

The Cod Family and Its Utilization

JOHN J. RYAN

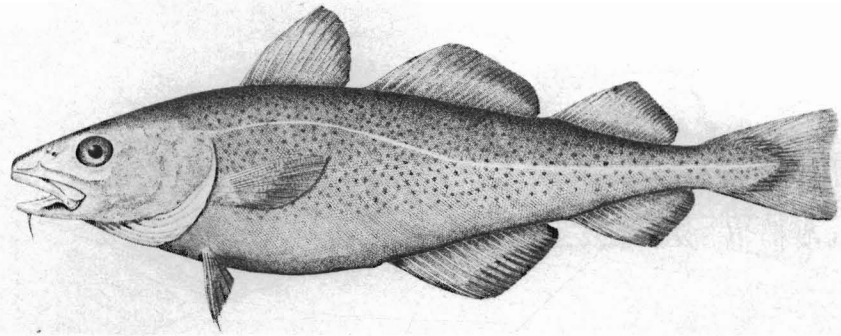


Figure 1.—Atlantic cod.

Introduction

Spanish explorers came to the New World to find gold and precious stones, but the French and Portuguese, followed by the English, crossed the Atlantic to catch fish, especially the Atlantic cod, *Gadus morhua*. In the 16th century, French and Portuguese vessels fished the Grand Bank off Newfoundland. By the early 17th century, the New England colonists were fishing for cod (Fig. 1) in the local waters. In 1624 "not less than 50 vessels from Gloucester" fished with handlines off the coast. In 1748, the first catch of cod from Georges Bank was landed.

Cod probably has influenced the course of American history more than any other marine fish. Its white flaky flesh was the foundation of power and wealth in colonial America. Cod was to young America what coffee was in recent years to Brazil; it was the first product shipped out of colonial Massachusetts. A large wooden codfish carving was hung in the Massachusetts State House in 1784 and is still occupying an honored position there.

As a commercial fish, cod had no peer: It was abundant all year. When split, salted, and dried, it kept almost indefinitely in any climate. Many long voyages could not have been possible

without dried cod, for ships could carry no perishable food as staples.

The cod family, from an economic point of view, is the most important of all the families of fishes. The members of the cod family are second only to the herring family in volume of commercial landings (Table 1). In contrast to the herring family, which is often used for industrial purposes, almost all of the cod, haddock, hakes, and whiting are used for human food. In 1976, 12,116,000 metric tons (t) (26,710,000,000 pounds) of the cod family were landed worldwide as compared with 15,089,000 t (33,196,000,000 pounds) of the herring family (Food and Agriculture Organization, 1976).

Classification

Twenty-five species of fishes in the cod family, Gadidae, are listed by the American Fisheries Society (Bailey et al., 1970). They include the following: 1) Toothed cod, *Arctogadus borisovi*; 2) polar cod, *Arctogadus glacialis*; 3) Arctic cod, *Boreogadus saida*; 4) saffron cod, *Eleginus gracilis*; 5) Pacific

cod, *Gadus macrocephalus*; 6) Atlantic cod, *Gadus morhua morhua*; 7) Greenland cod, *Gadus ogac*; 8) cusk, *Brosme brosme*; 9) fourbeard rockling, *Enchelyopus cimbrius*; 10) burbot, *Lota lota*; 11) haddock, *Melanogrammus aeglefinus*; 12) silver hake (whiting), *Merluccius bilinearis*; 13) Pacific hake, *Merluccius productus*; 14) longfin hake, *Phycis chesteri*; 15) luminous hake, *Steindachneria argentea*; 16) red hake, *Urophycis chuss*; 17) Gulf hake, *Urophycis cirratus*; 18) Carolina hake, *Urophycis earlli*; 19) southern hake, *Urophycis floridanus*; 20) spotted hake, *Urophycis regius*; 21) white hake, *Urophycis tenuis*; 22) Pacific tomcod, *Microgadus proximus*; 23) Atlantic tomcod, *Microgadus tomcod*; 24) Atlantic pollock, *Pollachius virgens*; and 25) walleye (Alaska) pollock, *Theragra chalcogramma*.

Although European ichthyologists separate the hakes and the cods because of differences in the structure of the skull and ribs, some American experts group them into a single family, and they are so listed by the American Fisheries Society.

Table 1.—World commercial catch of fish by species groups, 1973-76.

Species group	Catch (1,000 t)			
	1973	1974	1975	1976
Herring, sardines, anchovies, et al.	11,314	13,888	13,618	15,089
Cods, hakes, haddock, et al.	11,970	12,699	11,882	12,116
Freshwater fishes	9,293	9,244	9,599	9,532
Miscellaneous marine and diadromous fishes	8,676	8,382	8,021	8,445
Jacks, mullets, sauries, et al.	5,740	5,454	5,935	7,389
Redfish, basses, congers, et al.	4,320	4,865	5,071	4,950

Source: "Yearbook of Fishery Statistics, 1976," FAO, Rome, Vol. 42.

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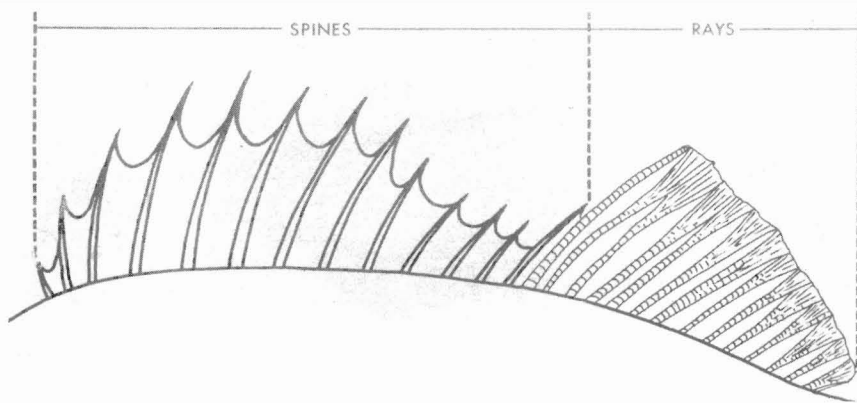


Figure 2.—Rays and spines.

The Cods

The cods, family Gadidae, are soft-finned fish lacking true spines; but in the whiting, the dorsal and anal fin rays are so stiff as to feel like spines. The cod family is distinguished from other soft-rayed fishes (Fig. 2) by the fact that the large pelvic fins are situated under or in front of the pectorals and not behind them as in salmon and herring. The cods are generally fishes of cold water, and most of them live close to the bottom.

Codfish are found on both sides of the Atlantic Ocean, in the north Pacific Ocean, and in the Arctic Ocean down to about 250 fathoms (457 m). The best cod fishing grounds are offshore banks including Georges Bank 150 miles (240 km) off Boston, Mass., and Grand Bank off Newfoundland where modern trawlers may take 35 tons of cod in only a few hours of fishing.

