schmidt's assumption that the westerly part of the Saragasso Sea is the spawning ground of the American eel as well as the European eel. Vladykov and March (1975), raise several points concerning the information and conclusions drawn from Schmidt's work. First, no female American eels have been taken in as advanced stages of sexual maturity, as have been reported for European eels. No spawning eels or eggs have been taken (Schmidt's evidence is based on the capture of young larvae). Schmidt followed the trail of the European eel by capturing larvae of decreasing size. Since he was not studying the American eel, it may be that the collection stations used were not in the proper locations to take American eels. The same applies to the water depth sampled. Each eel species seems to have its own depth and temperature preference, and again it may be that in sampling depths preferred by the European larvae, the American ones were missed. The actual spawning season is still only generally defined, particularly for the American eel.

There is limited information on the exact duration of the larval stage of the American eel (reported as 1 year as opposed to 2½ to 3 years for the European eel). If the western Sargasso Sea is the spawning ground for the American eel, the question is raised as to the mechanism by which the larvae successfully cross the complex currents of the Gulf Stream. Finally, there is the question as to how the American eels reach their southernmost limits of Trinidad and the Guianas which are about 13° of latitude south of the reported Sargasso Sea spawning area. The currents would take the young larvae north, not south, and seem to make a southern migration impossible. With these questions still unresolved, the best that can be said at this time is that the true spawning area of the American eel has not been definitely established.

Metamorphosis of Leptocephali to Elvers

Regardless of where they were spawned, by the time they reach the continental waters the change to elvers is accomplished. This change consists of a change in shape from leaf-like to the beginning of a cylindrical shape. Both the length and weight of the young eel decrease as it goes from leptocephali to glass eel, which is an unpigmented elver. The loss in weight is due mainly to loss of water from the body. The intestines become shorter and the long larval teeth fall out and are replaced by definitive teeth. These elvers go through a short inactive phase of metamorphosis during which these changes take place, and this is partly responsible for the loss in weight as well as the decrease in length. The young elvers after the inactive phase are vigorous and agile as they approach the coast.

About 1 year after hatching, around December and January, the American eels reach the coast and undergo the changes described above. The elvers are about 1½-2¾ inches (6.4-7.0 cm) long. The European eels reach the Spanish coast in October but do not complete their journey to the Baltic Sea until the following May.

As the glass eels approach brackish water, metamorphosis is completed and pigmentation begins. This requires a variable amount of time, and in many streams during the spring, migration of glass eels can be observed before pigmentation occurs. The upstream run to fresh water begins as early as February in North Carolina and in May and June in Canada. After pigmentation is complete, the elvers gain weight and increase in length. The change from elver to young eel is thus completed.

Only a portion of the young eels or elvers enter fresh water. The rest stay in estuarine areas such as tidal marshes and harbors or remain in coastal areas of the sea. While the evidence is not conclusive, it appears that the female eels migrate into fresh water while the males generally stay in the estuarine or coastal area.

Upstream Migration

The migration of the young elvers into fresh water lasts anywhere from a few days to a month or more. The elvers move upstream at night, and during the time of their spring run, may be seen by the thousands by use of a light on the water surface at night. They are very strongly oriented toward swimming against the current, and this fact has been utilized in trapping the elvers—opening of trap downstream, blind end upstream. During the daylight hours, the elvers will seek cover by burrowing into the mud or hiding under rocks.

As American glass eels enter fresh water, they average about 2½ inches (62 mm) in length and number about 2,500 per pound (5,500 per kg).

During the upstream migration, the elvers tend to follow along the banks of rivers and streams in shallow water. Their persistence during migration upstream is remarkable. They will cling to damp rocks and will even climb up concrete dams as long as the surface is moist. Should they reach a portion of the waterway where the current is too strong, they may leave the stream and go around it through the damp grass and over wet rocks along the edges until the swift water is passed and then return to the stream. When an obstruction is encountered, such as a waterfall or dam, during the peak of the migration, large numbers of elvers may collect while waiting their turn to climb the rocks or dam and thus resume their journey on the other side.

The more barriers between an inland body of water and the sea, the less likelihood there is of the elvers reaching it. It is possible for them to gain entrance to bodies of water with no visible connection to the sea. They may do this by using underground channels or even traveling overland through dew-laden grass if the distance is not too great. They will also use underground water pipes if an access can be found and have been known to fill the pipes in such numbers that they block them completely.

Eels rely primarily on olfactory stimuli to direct them to fresh water, and there is no evidence to indicate that the young elvers return to the same waterways which their parents inhabited. Indeed, since chance in the form of ocean currents and winds plays such a large part during their migration as larvae in the sea, the odds against any given elver returning to the exact same body of water occupied by his parents would seem astronomical.

The young eels populate warm shallow lakes in large numbers and tend to avoid extremely cold streams. After reaching their destination, they will remain in fresh water from 5 to 18 years, although this time is quite variable and eels as old as 20 years have been taken from fresh water.

Yellow Eel Stage

It is in the freshwater ponds, lakes, and streams that the eels change to the yellow state and assume the black-yellowish condition described earlier. This is the growth stage. The male European eel will stay in this stage for 8-10 years, while the females may remain in fresh water for 10-18 years. The American eel is believed to stay in fresh water a shorter time, generally from 5 to 10 years.

During their stay in fresh water, eels grow slowly. They are generally omnivorous during this period and will eat a wide variety of organisms such as insects, fish, crustaceans, snails, worms, and even one another on occasion. They rely on an acute sense of smell to locate and catch food. Eels definitely prefer fresh food and will not eat rotten or decaying material. They are active and feeding on warm dark nights. Feeding activity is largely related to light intensity—the less light, the more active. During daylight hours, eels generally hide in deep holes or bury themselves in mud, although occasionally they will be active during daylight hours. In cold weather, they become sluggish and inactive and will bury themselves in the mud. Should a body of water dry up, eels are capable of staying alive in the moist mud and will reappear after a rain has replenished the water supply.

At about 6 years of age, they develop tiny scales. These are definite and well-defined scales but are so small that they may escape detection.

Since eels will eat almost anything, they do have some effect on other fish populations. Larger eels have been reported to eat young salmon eggs. On the other hand, trout have been known to eat young eels. The eel is extremely hardy and can live out of water longer than most other fish because of the protection of the gills from drying out and the fact that it has a lower metabolic rate than a species such as the brown trout. Because the eel can thrive in such a variety of freshwater conditions, it is often thought to have a superior survival potential than most other fresh water fish, although in general this does not seem to be the case. Where there appears to be a struggle for survival between eels and trout or salmon, it is mainly due to the competition for a common food supply rather than predation by one species on another.

There is little information available on the habits of those yellow eels that remain in marine waters and estuaries. It is believed that at least some of them move into the warmer fresh waters and bury themselves in the mud during winter as do their freshwater relatives. It is also thought that when yellow eels have been reported migrating downstream in the spring that it may simply be some of these marine eels going back to saltwater.

In general, the more rapid the sexual development of an eel, the less is the body growth. Males develop faster than females and as a results are considerably smaller. There is a record (Bertin, 1956) of a female eel being kept in an aquarium for 38½ years and reaching a length of 55 inches (140 cm), and of another that was kept to an age of 25 years and grew to 43 inches (110 cm) and a weight of 5½ pounds (2,500 g). The increase in size and weight attained during the growth phase (yellow eel) depends more on the availability of the food supply than anything else. Temperature is also a factor since cold weather inhibits activity and cuts down feeding. A colder environment will also slow sexual development so that in the long run cold-water eels may grow to a larger size than their warmwater counterparts, although it takes them longer to do so. Eels of the same species, age, and sex can vary greatly in size, depending on environmental factors, and the weight of one eel may be as much as five times that of another of the same age.

Sexual Development

The sexual development of the eel, like so many other of its traits, is rather unique. About 90 percent of the European eels (and it is assumed the American eels also) pass successively through a neutral (no sex differentiation) phase, a period of precocious feminization (when they will begin to develop female traits), and a phase of juvenile hermpahroditism (both female and male characteristics) before becoming definitely male or female. In the young eel, the gonads are undifferentiated; this is the neutral phase. During the yellow eel phase, usually between 5 and 8 years of age, they will develop both male and female characteristics and yet be incapable of reproduction. This is the hermaphroditic stage and is generally a temporary condition, although some eels never leave this stage of development. Next, when the eel is nearing maturity and ready to leave the yellow eel stage for that of the silver (or bronze) stage, final differentiation into male or female takes place. This is usually not completed until the eels are well into their final marine migration towards the spawning grounds. Those that will develop into males are more precocious and will become silver eels, sexually mature, around 8 years of age, where the females will not reach maturity until 10 to 18 years (somewhat younger for American eels).

It is interesting to note that while most eels pass through these various phases of sexual development, about 10 percent are females from the very beginning. The final sexual determination of the other 90 percent is due to various external conditions as yet not clearly understood, but this is not the case for the 10 percent that are females from the beginning. Apparently, the environment plays no part in determining their sex. Final sexual maturity is completed by the time the spawning grounds are reached or shortly thereafter.

Silver Eel Stage

Each fall some of the larger and older yellow eels undergo transformation into silver eels. This change has not been well documented for the American eel, and most of the studies have been on European eels. Again, it is assumed that the following information applies to both species unless otherwise noted.

Several changes take place during this transformation. First, and most noticeable, is the change in coloration. The color of the European eel goes from yellowish to silver, while the American eel has been described as being more "bronze." This change in coloration from yellow to silver has been described by Bertin (1956) as "acquiring the specific nuptial dress or, a more appropriate term, migration livery" as it prepares for its long journey to the spawning grounds.

In addition to changes in coloration, this metamorphosis is marked by several other changes. The digestive tract degenerates and the eel ceases to feed. (For this reason, during the full downstream migration the silver eels are impervious to the temptation of any type of bait.) Other changes include an increase in the production and a thickening of the mucus, which is plentiful and copious during the yellow eel stage but thinner in nature, a thickening of the skin, and an accumulation of fat. There is an alteration in body flexibility and a change in locomotive behavior and the eyes are greatly enlarged. Sexual development is accompanied by an increase in endocrine activity. The number of chloride cells in gills increases and there are changes in osmoregulatory capacity to assist in adapting to a saltwater environment again (D'Ancona, 1960). Similar, although perhaps not exactly parallel, changes occur in the American eel, although the eyes do not enlarge as much (at least American eels with such extreme enlargement have not been taken, although there is the possibility that further enlargement takes place during the marine migration).

The passage of the silver eels from fresh water to salt water takes place between late August and mid-November for American eels, while the European eels generally run from October to December. The exodus of eels from European waters will run into millions and possibly billions of individuals. The silver eels will show as much determination in reaching the sea as the young elvers did in reaching their freshwater home.

The downstream movement is set in motion by changes in the environment. An increase in water level and a dark night seem to be favorable conditions for beginning the migration. Large runs of American eels often occur on warm, dark, stormy nights in late summer or fall. Light intensity is a critical factor, and this fact has been capitalized in catching eels during the fall run. Lights are placed in strategic positions to block the passage of the eels and to divert them into waiting traps or nets. On the Mediterranean coast, up to 10 tons of eels have been caught in one night during this fall run.

One of the remarkable adaptions that takes place during this final metamorphosis is the eel's ability to go directly from fresh water to salt water. This property of euryhalinity involves a series of complicated physiological changes that enable eels to resist changes in salinity. Part of this resistance is due to the thick viscous mucus or slime that coats the eel and forms a barrier to osmotic exchange between the eel's body and its environment.

A factor that helps sustain the eel during its long migration at sea without eating is a toxic property (ichthyotoxin) of the eel's blood. This toxin is potent enough to cause infections in humans who might come in contact with it through an open cut or break in their skin. The blood serum has a neurotoxin that can destroy red blood cells. In some way the toxin helps the eels to resist starvation, asphyxiation, and wounds. To quote Bertin (1956) again in describing the eel, "Its exceptional endurance, its untiring energy, and its tenacity of life which manifests themselves particularly on the long migrations would be sustained by the ichthyotoxin impregnating its whole organism."

Of the long spawning migration of both the European and American eels, little is known. Presumably, it takes them 2 or 3 months to reach the spawning grounds from North America and a longer period of time from Europe. What depths they swim at or what factors guide them to their final destination is unknown, but return they do. Here in the depths they mate, spawn, and presumably undergo disintegration of some type and die.

Summary of Life Cycle

The life cycle of the eel can be summarized as follows: Eels have several life phases and two distinct metamorphoses. First is the embryonic phase, lasting a few days, when they are nourished by the yolk sac. Second, the marine larval phase (leptocephalus) or dispersal phase, lasts 1-3 years, depending on the species. During this phase, they are carried by the ocean currents towards North America-Europe and feed on microplankton. Third is the inactive phase or first metamorphosis from leptocephalus into elver. This lasts a few months. Fourth is the growth phase or yellow eel phase which lasts several years in fresh water, estuaries, or coastal salt water. During this phase, the eels are omnivorous. Fifth is the second metamorphosis from yellow eel to silver eel. This is also an inactive growth phase and lasts about 1 year. During this time sexual maturity takes place. Sixth is the adult marine phase or phase of reproduction. This is the time of the marine migration to the spawning grounds, mating, reproduction, and presumably death.

FISHERIES

Of the seventeen or so species of eels of the genus *Anguilla* found in the world, five of them occur in the temperate zone. It is these temperate zone eels that constitute the vast majority of the commercial catch in the world. The European eel, *A. anguilla,* is caught by some 17 European countries plus Morocco and Tunisia in Africa, Syrian Arab Republic and Turkey in Asia, and the U.S.S.R. The American eel, *A. rostrata,* is taken on the east coast of Canada, the United States, and Mexico. The Japanese eel, *A. japonica,* is taken principally by Japan with lesser amounts by Korea and other Asian counties; the Australian eel, *A. australis,* is taken commercially by Australia and New Zealand. Another species, *A. dieffenbachii,* is also caught in the latter two countries but not reported separately in FAO (Food and Agriculture Organization, United Nations) statistics. Table 2 gives information on world catch of eels in thousands of metric tons (t) as reported to FAO for the years 1965 to 1973.

Table 2.—World catch of eels, *Anguilla* sp. (Food and Agriculture Organization of the United Nations, 1974).

Species	Country	Catch (1,000 t)								
		1965	1966	1967	1968	1969	1970	1971	1972	1973
European eel	Morocco	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0
A. anguilla	Tunisia	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.8
	Turkey	0.2	0.2	0.1	0.3	0.3	0.4	0.5	0.5	0.5
	Denmark	3.2	3.7	3.5	4.3	3.7	3.4	3.2	3.3	3.6
	German Dem. Rep.	1.1	1.2	1.3	1 2	1.0	1.1	0.8	0.9	0.9
	Italy	3.2	3.1	3.1	3.2	3.4	3.2	3.3	3.2	3.2
	Netherlands	2.6	2.8	3.1	2.7	2.8	1.5	1.2	1.1	1.1
	Poland	0.9	1.0	1.1	1.1	1.1	1.0	0.9	0.9	0.8
	Portugal	—[1]	—	—	—	—	—	—	0.1	0
	Spain	1.7	1.7	1.6	1.5	1.5	1.2	1.2	1.5	1.2
	France	1.7	1.3	2.0	2.7	1.9	4.2	4.9	2.6	3.9
	German Fed. Rep.	0.4	0.5	0.6	0.6	0.5	0.5	0.5	0.4	0.4
	Ireland	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1
	Norway	0.5	0.5	0.5	0.6	0.5	0.4	0.4	0.4	0.4
	Sweden	1.8	2.0	1.6	1.8	1.7	1.2	1.4	1.2	1.1
	U.K. N. Ireland	0.8	1.0	0.6	0.6	0.6	0.8	0.8	0.7	0.8
	U.S.S.R.	0.3	0.4	0.4	0.4	0.5	0.6	0.6	0.6	1.1
Total *A. anguilla*		19.1	19.9	20.0	21.5	20.0	20.1	20.2	17.9	19.9
American eel	Canada	0.8	0.7	0.8	0.9	1.1	1.1	1.2	1.1	0.7
A. rostrata	U.S.A.	0.8	0.6	0.7	0.8	0.9	1.0	1.1	0.9	1.1
Total *A. rostrata*		1.6	1.3	1.5	1.7	2.0	2.1	2.3	2.0	1.8
Japanese eel	Japan	18.8	19.8	22.8	26.7	26.5	19.4	16.8	16.5	17.3
A. japonica	Korea Rep.	—	—	—	0.3	0.4	0.1	0.2	0.1	0.1
	Other	0.2	0.2	0.3	0.6	1.6	2.0	3.9	—	—
Total *A. japonica*		19.0	20.0	23.1	27.6	28.5	21.5	20.9	16.6	17.4
Australian eel	Australia	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.2	0
A. australis	New Zealand	0	0.1	0.1	0.3	0.4	0.9	1.5	2.1	1.3
Total *A. australis*		0.1	0.2	0.2	0.5	0.6	1.0	1.7	2.3	1.3
Total, all *Anguilla*		39.8	41.4	44.8	51.3	51.1	44.7	45.1	38.8	40.4

[1]Dash indicates no data reported.

The world commercial catch is composed primarily of the European and Japanese eels. In 1970, for example, European eels accounted for 44,220,000 pounds (20,100 t) and Japanese eels for 47,300,000 pounds (21,500 t) out of a total reported world catch of 98,340,000 pounds (44,700 t). The U.S. catch that year, as reported to FAO, was only 1,000 t (2,200,000 pounds). The Japanese production of eels is largely from eel culture rather than harvesting of wild eels; and in 1970, of 19,400 t reported, 16,700 t were from cultured eels and 2,700 t from inland catch.

It can be seen from Table 2 that Japan is far and away the leading eel producing country in the world. European countries with significant production are Denmark, German Democratic Republic, Italy, Netherlands, Poland, Spain, France, and Sweden. In the past, England had an active eel fishery. The migration of elvers in the spring brought huge numbers of the young eels up the rivers. These swarms were called "eel fares" and were actively pursued. Yet, since 1963 no landings of eels have been reported from any part of the United Kingdom except Northern Ireland. European eel fisheries, in general, are feeling the impact of increased population and urbanization. Problems with pollution, waterways blocked by

Table 3.—Eel production and value in the United States by state, 1972.

State	1,000 lb	Metric tons	1,000 dollars
Maine	70	31.7	25
New Hampshire	5	2.3	1
Massachusetts	55	24.9	22
Rhode Island	22	10.0	8
Connecticut	48	21.8	14
New York	149	67.1	65
New Jersey	262	118.8	58
Delaware	45	20.4	11
Maryland	230	104.3	33
Virginia	492	223.2	145
North Carolina	77	34.5	12
South Carolina	42	19.1	4
Georgia	10	4.5	2
Florida	61	27.2	9
Total	1,568	709 8	409

dams and other obstructions, all inhibit the traditional freshwater fisheries for eels; and this, in turn, has promoted increased interest in eel culture. In fact, the harvest of eels has not increased much in the last 30 years.

Japan has had a long-standing eel fishery. This was the first country to turn to eel culture to supplement their harvest of wild eels. In recent years, the proportion of wild eels to cultured eels has steadily declined. There is an active fishery for elvers which are used to stock the ponds for cultured eels. The domestic catch of elvers cannot keep up with the demand and has prompted the Japanese to actively seek American and European elvers, although these are not considered as desirable as the Japanese eels.

In Australia and New Zealand, nearly all eels caught belong to the species *A. australis*. These eels were a traditional food for the native New Zealand Maoris, but it has only been in recent years, the late 1960's and early 1970's, that eels were fished commercially to any extent. They are now becoming an important export commodity. It is estimated that New Zealand has a potential sustainable harvest of 10-20 million pounds (4,535 to 9,070 t) of eels per year (Skrzynski, 1974), although the reported catch in 1972 was only around 4.5 million pounds (2,041 t). In Australia, silver eels are preferred. The fishery is increasing but still limited with about 0.5 million pounds (227 t) reported in 1972 and none reported in 1973.