The most important of the cods is the Atlantic cod, which includes several geographical subspecies. These are the Baltic cod, *Gadus morhua callarias*, found in the Baltic Sea and parts of the North Sea; the Kildin Island cod, *Gadus morhua kildinensis*, which lives in a salt pond, Lake Mogilno, on an island in the Baltic Sea; and the White Sea cod, *Gadus morhua marisalbi*, found in the Arctic Sea. The Greenland cod, *Gadus ogac*, often considered a separate species, is found mostly in inlets and in the shallow water of the Arctic Ocean from West Greenland to Point Barrow,

Alaska. Additionally, the Pacific cod, *Gadus macrocephalus*, is considered by most taxonomists as a separate species.

Atlantic Cod

The Atlantic cod (Fig. 1) is oval in cross-section with three distinct dorsal fins, two anal fins, and a nearly square tail. Its color varies from olive green to reddish brown depending on the background of its habitat. The lateral line is white, and the skin has many small scales. Most cod average about 3 feet (0.9 m) in length and weigh from 10 to 25 pounds (4.5 to 11.3 kg).

A giant cod was caught by commercial fishermen off the northern Massachusetts coast on a line trawl in May 1895 (Jordan and Evermann, 1902). It measured over 6 feet (1.83 m) in length and weighed 211¼ pounds (95.8 kg). This was an old fish, but no one knows how old.

The cod is found on both sides of the North Atlantic Ocean and Arctic Ocean down to about 1,500 feet (457.2 m). Although the cod is a demersal or bottom-living fish, when in search of food it may be found near the surface. It prefers rocky, pebbly, or sandy bottoms, and water temperatures from 32° to 50°F (0° to 10°C).

The adult cod feeds mostly on smaller fish such as sand eels, *Ammodytes* sp.; capelins, *Mallotus* sp.; herrings, *Clupeidae*; and other small cod, and/or shellfish such as shrimp, mussels,

clams, crabs, and squid. When hungry, it will eat almost anything such as false teeth, old boots, and pieces of wood. At times, it eats small floating mollusks which cause its flesh to exhibit a strong odor of iodine when cooked.

Cod migrate principally because of changes in the temperature of the water, better availability of food, and the search for suitable spawning locations.

Growth rates differ from ground to ground, but the cod is a relatively fast growing fish and can theoretically live to an age of 50 years. A 1-year-old cod is usually about 7 inches (17.8 cm) long; a 2-year-old will be about 14 inches (35.6 cm); and by the end of the third year, the cod is about 22 inches (55.9 cm) long. Growth is slower in colder waters. Cod in Arctic waters reach maturity in 6-8 years at 6-8 inches (15.2-20.1 cm) in length.

The cod is one of the more prolific fishes. It has been calculated that if all the eggs spawned by all female cod in one spawning season were to survive, the oceans would be one mass of cod (Jensen, 1972). One female cod may release from 3 to 7 million eggs at a time. A 75-pound (34.0-kg) female cod can produce 9.1 million eggs. Spawning takes place in shallow (5-25 fathoms or 9.15-45.7 m) waters usually in the early spring. The eggs are buoyant and transparent without oil globule and 1/20-1/16 inch (1.27-1.59 mm) in diameter. At 43°F (6.2°C), hatching may be expected in 14 or 15 days. The newly hatched larvae feed mainly on plankton and drift with surface currents. When the larvae have grown to a length of about 3 inches (7.6 cm), they move to the ocean bottom where they feed on worms and small shrimps. Only a few eggs out of the millions spawned will survive and become mature fish.

Pacific Cod

The Pacific cod, *Gadus macrocephalus*, (Fig. 3) is also known as cod, true cod, and gray cod. In appearance and habits, it resembles its cousin, the Atlantic cod. In 1976, close to 11,900,000 pounds (5,400 t) of Pacific cod were landed in the United States with a value of \$1.5 million (Robinson,

1977). The 5-year average was 9,200,000 pounds (4,170 t) compared with 56,000,000 pounds (25,100 t) of Atlantic cod. Its head is large (i.e., *macrocephalus*), and it has three dorsal and two anal fins. Its color is brown to gray on the upper surfaces and white on the anal and caudal fins with many brown spots on the back and sides. It grows fast, reaching an average length of 3 feet 3 inches (1 m) and a weight of 35 pounds (15.9 kg) in 2 to 3 years.

Pacific cod are found in the North Pacific Ocean from California to northern Alaska and in a great arc to Korea. Spawning takes place in winter or early spring, although the spawning grounds are relatively unknown (Hart, 1973). As many as half a million eggs may be produced by each female and they hatch in 8 or 9 days at 52°F (11°C). The young fish usually migrate northward to the colder waters of Washington, Oregon, or Alaska. They mature within 2-3 years with an 8-9 year life span (Hart, 1973).

The Pacific cod's white flesh has a mild flavor and flakes easily. It is marketed as fresh and frozen fillets with some of the catch sold as whole fresh fish. The early Pacific cod fishery was handicapped by false rumors by New England dealers that it was not a true cod and that it was an inferior fish that would not keep. Upon completion of the transcontinental railroads, markets widened.

Polar Cod

The polar cod, *Boreogadus saida*, (Fig. 4) normally grows to only 6-8 inches (15.2-20.3 cm) long, but may grow to 15 inches (38.1 cm). It resembles the pollock and is found in the Arctic Ocean from Greenland to Siberia. It is circumpolar, traveling the White Sea to Spitzbergen to Iceland, Greenland, Canada, Alaska, etc. The polar cod is generally not considered important for human food. It may be distinguished from related species by a forked tail and slender body (Leim and Scott, 1966).

A cousin, the Arctic cod, *Arctogadus glacialis*, is being fished by the Norwegians for meal and oil but is of little importance as a food.

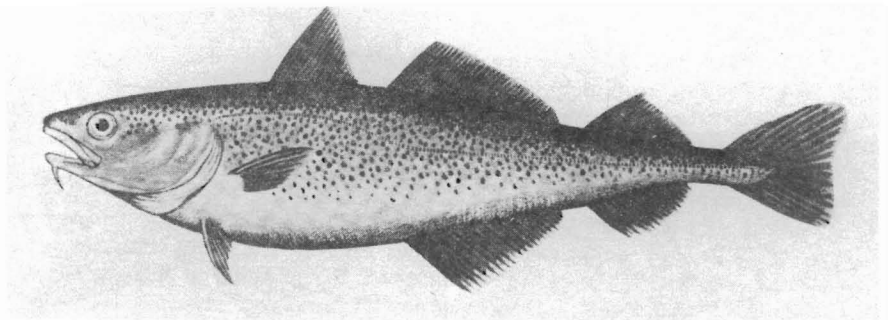


Figure 3.—Pacific cod.

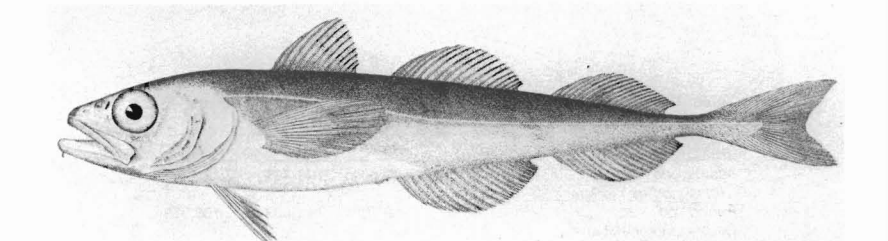


Figure 4.—Polar cod.

Greenland Cod

The Greenland cod, *Gadus ogac*, is very similar to the Atlantic cod, *Gadus morhua morhua*, in form, but it lacks the distinguishing round spots of the Atlantic cod, and its lateral line is not accompanied by a light longitudinal stripe on the tail as is the Atlantic cod. It grows to 28 inches in length and ranges from west Greenland, west to Point Barrow, Alaska, and thence along the Arctic coast east and south to the Miramichi estuary, Gulf of St. Lawrence, and Cape Breton Island (Hart, 1973). Its commercial importance is indicated by a catch of 4,642 t in 1975 (Table 2).

Haddock

The most valuable member of the cod family in the United States is the haddock, *Melanogrammus aeglefinus*, (Fig. 5). The primary distinguishing marks of the haddock are the black lateral line and sooty black shoulder blotch called the "Devil's thumb print" or "St. Peter's mark." Also, the

pointed first dorsal fin is different from that of other relatives.

Haddock are found in the North Atlantic Ocean along the coasts of Newfoundland, Nova Scotia, and the Gulf of Maine, and on Georges Bank, 150 miles (240 km) east of Massachusetts. In the northeast Atlantic, it is found off the coast of northern Europe, the British Isles, and Iceland. Haddock are bottom dwelling fish in areas where water temperatures range from 35° to 48°F (1.7° to 8.9°C). They are usually caught on an ocean bottom that is of hard, smooth sand; gravel; or broken shell. They like smooth areas between rocky patches.

Haddock in the Gulf of Maine spawn from late February until May with a peak in March and April. The haddock is a prolific fish for its size; a single fish may produce from 150,000 to 1,000,000 eggs. A 19½-inch (0.5-m) female produces 169,000 eggs; a 24-inch (0.6-m) one, 634,000 eggs; and a 28¼-inch (0.7-m) one, 1,840,000 eggs. Spawning occurs near the sea bed. The eggs of the haddock are

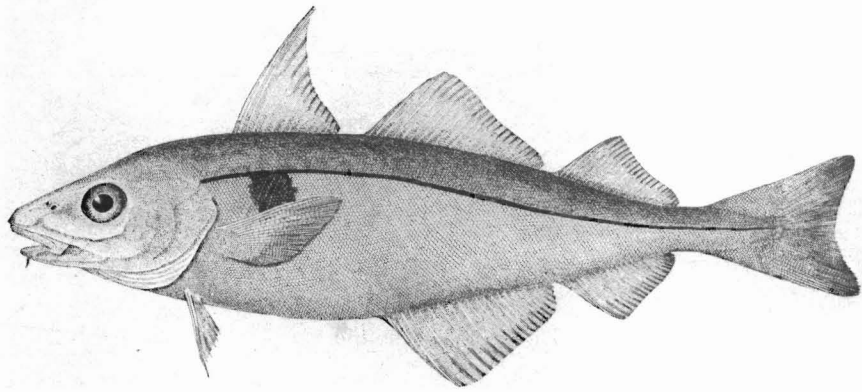


Figure 5.—Haddock.

Table 2.—World commercial catch of cod family, excluding hakes, in thousands of metric tons (live weight).

Species	1972	1973	1974	1975
Atlantic cod	2,742,700	2,540,000	2,811,495	2,422,131
<i>Gadus morhua morhua</i>				
Pacific cod	150,700	150,700	161,533	166,955
<i>Gadus macrocephalus</i>				
Greenland cod	—	1,000	3,391	4,642
<i>Gadus ogac</i>				
Polar cod	167,100	82,200	125,188	63,162
<i>Boreogadus saida</i>				
Haddock	549,200	624,900	581,488	529,132
<i>Melanogrammus aeglefinus</i>				
Pollock	653,700	662,800	716,411	680,101
<i>Pollachius virens</i>				
Alaska pollock	4,213,300	4,617,100	4,907,362	5,023,925
<i>Theragra chalcogramma</i>				
Ling	60,500	70,800	67,328	54,313
<i>Molva molva</i>				
Blue ling	8,000	11,400	9,782	12,244
<i>Molva dypterygia</i>				
Norway pout	525,100	500,400	895,499	695,388
<i>Trisopterus esmarkii</i>				
Bib	23,100	25,700	25,067	24,496
<i>Trisopterus luscus</i>				
Blue whiting	50,900	50,200	45,863	68,900
<i>Micromesistius poutassou</i>				
Atlantic tomcod	300	400	271	203
<i>Microgadus tomcod</i>				
Grenadier	7,300	3,900	14,100	37,295
<i>Macrourus</i> spp.				

Source: Food and Agriculture Organization of the United Nations, 1976.

buoyant and are found near the surface of the sea. Haddock eggs hatch in 13-24 days at 41°F (5°C), and the larvae are about $\frac{3}{16}$ of an inch (4.8 mm) long and drift with the current. The tiny haddock are nourished at first by the egg yolk and later feed on zooplankton. At about 4-5 months, the young haddock start to descend to the ocean floor where they live the rest of their lives (Bigelow and Welsh, 1924).

During its first 3 years, a haddock grows fast. A 1-year-old haddock averages $7\frac{1}{2}$ inches (19.05 cm) in length, a 2-year-old haddock measures $12\frac{1}{4}$ in-

ches (31.1 cm), and a 3-year-old haddock, 17 inches (43.2 cm). The haddock seldom grows longer than 36 inches (91.4 cm) in length or weighs over 25 pounds (11.3 kg). The haddock is a bottom feeder. Shrimp, crabs, worms, squid, and, at times, small fish form the diet for this species.

Most of the U.S. haddock catch is taken with otter trawls (Robinson, 1977). The otter trawl (Fig. 6) is a funnel-shaped net which is towed over the sea floor behind a fishing vessel. The mouth of the net is kept open by two wooden or steel otter boards—10

feet (3.0 m) long, 4 feet (1.2 m) wide, and 4 inches (10.2 cm) thick—that are rigged ahead of the net on towing warps in such a way that they behave like kites. The catch accumulates in a bag at the narrow cod end. The size of net depends upon the size and power of the vessel and the design of the gear. Some haddock are also caught with longlines, fish traps, and gill nets.

Landings of haddock in the U.S. during 1976 were only 12.8 million pounds (Robinson, 1977). From 1924 to 1966, the haddock fishery never yielded less than 100,000,000 pounds (45,000 t). Landings for a 5-year average for haddock (1971-75) were 13.2 million pounds.

Haddock are caught, handled, and processed about the same as the Atlantic cod. The haddock is used to make a number of smoked fish products such as finnan haddock and other cold smoked products such as the golden cutlet and the smoked single fillet. The chemical composition of haddock flesh is similar to that of cod.