In Canada, eels are found in most of the coastal rivers in Newfoundland, Nova Scotia, Prince Edward Island, and New Brunswick. Eels have entered the St. Lawrence River and reached Lakes Ontario and Erie. In fact, the best Canadian commercial fisheries are along the St. Lawrence estuary. The northeast shore of New Brunswick and the southwest coast of Nova Scotia also support small commercial eel fisheries. Canadian catches have run around 2 million pounds (907 t) per year the last 10 years and reached a high of 2.7 million pounds (1,224 t) in 1933. Most of the Canadian catch comes from Quebec where the fishing is primarily for silver eels (Eales, 1968).

In the United States, eel fisheries on a limited scale have existed since colonial times. In 1621, Edward Winslow of Plymouth wrote, "In September we can take a hogshead of eels in a night, with small labor, and can dig them out of their beds all winter." In fact, one of the rivers near Plymouth was called Eel River; and in 1833, the eel fishery in this same river was described: "It is appropriately called Eel River from the abundance of eels which it yields to the support of the industrious poor. Perhaps it will not be extravagant to say that about 150 barrels are annually taken there," (Goode, 1887).

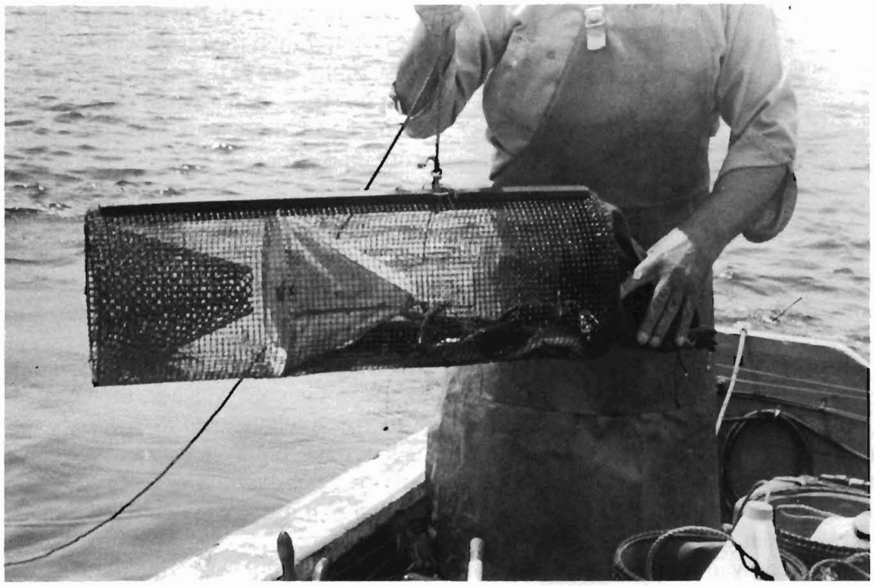
There were eels taken along the coasts of Cape Cod and Maine and Massachusetts in the 1600's and 1700's. In 1887, several eel fisheries were reported from Maine, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Delaware, Maryland, and North Carolina. In 1879, small catches from Gloucester, Newburyport, Salem, and Marblehead, all in Massachusetts, brought 5 cents/pound, while Boston with landings over a quarter of a million pounds (454 t) for that year seemed to be the center of the New England eel trade. New Jersey in the Cape May area also had a significant eel fishery in 1879. Most of these eels were speared in the winter or taken in the sea in summer and consumed locally or sent to New York or Philadelphia. The price paid to the fishermen was 4 to 5 cents/pound.

Over the last 40 years, the U.S. eel catch has remained fairly constant, ranging from a low of around 660,000 pounds (299 t) in 1962 to a high of about 2½ million pounds (1,134 t) in 1971 with the catch most years between 1 and 2 million pounds (454 and 907 t). Eel production and value sales for the year 1972 are given in Table 3.

The data in Table 3 show that in 1972 Virginia was the leading state in eel production with nearly half a million pounds (227 t) followed by New Jersey, Maryland, New York, North Carolina, and Maine, in that order. However, this situation may be changing rapidly. In Maryland, one of the primary uses of eels has been as salted bait for use in catching crabs on trot lines. Increased use of crab pots, which do not use salt eels for bait, has reduced landings in that state; and in 1973, only 157,000 pounds (71.2 t) were landed. North Carolina, on the other hand, has been rapidly expanding her eel fishery for export as a food product, and it is estimated that in 1973 the catch may have jumped to over half a million pounds (227 t) (Angel and Jones, 1974). Maine has been attempting to establish an elver fishery, with mixed results to date. Elvers will not increase poundage landed significantly since a pound (0.45 kg) may contain from 1,000 to over 5,000 individuals but can appreciably increase the value because of the high price per pound.

Several coastal states are taking an active interest in exploiting the increased demand for eels in Europe and Japan. It may be that the U.S. fisheries for this species will increase in future years as our resource seems to be greatly underutilized. However, based on the longer experience of both Europe and Japan, it seems unlikely that production of wild eels will ever rise above a few million pounds per year. Even an increase in landings to say 5 million pounds (2,268 t) annually would more than double present U.S. supply and at an average price of 30 to 40 cents/pound (0.45 kg) to the fishermen be worth $1.5 to 2.0 million a year. While little information is available as to the stocks or the maximum sustainable yield that can be achieved in the United States with eels, 5,610,000 pounds (2,544 t) a year would appear to be attainable. Due to the increasing pres-

Dip netting elvers (left), just one of several ways in which elvers are captured. At right is a catch of approximately 2 kg of elvers. Photos courtesy of the North Carolina State University Eel Culture Project, a part of the University of North Carolina Sea Grant Program.



The round or cylindrical eel pot (left) is commonly used by North Carolina eel fishermen. At right is the newer square eel pot which may replace the cylindrical one. Photos courtesy of the North Carolina State University Eel Culture Project, a part of the University of North Carolina Sea Grant Program.

sure on our waterways from population, power sources, and obstructions, it is likely that increased interest on the part of the United States in eel production will result in more attention being given to eel culture as was the case in Japan and is beginning in Europe.

METHODS OF CATCHING EELS

There are a number of means of capturing eels in use around the world. Most of these methods are essentialy the same as have been in use for hundreds of years. The method chosen depends on the type of eel, the stage of development one wishes to capture, and makes use of the biological habits of the eel during these different stages.

Eels tend to congregate at three different times. The first time is the spring run of elvers going upstream. These young eels are strongly oriented toward going upstream, and this fact can be capitalized on in capturing them. The yellow eels tend to congregate during their winter inactive phase in deep holes with muddy bottoms. Yellow eels may also be found in limited numbers making a spring run from fresh water to salt water. These are primarily male eels returning to their estuaries or marine environment and are therefore generally smaller than female yellow eels remaining in fresh water. In the late summer or fall, there is a second migration of silver eels from fresh water to the sea. Since these eels cannot feed, the method of catch is based on trapping them in their journey down the waterways to the sea. Yellow eels can be taken at other times when they are not

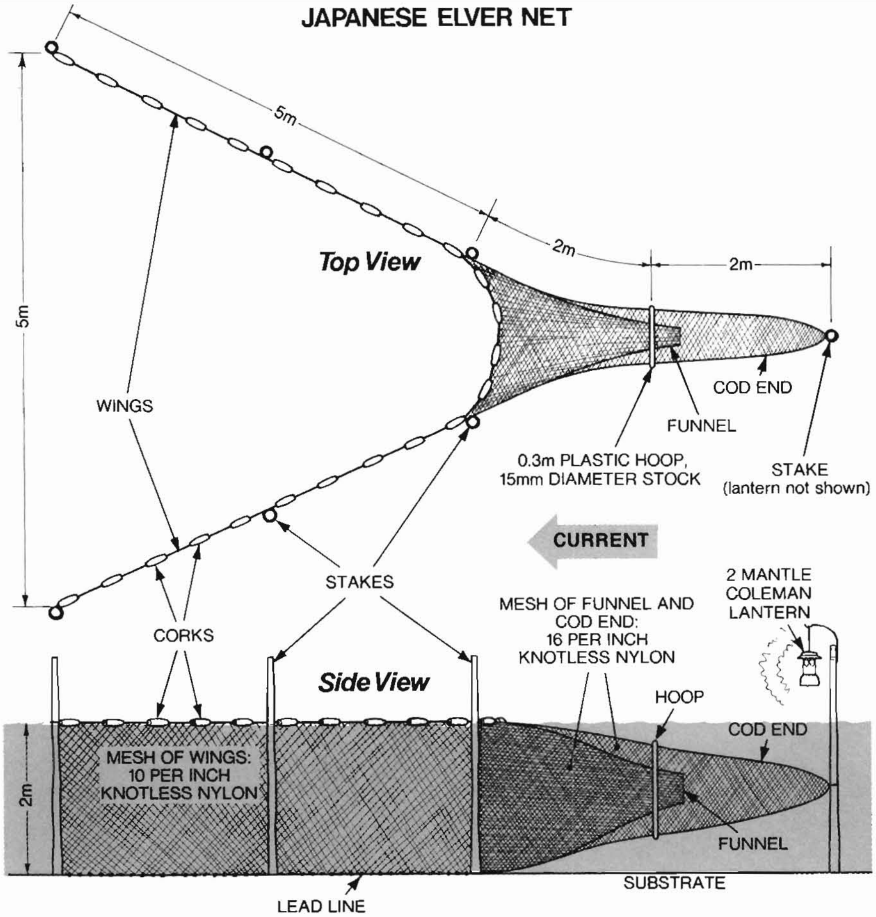


Figure 1.—Japanese elver net, from Topp and Raulerson, 1973.

closely congregated but are actively feeding, by using bait. We will consider ways of catching elvers.

Elvers are caught for food to a very limited extent. Young elvers or glass eels are fleshy, white when cooked, and reported to be quite tasty. Once they become pigmented elvers, they lose flesh, become tough, and are dark when cooked. In England, glass eels were used to make an elver cheese. In Spain, they were consumed in elver omelettes and as pates (Bertin, 1956). They may also be canned in oil. Most elvers are caught, however, for use in stocking inland lakes or for use in more controlled eel culture.

Fine mesh purse seines have been used in France from boats near the shore to capture the young elvers as they approach the coast. The purse seine is a long net of uniform width with a series of floats on the top and weights on the bottom so that it will float upright in the water. The net is fastened at one end to a boat or the shore and the other end moved by another boat (or by hand in very shallow water) to encircle a school of fish. Once the encirclement is completed, a line running through a series of rings along the bottom of the net is pulled tight to close or "purse" the net. The net is gathered in, forcing the elvers into a small pocket from whence they are lifted out with a small dip net.