Atlantic Pollock

The Atlantic pollock, *Pollachius virens*, (Fig. 7) also known as pollock, is another cod relative. It is dark greenish in color and usually olive or greenish gray with silver tints on the lower side. A light lateral line extends the length of the body and is in contrast to the dark sides. It has a spindle-shaped streamlined body with a forked tail. The average size is 2-3 feet (61.0-91.4 cm), and the average weight is 4-12 pounds (1.8-5.4 kg) (Bigelow and Welsh, 1925). Large pollock feed on other fish while the smaller ones feed on crustaceans.

The pollock is seldom taken at above 50°F (10°C) temperatures. Most of the pollock are caught in mid-water using high opening trawls. It is one of the most active members of the cod family. It occurs in large schools that may be found at any level between the surface of the water and the bottom.

The pollock spawns in late fall and early winter. Large pollock may produce over 4 million eggs, although the average number is about 22,000. The buoyant eggs hatch in 6 days at 50°F

(10°C) water temperature. The fish grows to 5-7 inches (12.7-17.8 cm) by the end of the first year and usually achieves 18 inches (45.7 cm) by the end of the third year.

Small pollock migrate into coastal waters in the spring and remain all summer. In the winter, they move to deeper water. Pollock often school at this time with 80 percent of the landings taken during October, November, and December.

The pollock is similar in flavor, odor, and texture to cod and haddock and is usually marketed in fillet form. It makes a good dry salt fish, and some are smoked.

Alaska Pollock

The Alaska pollock, *Theragra chalcogramma*, (Fig. 8) has become an important food fish. Pollock blocks accounted for 25 percent of all block imports in 1976. The Republic of Korea was the principal supplier of pollock blocks (61 percent of the total) followed by Japan (11 percent of the total) (Capalbo and Kinoshita, 1977).

The Alaska pollock, low in the marine food chain, feeds on planktonic crustaceans such as copepods, amphipods, and shrimp-like euphausiids. These are concentrated in the nutrient-rich, shallow waters of the continental shelf and slope. The pollock is usually mature at 3-4 years when it is about 15 inches (38.1 cm) long.

The Hakes

For many years, the hakes were considered to be trash fish. Recently, foreign vessels have started to exploit several hake species (Table 3) (Fig. 9). These include the whiting or silver hake, *Merluccius bilinearis*, (Fig. 10); the Atlantic hake, *Merluccius albidus*, found on Georges Bank and off the middle Atlantic States; and the Pacific hake, *Merluccius productus*, found in the North Pacific Ocean. In the eastern Atlantic, a close relative of the silver hake, the European hake, *Merluccius merluccius*, is found. It also occurs off North Africa in both the Atlantic Ocean and the Mediterranean Sea.

Large amounts of hake are being used for the production of fish blocks

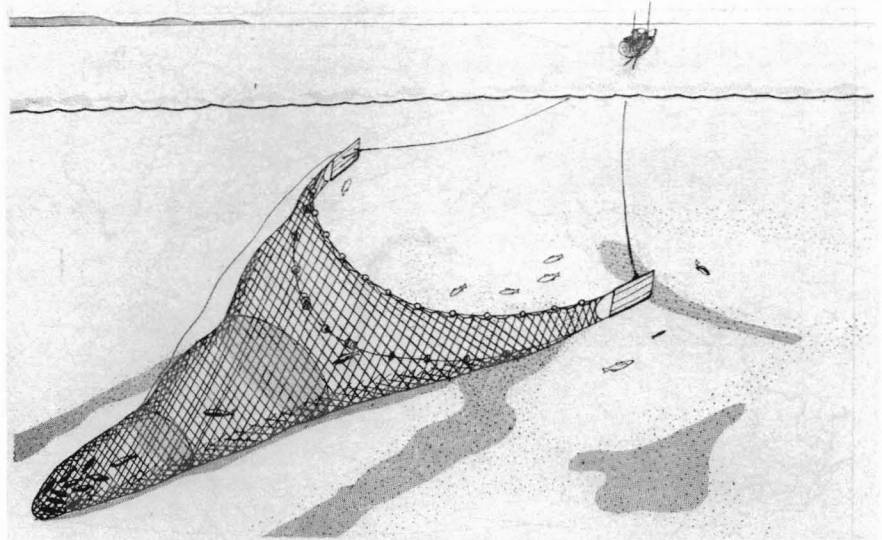


Figure 6.—Otter trawling.

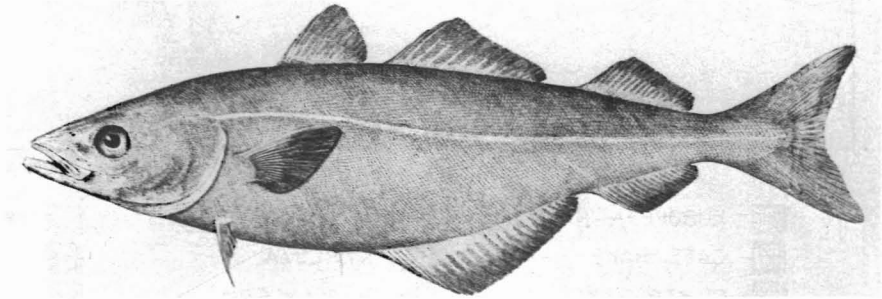


Figure 7.—Atlantic pollock.

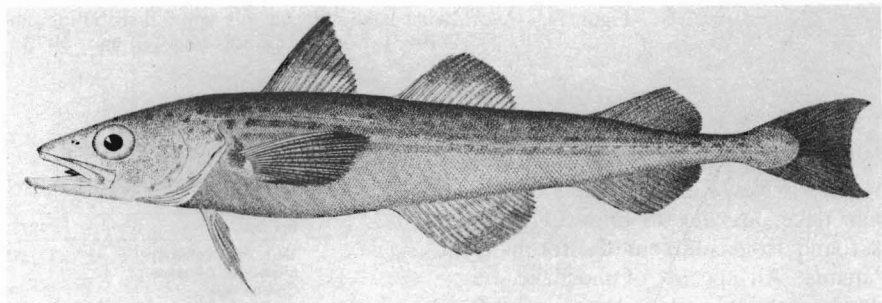
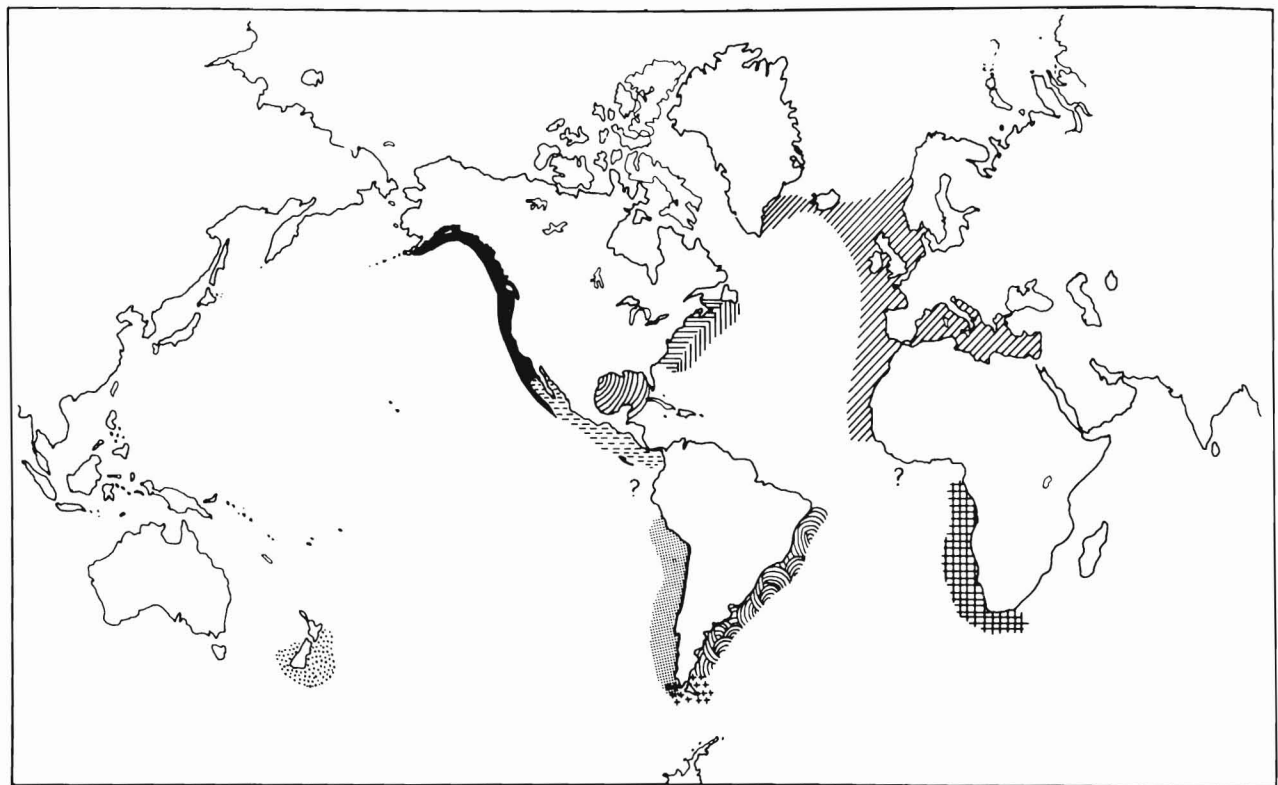


Figure 8.—Alaska or walleye pollock.

and dressed fish. South American hake, *Merluccius hubbsi*, is a resource with an estimated stock of 3,000,000 t and a possible yield of 555,000 t per year, offering an alternative to shortages of the Atlantic cod. The Chilean hake,

Merluccius gayi, is being sought by a Polish-Peruvian fishing company off the Peruvian shelf. The South African hake, *Merluccius capensis*, is another species presently under development as an alternate to Atlantic cod. The New














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|---|---------------|---|----------------------|---|------------------|
|  | EUROPEAN HAKE |  | <u>M. MAGNOCULUS</u> |  | PANAMANIAN HAKE |
|  | CAPE HAKE |  | MERLUZA |  | PACIFIC HAKE |
|  | SILVER HAKE |  | <u>M. POLYLEPIS</u> |  | NEW ZEALAND HAKE |
|  | OFFSHORE HAKE |  | CHILEAN HAKE | | |

Figure 9.—Worldwide hake, *Merluccius* spp., distribution, modified after Cabo (1965). Source: Grinols and Tillman, 1970.

Zealand hake, *Merluccius australis*, occurs off New Zealand. The Panamanian hake, *Merluccius angustimanus*, is found from southern California to Panama. All species of the hake are slender, streamlined in shape, and differ from other cod species in having two dorsal fins and one anal fin.

Otter trawl is the main fishing gear used for hake, although pound and trap nets are also used. Despite the soft texture, hakes are amenable to mechanical handling on ship or ashore.

Whiting

Whiting or silver hake, *Merluccius bilinearis* (Fig. 10), are found on the

Table 3.—World commercial catch of hakes, 1972-75, in thousands of metric tons.

Species	1972	1973	1974	1975
Silver hake (whiting)	233,000	434,900	225,625	230,529
<i>Merluccius bilinearis</i>				
Chilean hake	107,600	223,900	163,652	142,593
<i>Merluccius gayi</i>				
Argentine hake	139,300	187,500	199,400	152,400
<i>Merluccius hubbsi</i>				
Pacific hake	119,600	163,500	205,786	230,350
<i>Merluccius productus</i>				
Benguela hake	100	100	100	496
<i>Merluccius polli</i>				
European hake	116,500	129,500	131,666	136,779
<i>Merluccius merluccius</i>				
Cape hake	1,111,300	892,600	726,934	626,751
<i>Merluccius capensis</i>				
Senegalese hake	36,900	101,700	102,822	86,530
<i>Merluccius senegalensis</i>				
Red hake	76,100	66,700	36,334	32,319
<i>Urophycis chuss</i>				
White hake	21,200	18,400	18,337	19,810
<i>Urophycis tenuis</i>				

Source: Food and Agriculture Organization of the United Nations, 1975.

continental shelf from Newfoundland to South Carolina. In winter, these fish move into deeper water and go further south. Whiting are silvery over the whole body with brown or dark gray tints on the upper surface of the body. They have two dorsal fins and one anal fin with no barbel on the lower jaw. They reach a length of about 2½ feet (0.8 m) and a weight of 5 pounds (2.3 kg).

Whiting are lean, firm textured, flaky fish and are very tasty. The two major U.S. market forms are either headed and eviscerated fish or filleted. A small amount of the headed and eviscerated whiting is smoked.

Pacific Hake

Pacific hake, *Merluccius productus* (Fig. 11), are found from the Gulf of California to the Gulf of Alaska and from the surface to 491 fathoms (900 m). Most Pacific hake are from 1 to 1.5 feet (30 to 46 cm) long with a record length to about 3 feet. Their color ranges from gray to dusty brown with a brassy overtone. Because of certain deficiencies of texture of the flesh, the Pacific hake has not commanded a very large market. Recent attempts to popularize this fish may result in more widespread acceptance.

White Hake

White hake, *Urophycis tenuis*, (Fig. 12) also called Boston hake, is muddy colored or purplish brown on the back. The sides at times are bronze and the belly is grayish white or yellowish white, peppered with tiny black dots. The maximum length is about 4 feet, the weight 40 pounds, but most average no more than 5-8 pounds. There are only two dorsal fins (the second is much longer than the first), one anal fin, and the ventral fins are long and narrow. It is distributed in deep water from Newfoundland to Cape Hatteras and is usually found on soft, muddy bottoms. It feeds on small crustaceans, squid, and small fish (Bigelow and Welsh, 1925). The larger fish are usually marketed as fresh or frozen fillets, while the smaller ones are used for animal feed.