Another method of catching elvers is used in streams or rivers and involves trapping them as they make their way upstream. So strong is the instinct to travel upstream that a V-shaped trap with the small end upstream leading to another enclosure will catch elvers. As long as the flow of water is not reversed (as from tidal action), the elvers will continue to head upstream and not turn around and escape through the downstream opening. The trap is placed in a constricted part of the waterway or has wings or leaders of fine mesh netting of wire set to direct the elvers into the trap.

A trap of this type can be made using any fine mesh screen, although nylon is preferred to metal since it is not susceptible to rusting. A good description of an elver trap is given by Sheldon (1974). The Japanese use a mesh net and an upstream light source to catch elvers (Fig. 1). Lights can be used to attract glass eels, but once they become pigmented the elvers will avoid light.

Elvers may also be taken from areas below obstructions such as waterfalls or dams with dip nets. In small shallow pockets of water, an aquarium-type dip net is better than the larger variety (because of the size of the water pocket). It must be stressed that while many modifications of these nets and traps will work if positioned in the right spot, they are useless unless one knows when the elver run will occur in a given area and which streams, rivers, etc., are most frequented.

Yellow Eels

Since yellow eels are actively feeding except in cold weather, they can be attracted by bait. A large variety of baited traps have been used successfully to catch them. Goode (1887) described a trap used in colonial times: "When ascending the rivers and small streams in the fall or leaving them in the early spring, large quantities are taken by obstructing the flow of water and placing in the center of the stream a strong barrel pierced with auger holes into which the eels creep, but out of which, curiously enough, they seem unwilling to stir. The barrels have been so filled at times as to suffocate a large part of the catch before morning." It is interesting to note the reverse run of eels mentioned here—that is, descending in the fall and ascending in the spring. Either this was a large run of male eels or Goode has made an error. He later describes a box trap used in New Bedford, Mass., in the 1800's as being 4 feet long and 10 inches wide with slatted sides and 4-inch square holes in each end with 2 small wooden slats that opened when the eel went in but snapped shut behind him. These traps were weighted with stones and used clams for bait.

All baited traps or pots, of which there are a wide variety, operate on the same principle. The eels are attracted by the smell of the bait into the large end of a funnel-like opening. The narrow end of the funnel leads to a small opening into a container and quite often the process is repeated into a second compartment. Sometimes the bait will be exposed to the eels after they enter the trap and in other cases only the odor will reach them as the bait itself is protected by a bag or perforated container of some type.

Eel pots come in all shapes and sizes. A pot or trap made of willow branches was used by the American Indians and the early colonists and is still in use to some extent in parts of the United Kingdom and Canada. This trap resembled a large basket with the funnel-like opening forming a double lining into the basket. The smaller end of the basket was tied off with twine while the trap was fishing and released to remove the captured eels.

From willow branches, the construction of eel pots evolved more to those with wooden frames and netting. Traps were also made of wood slats and were either round or rectangular in shape (Fig. 2). Today, most eel pots closely resemble the eel pot in the middle of Figure 2, except that they are made of galvanized wire rather than twine netting. The cones or funnels may be of wire, nylon cloth, nylon twine, or even light gauge sheet metal. The bait is placed in the last section so the eel must pass through both funnels before reaching it, thus making it doubly difficult to find the two small openings that would lead to escape. Detailed information on the construction of both a round and a square pot made of galvanized wire or vinyl coated wire is given by Berg et al. (1975).

Other baited traps have been made from such simple things as a section of pipe to which a burlap sack is tied. The sack will contain the bait and perhaps some hay or straw to make it more difficult for the eel to find his way back out of the pipe. Modified lobster and crab traps have been used. The entrances are changed to a funnel arrangement; and, of course, the space between the wood slats or the size of the mesh in the wire must be small enough to prevent the eels from escaping. The traps made from wooden slats are also shown in Figure 2.

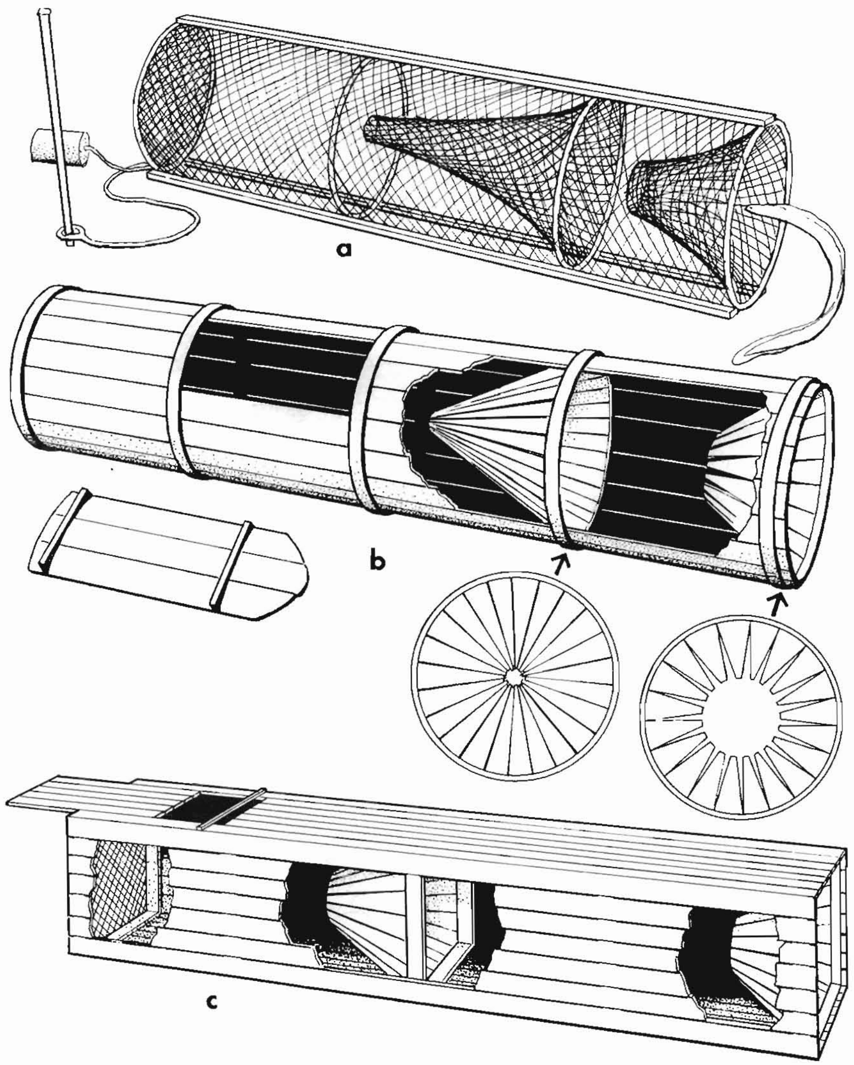


Figure 2.—Eel pot (a), slat trap (b), and basket trap (c) (after Dumont and Sundstrom, 1961).

The bait used in these traps must be fresh and can be placed loose or fastened in the inner chamber (usually called a "parlor") or can be cut or chopped fine and placed in a bag. Most any form of marine life can be used as bait, depending on what is available locally. Herring is often used, but menhaden, alewives, mackerel, squid, crabs, clams, mussels, and even fish waste ("gurry") from a filleting operation could also be used as long as they are fresh. Frozen bait can be used either slacked out (thawed) or frozen as it will quickly thaw in the water. The pots should be tended daily, and the bait changed. Pots and traps are usually set in rivers or streams with the opening facing downstream[1] or in estuarine areas facing the tide and anchored with

[1]Upstream during the downstream migrations in the spring.

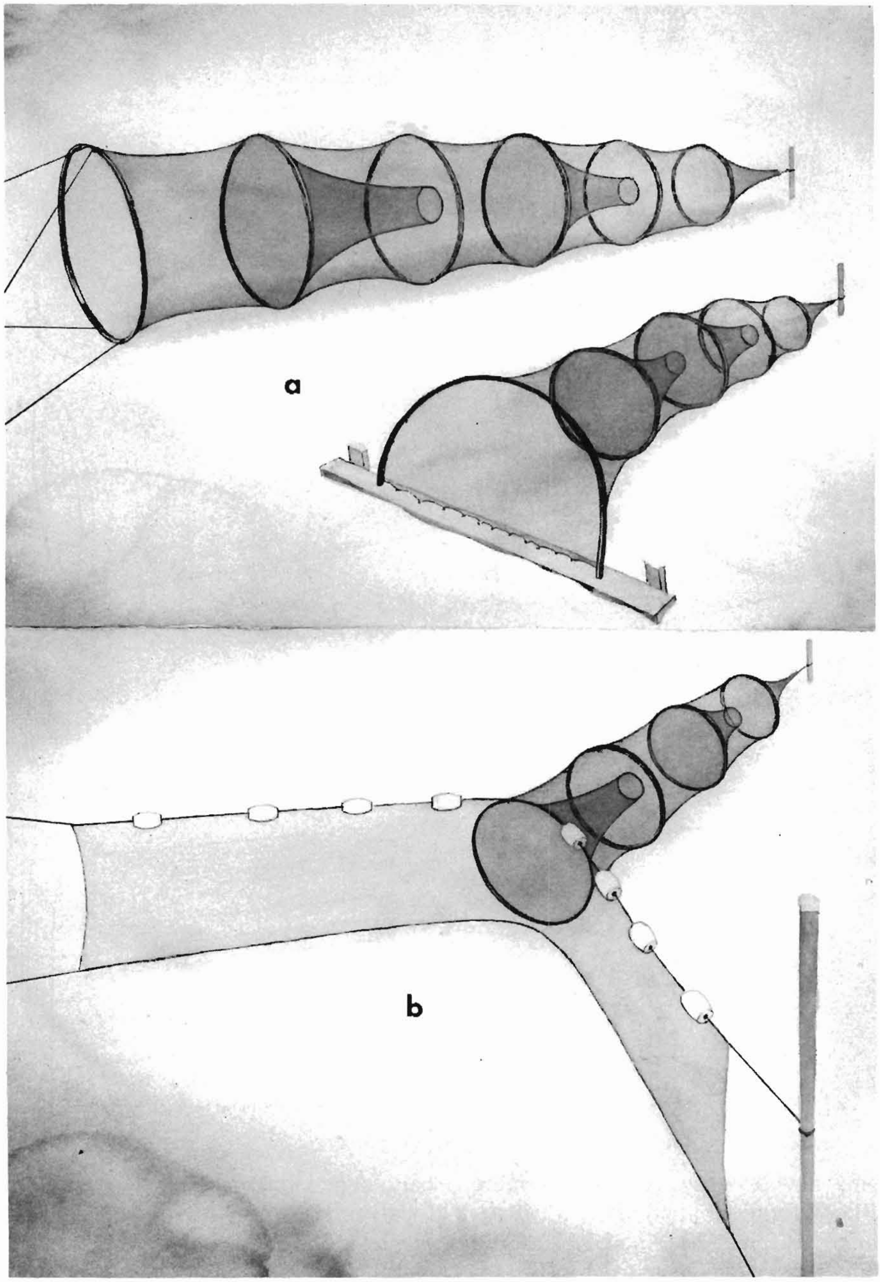


Figure 3.—Hoop net (a) and fyke net (b) (after Dumont and Sundstrom, 1961).

ballast or rocks, bricks, or cement. The number of pots set should be limited to those that can be tended daily.