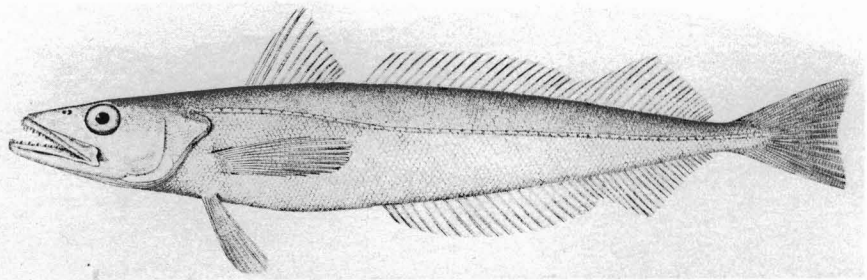


Figure 10.—Silver hake.

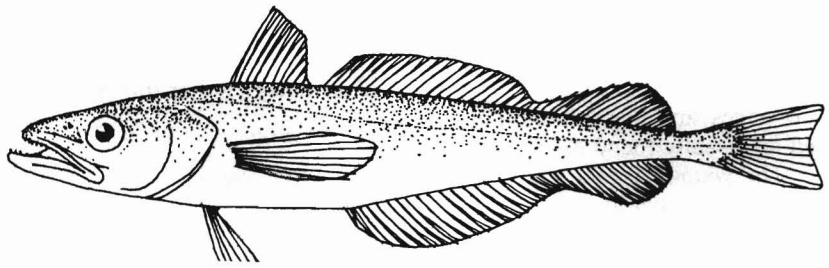


Figure 11.—Pacific hake.

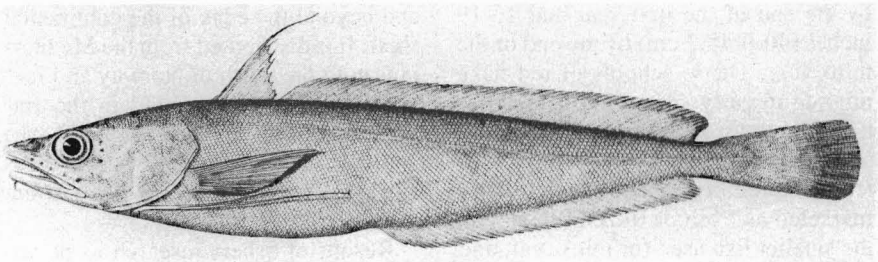


Figure 12.—White hake.

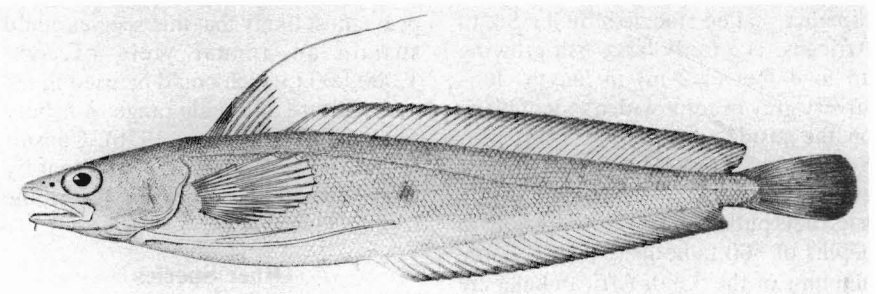


Figure 13.—Red hake.

Red Hake

The red hake, *Urophycis chuss*, (Fig. 13) usually weighs 1-3 pounds

(0.45-1.4 kg) and seldom measures over 30 inches (76.2 cm) long. It is reddish in color on the back and sides and white to yellowish on the belly.

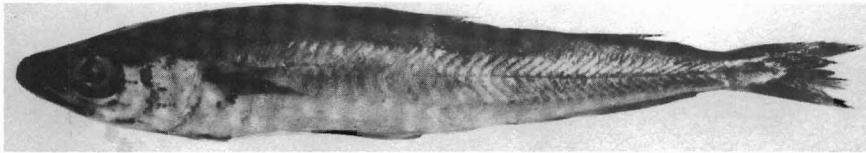


Figure 14.—Blue whiting.

Red hake is abundant off the U.S. east coast and could be used to produce fish protein concentrate. A 5-year average landing (1971-75) of red hake was 2,680,000 pounds (1,220 t) with 4,970,000 pounds (2,250 t) landed in 1976 (Robinson, 1977).

Red hakes are sluggish swimmers which are usually found over soft bottoms. The young hakes are abundant, close to shore in eel grass beds. They feed on small crustaceans, squid, and small fish (Bigelow and Welsh, 1925). Spawning usually occurs from July through September in shoal waters. Red hake grows to 8 inches (20.3 cm) by the end of the first year and 16-19 inches (40.6-48.3 cm) by the end of the third year. Dense schools of red hake migrate in early spring into shoal waters. Hakes move around less than cod and haddock and tolerate a greater temperature range. Red hake is usually marketed as fresh or frozen fillets with the smaller fish used for mink, cat, and poultry feed.

South African Hake

The South African hake, *Merluccius capensis*, called stockfish by the South Africans, is a fairly large fish growing up to 4 feet (1.2 m) in length. It is silvery gray in color with a spot of black on the inside of its lower front fins. South African hake is a bottom dweller and is usually caught by trawlers in huge nets pulled along the sea bottom in depths of 300 fathoms (549 m). Large amounts of the South African hake are made into fish blocks which are used for producing fish sticks and portions.

Argentine Hake

Argentine hake, *Merluccius hubbsi*, is usually found off the coast of Uruguay during winter (May-June). The schools then concentrate in the southern Argentina region (lat. 42° and

45°S). It has been estimated that a possible annual yield of 1,200,000,000 pounds (555,000 t) could be exported. Most of the production goes into fillet blocks, but consideration is being given to boil-in-the-bag frozen products to take advantage of superior packaging.

Blue Whiting

The blue whiting, *Micromesistius poutassou*, (Fig. 14) is also a gadoid fish and can be recognized by its bluish color, long slender shape, and lack of barbel.

Blue whiting is usually found in waters >100 fathoms (>183 m) deep on and beyond the edge of the continental shelf. It is distributed from the Mediterranean to the north of Norway and Iceland, and some are found in the Barent's Sea and off Spitzbergen. Large amounts have been found west of Britain and in the Norwegian Sea (Anonymous, 1976).

Results of fishery research work carried out so far indicate that a stock of at least several million tons of blue whiting exists in the northeast Atlantic west of the British Isles. At present, it appears most likely that this species could sustain an annual yield of over 1,000,000 t which could be used in the manufacture of a wide range of fishery products (Anonymous, 1976). Considerable research is being carried out by Great Britain to market this fish in the form of fish blocks.

Other Species

Burbot

A freshwater relative of the Atlantic cod, the burbot, *Lota lota*, is found in the Great Lakes and in smaller lakes and some rivers of the north central states and Canada. Usually, it remains in the deeper part of the water. It is a long and rather slender fish with three

whisker-like barbels. It looks more like cusk than a cod. The average size of burbot is about 15 inches (38.1 cm) long and 1 pound (454 g) in weight. The burbot also occurs in the northern part of Eurasia.