In addition to baited traps, a variety of unbaited traps and nets are used. Gear of this type depends on leading the prey into an easily accessible opening from which the return is restricted—just the same principle as in the baited traps except now the eel is diverted from his course of travel into the trap rather than entering it actively to seek the bait. The most common examples of the unbaited trap are the hoop net or the fyke net. A hoop net is made by covering hoops or frames with netting or wire mesh. They are usually of decreasing size from front to back and have one or more funnel-shaped openings inside. The mouth of the net can be several feet in diameter and tapers down to a small terminal hoop (Fig. 3). A fyke net is a hoop net with one or two leaders or wings extending out from the opening to lead the fish into it. These traps work best where they can be so located in a restricted body of water that the fish cannot get around them.

Hooks can also be used to catch eels. These are generally put out in sets and the method of fishing called trawling, longlining, or trotline. The gear consists of a long line to which shorter and lighter lines with hooks are attached at intervals. At each end of the line will be a weight or an anchor attached to a float or buoy. In rivers and streams, one, or both, ends of the line may be tied to a tree or stake on the bank. Eels can be taken from spring to fall by hooks. However, hooks are more apt to injure or kill the eels than are traps. This is important if the intended market for eels demands live delivery.

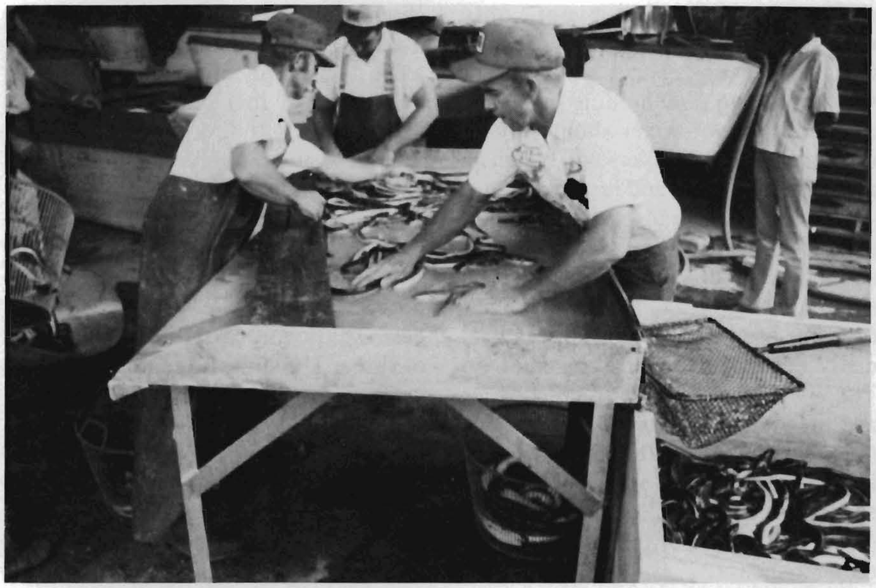
Another method of catching eels involves a line but no hook. A single line is fished by hand or with a rod and reel. Worms are threaded end to end by means of a dull needle. Several worms are threaded on the line, then the worms and line are formed into loops by winding around one's fingers. The loops are tied together then fastened to the end of the fishing line. The bait is fished on or near the bottom. When the eel bites, steady but gentle pressure is kept on the line until the eel is lifted out of the water. The eel has many small teeth that become entangled in the baited loops; and if the line is pulled in steadily, they will not fall off. In England, a length of wool may be used to thread the worms and the method of fishing called "bobbing." This is primarily a sportfishing method and is used on warm summer nights.

In the winter when the eels bury themselves in mud, they can be taken by spears. The inactive eels will be found concentrated around entrances to lakes or rivers or streams or in deep holes near tidal entrances to fresh water or estuaries. The taking of eels by spears or forks is called spearing, gigging, or in England—"pritching." This method was used in colonial times in the United States and is still the same today. Since the eels are often killed by this method, it is used mainly for sports purposes where the eels will be consumed soon after catching. The secret of success to this method is to find where there is a concentration of eels buried in the mud. Once a suitable spot is located, it can usually be used year after year, and the easiest way of finding such a spot is to contact someone who has speared eels in the past. In cold weather, a hole can be chopped in the ice. A three (or more) pronged spear is used with a long handle. The prongs of the spear are usually barbed. Some spears will have an unbarbed center prong with the barbs on the two outside prongs facing in. A variation of this type spear is one that has an unbarbed center prong and two outside spiny loaded clamps that prevent the eel from wriggling off the center prong. Other methods use a spear with serrated blades. When the spear is pushed down on the eel, it is forced up between two of the serrated blades. The eel is thus imprisoned between the teeth but not pierced.

Silver Eels

Silver eels are the most desirable for smoking as they have a high fat content. They have fattened in preparation for the long marine migration during which they cannot feed. During the fall run, silver eels can be caught in large numbers by various forms of unbaited traps and nets. Some of the traps designed for fishing silver eels are very elaborate and require considerable time and expense to construct. Obviously, these more elaborate traps are only used where the commercial harvest is sufficient to justify their expense.

By and large, eel fishing has not reached the stage of commercial development where these elaborate methods of trapping are used. In Canada, one type of trap or weir is built in the summer when the rivers are lowest by making a large V in the river with the small end downstream. The wings or sides of the V may be made of stones, branches, brush, poles, or planks. These wings must be strong enough to resist the flow of water and the impact of floating debris. The wings lead to a sluiceway or capture box that must be so designed as to permit ready passage of water while retaining the eels. Eales (1968) reports that "at St. Jean (Iberville), Quebec, a highly profitable weir has been operated at the same site for more than 100 years by five generations of a family. The catches have averaged about 60,000 pounds (27.2 t) per year and have recently[2] climbed to 100,000 pounds (45.4 t) per year."



Sorting wild-harvested eels to remove those below market size. Photo courtesy of the North Carolina State University Eel Culture Project, a part of the University of North Carolina Sea Grant Program.

The construction of weirs varies depending on the water conditions and the materials at hand and local regulations. They all are designed to lead the eels during their downstream migration into an area from which they cannot escape. Less elaborate means, such as fyke nets and hoop nets described for catching yellow eels, can be used in smaller streams.

One thing must be kept in mind in catching eels. Since most of the fishery takes place in fresh water, State and local regulations should be carefully considered before any method is attempted. The more elaborate weirs and traps actually block off a whole section of the river, and generally the placement of such devices must be cleared and approved by the appropriate authorities.

[2]1968.

STORAGE AND TRANSPORT

Elvers

The demand for elvers is for use in stocking natural bodies of water or for culture purposes. This means that the elvers must be held and transported alive if they are to have any market value. At the present time, the demand for elvers is primarily in Japan and to a lesser extent, Europe, so that transportation for considerable distances is involved.

After being caught, the elvers can be held temporarily in small holding nets until a sufficient quantity is accumulated for transporting them to shore. The most important consideration in holding elvers is to ensure a sufficient supply of oxygen—about 11 ppm. A holding pen or box about 2 feet × 4 feet × 2 feet (61 cm × 120 cm × 61 cm) with small mesh screens on the ends can be used near the point of catch. This box should be placed in a flow of water so the water will pass through the box. With a good water flow, about 20 pounds (9.1 kg) of elvers can be held in a box this size. The screen must be cleaned daily to ensure a good flow of water and any dead elvers removed.

A collecting station ashore can use a natural flow of water to maintain the oxygen level. In any event, only natural, unchlorinated water should be used. Since the elvers instinctively swim upstream, any holding pen using a natural flow of water should not be overstocked, as the elvers will bunch up at the upstream end and may suffocate.

Elvers can be transported for short distances in aerated tanks. For overseas shipment by air, the Japanese prefer shipping them on ice. About 10 pounds (4.5 kg) of elvers are placed in a specially designed Styrofoam[3] container. The elvers are mixed with crushed ice and the containers packed in 50-pound (22.7-kg) master cartons. A similar unit is made of expanded polystyrene, measures 32½ inches × 3½ feet × 4 feet (0.83 m × 0.89 m × 1.2 m) and weighs only 8 ounces (227 g). A slitted sliding top provides ventilation. Each box holds 4 pounds (1.8 kg) of elvers. A separate section inside the box holds a 2½-pound (1.1-kg) cake of ice which provides cool fresh water as it melts.

Yellow and Silver Eels

Both the small domestic market for eels and the European market pay a premium for live eels. It is usually desirable to hold eels for a week or two in running water to purge them and to eliminate any muddy flavor. Any enclosed pen or box that permits a flow of water through it will do for a holding station as long as it is tended to ensure a flow of water and to eliminate dead eels. (Handling of dead eels will be discussed in the section on processing.)

Eels are normally collected with a truck with one or more tanks. One arrangement uses a paired series of small tanks on a flatbed truck. Each tank is filled with fresh potable water. An aeration unit is mounted on each tank to provide oxygen. Other arrangements utilize small tank trucks or large tanks mounted singly or in pairs. As long as the eels are not overcrowded and aeration is sufficient, little difficulty is encountered in transporting eels several hours, even in hot weather.

Eales (1968) lists several points that should be considered in designing a holding container for live eels: 1) With a constant supply of aerated water, 100 cubic feet (3 m^3) of water will hold 1,500 pounds (682 kg) of eels. If the rate of water supply is limited, the eel-water ratio should be substantially limited. 2) Remove dead eels as soon as possible from the container. 3) The inside of the tank should be smooth to prevent abrasion of eels. 4) Handle live eels as little as possible to prevent loss of slime. The slime layer aids the eels in maintaining their salt balance, and loss of this protection may cause death. 5) Be sure the openings around the container are small as eels can escape from very narrow openings. Variations of these tanks have been used. In England, one company used a barge with a perforated steel bottom. The barge is kept afloat by two buoyancy tanks and can hold a million pounds (454 t) of eels. The Dutch have used ships to pick up eels from Canada, the United States, Europe, and Africa. One of the ships, *Mercurius*, is a 300-ton (272-t) converted naval landing craft which uses circulating seawater. The other ship has a perforated hold which permits free exchange of water with the surrounding sea. Eels transported this way are subject to whatever sources of pollution are present in the surrounding water, and one shipment of eels was killed in the St. Lawrence waterway by a temporary pollution condition.

In Great Britain, tray boxes are used for transporting live eels from Ireland to London. The unit consists of an outer case 36 inches × 18 inches × 14 inches (0.91 m × 0.46 m × 0.36 m) made of ½-inch (12.5-mm) pine. Each case has five trays about 2 inches (50.8 mm) deep. Each tray is divided into two compartments. The four bottom trays are packed with about 20 pounds (9 kg) of eels each. The top tray is filled with crushed ice. All the trays have 20 half-inch (12.5-mm) holes in the bottom so the melt water trickles down over the eels in all the lower trays.

Air shipping live eels from the United States to Europe is done by packing them in 30-pound (13.6-kg) lots in polyethylene bags. The bags are vented near the top and contain a small piece of ice. The bags are packed in wax-impregnated boxes. For air shipment, it is very important that the containers are water-tight to prevent leakage in transit.

Eels can be held for several months without feeding. However, in general, it is probably not a good idea to hold them for more than a few weeks. If longer storage is necessary, the eels should have access to salt water occasionally; otherwise, they tend to get hard and lose their wriggling characteristics. They should not remain in salt water more than 24-48 hours at a time or they may lose their slime and die (Eales, 1968).

PROCESSING

Frozen Live Eels

As mentioned in the previous section, the most lucrative market for U.S. eels is in Europe. This market pays highest price for live eels. Shipment of live eels poses several problems connected with packing methods, transport scheduling, and possible delays en route. Eels that die in transit may not be accepted at all; or if they are, the price is greatly reduced. An alternate way of marketing is to ship the eels in frozen form. This reduces the price received but also reduces the risk involved in shipping live eels.

Eels should be held in fresh water for 1-2 weeks after capture to permit them to clean, or purge, themselves of feed. This also helps to eliminate any off flavor that might be present with eels taken in muddy water. The eels are then size graded, with the most common sizes being ¼-½ pound (0.11-0.23 kg), ½-1 pound (0.23-0.45 kg), and over 1 pound (>0.45 kg). The graded eels are packed live in 25-pound (11.4-kg) lots in plastic bags which are, in turn, inside a wax-impregnated corrugated cardboard box. Freezing should be done rapidly at −40°F (−40°C). During the freezing process, the eels will intertwine. The European buyers look for this condition, and if it is not present consider this evidence the eel was dead when it was frozen and may reject the entire lot. Usually two of the cardboard cartons are packed in an

[3]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

insulated master carton for air shipment or in uninsulated master cartons for shipment by refrigerated ship. The cost of the latter method is considerably less, and if a sufficient volume is involved would be the preferred shipping method on the basis of economic considerations.

Killing and Cleaning

Most of the eels consumed throughout the world are smoked. Jellied eels are preferred in parts of England. Limited amounts are used as fresh or frozen eels. Most of the U.S. eels frozen alive and sent to Europe will be used for smoking.

Live eels can be killed by placing them in a container and liberally sprinkling them with salt. They should not be buried in the salt; just a good sprinkling will do. They should be left for about 2 hours. This process also aids in removing the slime. Electro-killing has been tried by placing the eels in water and then passing an electric current through the container. This will kill the eels but presents possible safety hazards for the workers and still leaves the problem of getting rid of the slime.

Once the eels are dead, the slime can be seen floating on the surface of the brine. The slimy water is poured off and the eels thoroughly washed in fresh water. This may take up to a half hour in cold water, after which they are scraped or scrubbed to remove any remaining traces of slime. It is important to remove all slime since failure to do so may affect the flavor of the finished product. If the eels are to be smoked with skin on, the scrubbing will also improve the appearance.

Once the eels are washed, they are gutted. If the eels are to be used in the skinned form, it is easier to skin them before gutting. To skin, fasten the eel with a nail or clamping device on the head in a vertical position. Make a circular cut about three inches behind the head. The cut should not penetrate the flesh as there is a danger of cutting into the gall bladder, and this can cause off flavor. Also, care should be taken to avoid contact through an open cut with the blood from the eel because of its toxic properties mentioned earlier. Next, lay the skin back from the cut and strip it off intact using a pair of pliers.

Gutting the skinned or unskinned eels is facilitated by sprinkling salt or sawdust on it or dipping one's hands in salt or using a rough cloth to hold and getting a good grip on the fish. With a sharp knife, make a shallow cut from the gills to a point about 2 inches past the vent (to expose the kidney). In removing the viscera, a knife with a rounded, blunt end and a serrated edge is helpful. The rounded part of the knife is used to separate the lower part of the gut from the body cavity near the vent. The serrated edge is used to remove the blood vessel along the backbone and the kidney. The knife is then slid forward to complete removal of the viscera (Lynch, 1964). Scrub out the gut cavity to remove all traces of blood and rinse with cold water.

If the eels will not be further processed, it is advisable to remove the head and the last 2-3 inches (50 to 75 mm) from the tail. The eels can then be cooked fresh or frozen. If frozen, they should be packaged in a good gas/vapor proof material. Eels, especially silver eels, have a high fat content and unless adequately protected during frozen storage may develop rancidity (Berg et al., 1975).

PREPARATION OF EELS

Fresh or Frozen Eels

Eels can be used fresh or frozen for frying, baking, smoking, or gelling. Fresh eels are preferred for gelling, and eels for smoking should have the head and skin left on.

Fried eels are prepared by starting with a cleaned and skinned eel cut into 3-inch sections. Wipe the sections dry and dip in an egg batter then in bread crumbs. Deep fat fry at 375°F (190°C) for 3-5 minutes. A more elaborate Italian recipe is Eel Neapolitan:

1½ pounds (0.7 kg) of dressed eels
3 tablespoons olive oil
1 clove sliced garlic
1 medium can of peeled tomatoes
½ teaspoon salt
½ teaspoon pepper
4 thin slices of Italian bread, toasted
10 ripe (black) olives, chopped
1 tablespoon seedless raisins
½ cup water

Cut the eel into 2- to 3-inch (51- to 76-mm) pieces. Brown garlic in oil. Remove the garlic from the pan and add tomatoes, salt, pepper, and eel. Cook 10 minutes then add olives, raisins, and water. Cover pan and cook about 20 minutes or until the eel is tender (cooking time will vary depending on size of eel). Place slices of toast in a dish and pour the mixture over them. Serve hot.

Smoked Eels

Smoking has been the traditional way of preparing eels. They are one of the most important smoked fish products in Germany and the Netherlands. Eels may be smoked from either the fresh or frozen state, although fresh eels are reported to give a better finished product. Frozen eels thawed and deslimed are dressed as described earlier. Skin and heads remain on. Large eels may be cut into two sections before smoking, but most eels are smoked whole.

An Australian method of smoking, based on the German method, is as follows: Eels weighing 9-14 ounces (257-400 g) are cleaned and dressed. They are placed in a brine. The brine concentration may be as low as 10 percent for 24 hours, but unless cooled with ice, the eels may spoil before the brining process is complete. In hot weather, more often a strong brine (100 ppt salinometer) is used. The time will vary from 2 to 24 hours, depending on the degree of salt desired. After removal from the brine, they are washed with fresh water and air dried. The eels are then hung by the head on hooks and dipped in boiling water until the sides open out. The fish are then placed in the smokehouse and given a two-stage hot smoke.

In the first stage, hardwood chips are burned to give clean hot flames and quickly bring the temperature up to 248-257°F (120-129°C). This temperature is maintained for 5-10 minutes so the eels are partially cooked and oil and water content is lowered. In the second stage, the flames are smothered with damp chips and the draft reduced to

Smoked eels. Photo courtesy of the North Carolina State University Eel Culture Project, a part of the University of North Carolina Sea Grant Program.

produce a heavy smoke. The temperature is lowered to 104-122°F (40-50°C). Smoking time is from 90 minutes to 4 hours, depending on the size of the eels; although for some markets, this time can be extended to as long as 12 hours. The eels are then cooled in the smokehouse and given a light brushing of edible oil on the outside to improve appearance. Yield is about 60 percent of live weight (5-10 percent loss in gutting and about 30 percent loss during the hot smoke process) (Anonymous, 1955).

Another method used in England in a mechanical smokehouse calls for using eels ¾ to 1½ pounds (0.34 to 0.68 kg). The eels are brined (lightly for domestic use and heavier for export) and smoked for 1 hour at 95°F (35°C), 30 minutes at 120°F (49°C), and finally at 170°F (77°C) for 1 hour. The smoking loss is about 15-20 percent by this method. The smoked eels must be refrigerated and have a chilled storage life of 3-4 days (Horne and Birnie, 1969). It should be noted that any smoking of eels for sale in the United States must be done according to the guidelines established for smoked fish by the U.S. Food and Drug Administration.

Smoked eels may be sold chilled, frozen, or canned as a fully preserved product. Chilled smoked eels have a relatively short storage life and must be properly refrigerated at all times. Frozen smoked eels require the same type of package protection as do unsmoked eels.