The flesh of the burbot resembles that of the cod and haddock. Salt burbot is very much like salt codfish and is very popular in Europe for its white and delicate flesh. Large quantities of burbot are marketed as pet food.

Tomcod

There are two tomcods: 1) The Atlantic tomcod, *Microgadus tomcod*, and 2) the Pacific tomcod, *Microgadus proximus*. The Atlantic tomcod, also called frost fish, looks exactly like Atlantic cod but is much smaller and has blotchier color patterns. The maximum length is about 14 inches (35.6 cm) with most 9-12 inches (22.9-30.5 cm) long.

The Pacific tomcod is found from California to Alaska. Both species live in estuaries or shallow water and are often caught by recreational fishermen. Tomcod has limited commercial use as human food because it is not abundant enough.

European Cods

Some members of the cod family which are landed in England and northern Europe are the big or whiting pout, *Trisopterus luscus*; the European whiting, *Merlangius merlangus merlangus*; the poor cod, *Trisopterus minutus minutus*; the Norway pout, *Trisopterus esmarkii*; and the fork beard, *Phycis blennoides*. The European ling, *Molva molva*, is dried as stockfish in Iceland. This species is not common to the Atlantic waters of North America (Jensen, 1972).

Fourbeard Rockling

The fourbeard rockling, *Enchelyopus cimbrius*, occurs on both sides of the North Atlantic. Color of back is brown or dark olive with a white belly dotted with brown. On the North American side, it is found from Newfoundland to New York in coastal waters and as far south as North Carolina on the continental shelf (Bigelow and Welsh, 1925). It is small, reaching a length of about 1 foot (30.5 cm). The

fourbeard rockling is a bottom dwelling fish found in depths of water from 2,000 to over 4,000 feet (610 to over 1,220 m). Its principal foods are small fishes and crustaceans. It has no economic value.

Cusk

Cusk, *Brosme brosme*, also occurs on both sides of the Atlantic (Leim and Scott, 1966). On the North American side, it is found from Newfoundland to Cape Cod and may go as far south as New Jersey. It is found in waters from 10 to 300 fathoms (18.3 to 549 m). It prefers cool water and a rough, rocky, gravelly, or pebbly bottom. Its color varies according to the bottom where the fish live: The back ranges from sooty to dull reddish brown with grayish lower sides; white dorsal, anal, and caudal fins have black margins edged narrowly with white. It is easily separated from other relatives by the fact that it has but one dorsal fin. Its average length is 1½-2½ feet (0.5-0.8 m), and the weight varies from 5 to 30 pounds (2.2 to 13.6 kg). Spawning takes place in spring and summer. Cusk feed on crustaceans and shellfish. The cusk is a good food fish marketed largely as fresh and frozen fillets in the commercial fisheries north of Cape Cod. Unlike most of the other bottom fishes, it does not school but is solitary. It is usually caught incidental to cod fishing. The European cusk (torsk) is found on the European coast, on the north coasts of the British Isles, Denmark, the northern part of the North Sea, and Kattegat to Iceland, and the Murman Coast (Leim and Scott, 1966).

False Cods

Because of the successful marketing of cod, a number of "false cods" have appeared (Jensen, 1972). These "false cods" include the sablefish, also called blackcod, *Anoplopoma fimbria*, (southern California to northwestern Alaska); the longspine channel (thornyhead) cod, *Sebastolobus altivelis*, (from Baja California, to the Aleutian Islands); the chilipepper, *Sebastes goodei*, (Baja California, to Cape Scott); the lingcod or cultus cod, *Ophiodon elongatus*, (southern Cali-

fornia to northwestern Alaska); and the bull or blue cod, *Scorpaenichthys marmoratus*, actually a sculpin whose common name is cabezon (off the Pacific coast).

Most of these species belong to the scorpion fish family, *Scorpaenidae*. The Pacific coast's sablefish has a high reputation as a smoked product. Lingcod is a member of the Hexagrammidae family, a group known as greenlings. It is highly esteemed as a food fish on the Pacific coast. It is marketed as dressed, fillets, and steaks. A large portion goes into the "fish and chips" trade.

Utilizing the Cod

Cod as Food

As a food fish, cod is very adaptable. Its flesh is nutritious without being fatty. It adapts to almost all forms of fish cookery with its meat being white and delicately flavored.

A yield of 41-45 percent is typical for machine filleted skinless cod with an average of 43 percent. On an average, the chemical composition of the Atlantic cod is as follows: Fat, 0.3 percent; protein, 17.9 percent; ash, 1.1 percent; and moisture, 81.1 percent (Sidwell, 1974).

The flesh of the cod family is rather coarse grained and low in fat because the fish store most of their fat in the liver rather than in the flesh.

As the cods usually have their gills removed from April to November and are eviscerated at sea, the best signs of freshness in eviscerated cod are firmness of flesh, odor in the belly cavity, and the condition of the eyes. If the eyes are cloudy and sunken, spoilage may be present. The appearance and odor of the slime is an indicator of freshness.

One factor that has led to the increased consumption of cod in recent years has been the rise of "fish and chips" type restaurant chains. One such restaurant chains' consumption of cod blocks is now running in excess of 9,000 t (20 million pounds). Other fast food service chains have elected to use cod rather than alternative species in their fish sandwiches. Medium priced, family style restaurants are also large

users of cod fillets and breaded portions.

Harvesting the Cod

Today, about 85 percent of the Gulf of Maine Atlantic cod catch is made by otter trawls, only about 10 percent in longlines, about 1 percent in gill nets, and less than 1 percent in pound nets or handlines (Jensen, 1972). Others are caught by traps, jiggers, and Danish seines. In 1976, 55,800,000 pounds (25,300 t) of Atlantic cod were landed in the United States (Robinson, 1977). The 5-year average (1971-75) was 53,200,000 pounds (24,100 t).

Normal cruising duration for trawlers is 7-10 days when trawling for cod and other groundfish. Fishing operations are from 4 to 7 days in duration, the average being 5 days. Fishing operations are carried out "round-the-clock" by alternating deck crews.

Handling the Catch

Aboard the vessel, the fish are removed from the water as soon as possible after catching. Trawl-caught fish are washed to remove sand, mud, or debris. They are always eviscerated to eliminate bacteria and enzymes from the intestines. Often the gills are removed between April and November, and the fish are washed again in clean water. The cod are then stored in enough crushed ice to keep them as close to 32°F (0°C) as possible. Correct icing requires a great deal of care and experience. Sufficient ice should be placed on the floor of each pen. Ample ice should be placed at the sides of the vessel and adjacent to the wing boards of each pen.

Boxing is being adopted aboard many of the progressive vessels because it can be the most satisfactory method of stowing fish in the hold. It offers the additional advantage that the fish can be landed in the same boxes and distributed without further rehandling. Boxed fish are not often crushed or bruised as shelved or bulked fish. The contents and the date of catch may be recorded on each box. The boxes may be either wooden, light plastic, or metal alloy. They are designed so that a stack of them is stable. Drainage is designed

so that the melted ice water runs to the corners of the bottom so the box will not drain into the box below. They make unloading the fish much simpler.