Jellied Eels

The method given for preparation of jellied eels is used commercially in Great Britain where this product is popular. Eels are cleaned, dressed, skinned, and cut into 2-inch (51-mm) pieces. The pieces are parboiled for 10 minutes in water with 2 percent vinegar, 3 percent salt, and 2 ounces (57 g) of mixed pickling spices per gallon. After cooking, the pieces are drained, cooled, and packed in glass jars or flat cans and covered with a 10 percent gelatine solution containing 1 percent acetic acid and a few drops of lemon essence. The containers are vacuum sealed and heat processed. The process may be varied by using a spiced vinegar-salt solution to cover the cooked meats in the container (Horne and Birnie, 1969).

Proximate Composition

The fat content of eels is highly variable. Silver eels will usually have a higher fat content than yellow eels. The content of the American yellow eels, edible portion only, is about 72 percent water, 19 percent protein, 9 percent fat, and 1 percent mineral or ash. For smoked eels, edible portion, it is 50 percent water, 19 percent protein, 28 percent fat, and 2 percent ash (Chatfield and Adams, 1940). Typical composition of raw European silver eels is 58-60 percent water, 14 percent protein, and 26-28 percent fat. Because of the high fat content of silver eels, the calorie value can be as high as 1,350 calories/pound (0.45 kg) (Horne and Birnie, 1969).

MARKETS

Since the days of the early American colonists, there has been a steady, but small, commercial fishery for eels in the United States. For the 40 years preceding 1974, the domestic catch of eels had been fairly constant between 1.3 and 2.5 million pounds (590 and 1,134 t) annually. Nearly all of these eels went to satisfy domestic ethnic markets primarily in the large population centers of the northeast. It is only in the last few years that interest has developed in the possibility of expanding our eel fisheries to meet the increasing demand, and correspondingly higher prices, of the export market.

Elver Market

The market for elvers has been stimulated by the failure of commercial harvest in Europe and Japan to satisfy local demands. This has led to an increased interest in eel culture in Europe and an expanded interest in the long-established culture operations in Japan. Spain is the only country where there is a direct market for elvers for food purposes. All other markets seek elvers for use in stocking natural waterways or for eel culture.

Germany, Netherlands, England, and France are all exploring eel culture operations. The primary market for elvers at this time, however, is Japan. Reports on the prices paid for elvers have varied widely. A range of value from $50 to $900 per pound (the higher price was for small elvers running 7,000 and over count per pound) was reported in Maine (Ricker and Squires, 1974). The U.S. Regional Fisheries Attache in Tokyo reported that one Japanese firm quoted a retail price for Japanese elvers of $417 per pound in 1973 (Folsom, 1973). However, American elvers are not considered as desirable by the Japanese as their local species, and these reported high prices should not be expected by anyone seeking to go into the export elver market in this country.

Maine fishermen have been interested in the Japanese elver market. Prices received are much lower than the figures cited above would indicate—about $20-$99/pound (0.45 kg) for Asian eels and $14/pound (0.45 kg) for European elvers. In 1971 and 1972, the Japanese paid an average of approximately $12 and $4/pound (0.45 kg) for U.S. elvers.

There are several reasons why American and European elvers bring a lower price on the Japanese market. The smaller the elver, the higher the price. That means that the young glass eels are highest in value. There is the problem of shipping them so they arrive alive and remain in good condition after they are stocked. The price paid reflects this risk. The American elvers are received later in the growing season than the Japanese elvers, and this has an adverse effect on their growth and eventual time of marketing. The American (and European) eels are adapted to cooler water than their Asian counterparts and grow slower, and the Asian eels are collected at a younger age so there are more per pound.

Despite these drawbacks, it would appear that the Japanese demand for elvers will continue to grow. This means that there is a potential for the development of a U.S. export market for elvers. Astronomical prices should not be expected, however, and any entry into this field should be done with caution until the holding and shipping techniques are well developed and the market established (Folsom, 1973). While the price received per pound is relatively high, there are several risks involved in the part of the supplier; the greatest being the death of the elver in transit. Prices received for elvers must cover the costs of catching, buying the elvers locally, construction and operation of pickup facilities and holding stations, packing materials, and air freight and marketing fees. The profit margin should be carefully examined before a large scale elver operation is launched.

Markets for Adult Eels

The market for larger eels is primarily in Europe, although there may be some potential in Japan as well. In 1972, Japanese importers were offering $1.23 to $1.36/pound (0.45 kg) of live eels weighing 150-200 g (about 6-8 ounces). For frozen eels of the same size, the price was 22-27 cents/pound (0.45 kg). In contrast, $2.50-$3.00/pound (0.45 kg) was the price for Asian eels (Folsom, 1973).

In 1972 a firm delivered 70 tons (64 t) of live eels by air freight to England. Mortality rates were generally under 2 percent. Live eels are flown to Germany from several east coast States, particularly from Maine, Massachusetts, Pennsylvania, Virginia, and North Carolina. Prices paid to New England fishermen have generally been in the 25-35 cents/pound (0.45 kg) range. One dealer in North Carolina paid an average price to fishermen in 1972 of 23 cents/pound (0.45 kg) and in 1973, 45 cents/pound (0.45 kg). Dealers in North Carolina and Virginia have shipped frozen eels to Europe, primarily Germany, for further processing as smoked eels. The price for frozen eels is much less than for live eels. The relative prices are similar to those quoted for the Japanese market.

The export market would seem to offer the greatest potential for expansion. The domestic ethnic market in the northeast is quite stable, and the possibility of expanding domestic consumption in the near future is limited without a considerable marketing and promotion effort.

EEL CULTURE

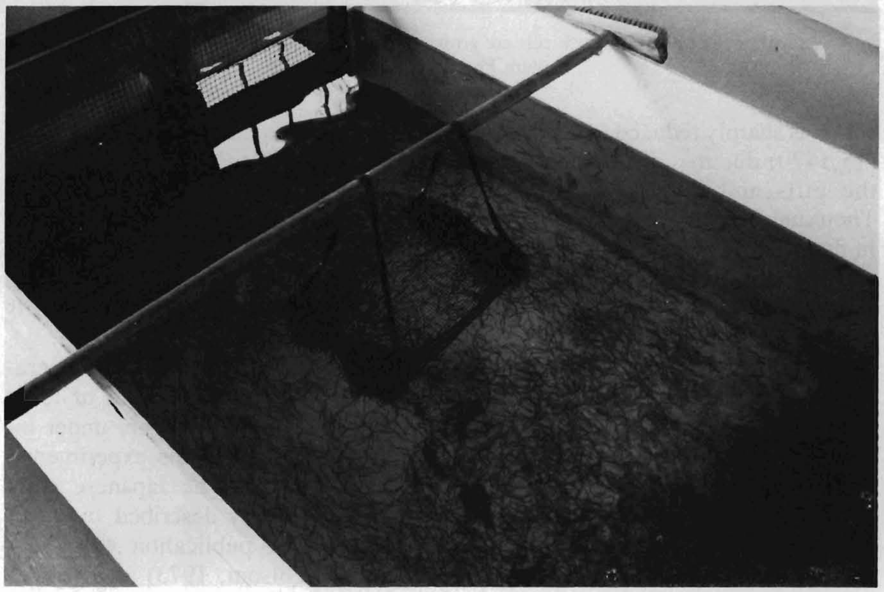
As the demand for eels throughout the world continues to grow and as supplies of readily available wild eels becomes more restricted, the interest in culture of eels increases. Eel culture is not a new technique and involves catching elvers and placing them in a suitable environment for growth to market size. Elvers were thus reported to have been transported and raised in ponds in Macedonia over 2,000 years ago. The next step beyond transporting of elvers to natural bodies of water is to place them in specially constructed ponds and this is eel culture.

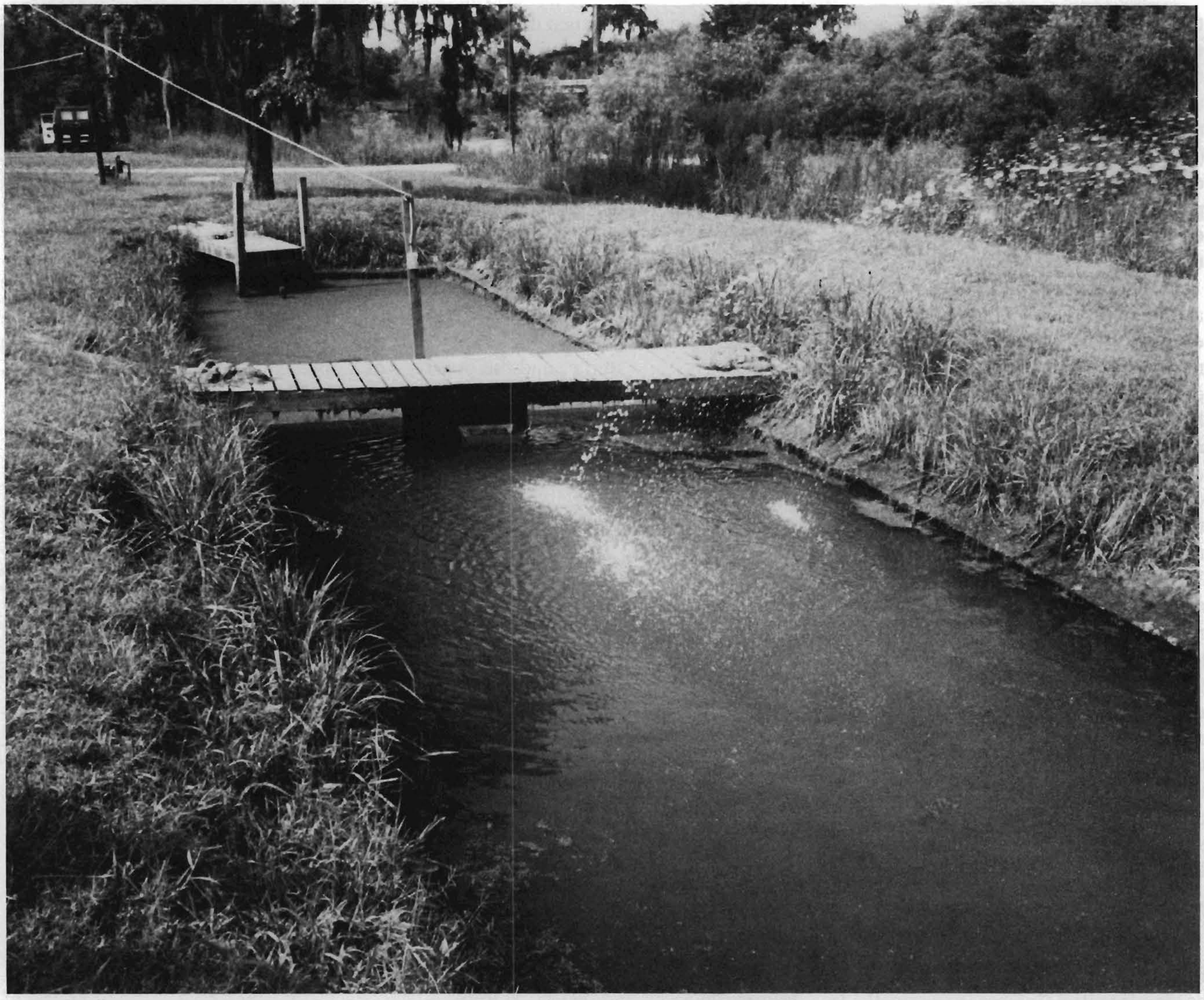
Culture, as used here, means that something is done to assist or control the growth of eels that is different from the natural or wild state. Transporting elvers to a natural body of water where they live and grow on whatever food is available and then are harvested as any wild fish would be is the simplest form of culture under this definition. This is what the Macedonians did and it is the method used for centuries in the Valli of Comacchio in Italy. This is a lagoon of 80,000 acres (32,389 hectares) located between two branches of the Po Delta and divided by dikes. It provides about 2 million pounds of eels per year (Eales, 1968).

A more controlled culture method is one that uses natural or artificially constructed bodies of water where controlled feeding, management, and harvesting are practiced.

The Japanese have practiced controlled culture of eels since 1879. Eel culture did not become a significant source of supply in Japan until the early 1960's. In 1962 about 7,600 tons (6,893 t) of cultured eels were harvested in Japan. By 1969, this increased to 23,000 tons (20,861 t). A year later the production of cultured

An indoor tank holding 5 kg of elvers for parasite and disease treatment and initial feeding. Food is placed in the wire mesh tray at center. Photograph courtesy of the North Carolina State University Eel Culture Project, a part of the University of North Carolina Sea Grant Program.





A small outdoor pond in which eels are grown to market size (¼-½ pound). Photograph courtesy of the North Carolina State University Eel Culture Project, a part of the University of North Carolina Sea Grant Program.

eels was sharply reduced to 16,700 tons (15,147 t) due to a disease that affects the gills and kidneys of the eels. Thousands of eels died and losses were in the millions of dollars. This disease was thought to come from the first elvers imported from Europe in 1969 (Folsom, 1973).

Although Japan has the best established eel culture operation, interest is increasing in Europe and the United States. In the United States, an experimental eel culture operation has been started by the University of North Carolina. In Europe, eel culture activities are being carried out in Spain, Italy, Great Britain, and France (Angel and Jones, 1974). New Zealand has at least two eel culture operations also. Taiwan began experimenting with eel culture in 1967. In 6 years, the industry rapidly expanded, and in 1973, an estimated 10,000 tons (9,070 t) of eels were raised (Forrest, 1974).

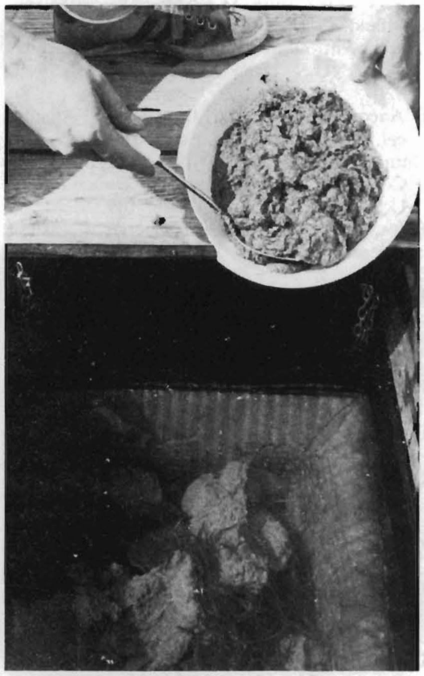
Most of the European culture operations rely on natural sources of feed. More intensive methods are under investigation or are in the experimental stages, however. The Japanese pond culture of eels is described by J. F. Sanders in the publication *Australian Fisheries* (Folsom, 1973) as follows:

"Elvers are caught in the winter as they migrate upstream from the spawning grounds in the open sea, and are cultured in relatively small ponds of 150 to 350 square meters by 70 cm deep. This phase of culture lasts for about one year, during which time the young eels grow to about 20 gm in weight. The original stocking density is about 500 to 600 gm per square meter.

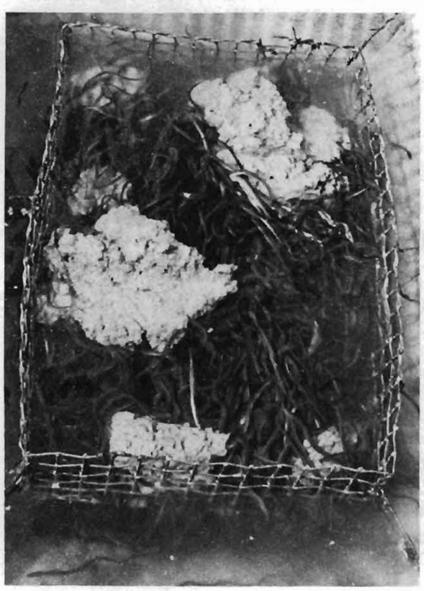
"The growth of individual eels is tremendously variable and constant culling is required during all stages of culture to ensure approximately uniform sizes in each pond.

"When elvers begin feeding they

are given small oligochaete worms for about two to three days, then for seven to ten days a paste of mixed oligochaete worms and fish flesh. Then they are weaned on to fish flesh or synthetic diets especially formulated for eels. They are fed twice a day and the quantity of feed given is about 30 percent of body weight.



Placing food in a feeding tray (above) in the outdoor pond. Below, young eels consume the prepared diet. Photographs courtesy of the North Carolina State University Eel Culture Project, a part of the University of North Carolina Sea Grant Program.



"Young eels prefer to eat in a darkened place and feeding is done in a shelter at one side of the pond. The food is placed in a wire basket suspended just above the water to prevent undue contamination of the water. When young eels reach a weight of 20 gm they are ready for the next phase which takes them to adulthood.

"The aim of adult culture is to produce 150 gm eels for market and this is achieved in about two years from the elver stage, which is double the growth rate of wild eels. The size of the adult ponds is about 3,000 to 10,000 square meters by 50 cm deep. The stocking rate is about 500-700 gm of seed eels per square meter of pond. Growth is most rapid during April to October and during the period the eels must be fed as much as possible. The quantity of food supplied is about 10 percent of body weight and is fresh or frozen fish flesh or synthetic diets. If fish flesh is used the feed coefficient is 6 to 7 while for synthetic diets it is less than two. (Feed coefficient is pounds feed required per pound of weight gain.)

"During culture care must be taken to maintain a satisfactory water quality. As all phases of culture are in still water and the density of stocking is high, the maintenance of water quality is relatively difficult. pH levels in the water should be about 8.0 to 9.2 during the daytime, and about 6.8 to 7.2 at night.

"Ponds located on acid soils usually have a pH around 5.5 to 6.5 which is too low for satisfactory eel culture. A high dissolved oxygen level is absolutely necessary and the minimum desirable value for eels is 2.0 to 2.5 cc per litre. Water wheels which oxygenate and mix water layers are a common feature of eel ponds. Satisfactory levels of calcium nitrate and phosphate should be maintained and this can often be done by the addition of fertilizers.

"Ponds are usually drained and the bottom mud turned and sprinkled with lime at the end of each year.

"The species composition and abundance of micro-organisms is of considerable importance during eel culture. In general phytoplankton are beneficial to eel culture and zooplankton are not. Well managed eel ponds are a blue-green color, with a plankton composition of 0.3 to 2.9 percent zooplankton and 97.1 to 99.7 percent phytoplankton."

Disease control is an important factor in a successful culture operation. There are some 10 different types of disease that affect Japanese eels, and any one of them is capable of wiping out an eel farm overnight (Folsom, 1973). European and American eels also are susceptible to disease although the types and extent of the problem are not as yet as well defined. To date, eels have not been spawned successfully in captivity thus the importance of obtaining elvers to start the culture process.

Despite the problems facing the culturist, the potential for gain is great. If one started with a pound of elvers containing 2,000 individuals and had a survival rate of 80 percent by the time they reached a half pound, there would be an 800-fold increase in weight. If the elvers cost $30 and the finished product brought $1.25 per pound, this would be $1,000 or an increase in value of 33-fold. Balanced against this potential increase in value is the risk of loss through disease or a depressed market that could lower the prices. Also, there is the cost of feed, labor, facilities, transportation, and marketing to be considered. Any would-be culturist would be well advised to start on a small basis and develop the necessary information relative to the conditions where the operation is to take place, before investing large sums of money in a large-scale culture operation.

SUMMARY

We have reviewed some of the characteristics of the genus *Anguilla,* the common eel. This fascinating creature is a true fish with a unique life cycle that is still not fully understood. The European species spawns in the Sargasso Sea, and the American species is thought to spawn somewhere to the west of its European relative. After spawning, the young leptocephali travel toward their respective continents. For the European eel, this trip

lasts 3 years, while the American eel completes the journey in about 1 year. When they reach the coast, the leaf-like leptocephali undergo metamorphosis to glass eels and then to pigmented elvers. Females head upstream into fresh water while males stay near the coast. They spend several years here as yellow eels. Finally, they change to silver eels and begin the reverse migration to their breeding area where they spawn and die.

Eels have an ancient and well-established following of avid consumers in Europe and parts of Asia, particularly in Japan, but are relatively unutilized in the United States. World catch, fishing methods, processing, preparation techniques, and information on eel culture throughout the world were also covered.

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