Selling the Catch

The fisherman's catch may be sold in a variety of ways. Fish may be sold at auction or directly to a shore plant at the prevailing auction prices. In some cases, the boats may be working under contract or be owned by a shore plant. In the Boston area, the catch is sold to the processors through the New England Fish Exchange. At the Exchange, processors are offered, through public auction, the opportunity to bid for each vessel's catch. State and Federal fish inspectors may examine the catch for condition and quality.

Once the catch has been sold, unloading of the fish is begun. The fish are hoisted out of the hold of the vessel in 100-pound (45.5-kg) capacity canvas baskets which are emptied into wooden "weigh" boxes mounted on scales. After weighing, the fish are transferred into carts, boxes, or barrels and transported to the fish plants for processing. If the fish are not processed immediately, they are iced or held in chill rooms at as close to 32°F (0°C) as possible.

The usual market classifications in the New England Fish Exchange are: Scrod, 1.5-2.5 pounds (0.7-1.1 kg); market, 2.5-10 pounds (1.1-4.5 kg); large, 10-25 pounds (4.5-11.3 kg); and extra large, over 25 pounds (> 11.3 kg).

Today the usual market forms of cod are dressed fish, steaks, skin-on fillets, and skinless fillets. Dressed and steaked cod are sold freshly iced, and the fillets are sold both fresh and frozen. The steps involved in preparing fillets consist of: 1) Washing the fish, 2) filleting the fish, 3) skinning the fillets (where applicable), and 4) washing or brining the fillets.

Processing

In processing, the fish are first washed with cold potable water or chlorinated seawater to remove slime, blood, and ice. The washed fish are then carried by conveyor belt to the

filleting area where filleting operations are done by hand or, in the more modern plants, by automatic machinery. After filleting, the fillets may or may not be skinned. If the fillets are skinned, the skin is removed either by hand or by automatic machinery. The fillets are then conveyed on a moving belt to a tank containing brine or water for washing the fillets. Brine, when used, is normally 10-15 degrees salometer. After brining or dipping in water, the fillets are drained on an inclined conveyor belt and conveyed to the packing tables where they are inspected for blemishes.

Fillets

Fillets used in retail trade are placed in either 12-ounce (0.3-kg) or 1-pound (0.45-kg) telescoping cartons which in turn are overwrapped with heat-sealable, moisture-vapor-proof material. Fillets used for the institutional trade are wrapped in approximately 1-pound (454-g) packages using a transparent innerwrap of cellophane or its equivalent and which are, in turn, packed into 5- or 10-pound (2.3- or 4.5-kg) wax cardboard master cartons. Slack fill is avoided during packaging, since the presence of voids will contribute to a loss of quality during frozen storage.

The packaged fillets are blast frozen in air or are plate frozen; the latter method is more common and results in a better looking packaged product. In the plate freezer, the filled packages are placed in metal trays which, in turn, are inserted between two refrigerated plates. When the freezer is loaded, the refrigerated plates are hydraulically lowered so that contact is maintained between the top and bottom of the packages and the refrigerated plates during the freezing period. Suitable spacers are used between plates to maintain sufficient space between cartons to prevent their being crushed during freezing. After freezing, the packages of frozen fillets are packed in master cardboard cartons and placed in frozen storage. To prevent rapid loss in quality during storage, a temperature of less than 0°F (-18°C) should be maintained until the fillets, as well as all other fishery products, are delivered to

the consumer at the retail market. Freezer storage temperatures above 0°F (-18°C) result in a rapid loss in quality due to toughening and rancidity.

Fish Fillet Blocks

A large portion of the foreign cod caught is imported for the production of fish sticks and portions. Fish fillet blocks are prepared by placing the boneless and usually skinless fillets in a fiberboard container either parallel or perpendicular to the long axis of the container. The thick part of the fillet is placed adjacent to the edge of the container, and the thin portion is placed in the center. The depression is filled up with fillets until the desired weight is obtained. The most popular weights of fish blocks are 13.5 pounds (6.1 kg), 16.5 pounds (7.5 kg), and 18.5 pounds (8.4 kg). For freezing, the blocks are put into a tray and placed into a multi-plate compression freezer with spacers slightly smaller in depth. This causes a slight compression which smooths out the surface and fuses the fillets into a single block.

The fish blocks are further processed by cutting with a band saw or gang saw (series of circular saw blades on a single axis) or by shearing with a guillotine-type machine into fish sticks or larger fish portions in sizes between 1.5 and 5 ounces (43 and 142.0 g). These sticks or portions are covered with a liquid batter and then dusted with bread crumbs. Recently, a new processing technique using a tempura-type batter as the sole covering has been quite successful. Tempura is a viscous batter which is applied over a flour or dry batter base and then fried. The batter and breading ingredients are usually supplied by specialty manufacturers of these items. Following battering and breading, the sticks and portions may be heated in oil at about 375°F (190.6°C) for 30 seconds or less. Following this operation, the sticks and portions are cooled and may be either individually frozen and packaged or packaged and frozen in a plate freezer. As is done with the frozen cod fillets, a storage temperature of at least 0°F (-18°C) should be maintained to retain the quality of the sticks and portions.

Salted Cod

Although the amount of salted fish produced in the United States is very small, imported salt-dried cod is still used as such or as fish cakes. Salt-dried fish is normally prepared by heading the eviscerated fish and splitting it open to the tail. After removing the backbone, the fish are washed and the black lining is removed. The washed fish are salted flesh side up either in a large barrel or piled on a solid floor (kench). The fish are laid in piles with layers of salt in between until the top layer of fish is reached, which is placed skin side up.

Salt content of cod varies from 4 percent for a very lightly salted product with a curing time of 2 days to 20 percent for a heavily salted product cured for about 21 days. The heavily cured salt cod is usually dried to about 40 percent moisture content. At low temperatures of 32°-40°F (0°-4.41°C) no bacterial spoilage in hard cures may be noticed for years. With lighter cures, storage at chill temperatures is essential.

The traditional method of drying was to expose the fish to sun and wind, usually on frames known as flakes. As this method is slow, artificial drying became popular. The most suitable air temperature is 75°F (23.9°C) with a range of 60°-80°F (15.6°-26.7°C). Relative humidity of the dryers should be 50-55 percent as dried salt fish absorbs water at relative humidities above 76 percent. Salt cod, after drying, is often skinned and boned by hand and packaged in small wooden boxes or plastic films in 1-pound portions.

A new rapid salt-curing technique has been developed at the Gloucester Laboratory (Northeast Fisheries Center, NMFS) which produces a salt-cured fish in less than 8 hours (Mendelsohn, 1974). It involves grinding the fish to increase the surface area exposed for salting. After grinding, the fish is covered immediately with brine so exposure to oxygen is almost obviated. Additional salt to maintain saturation is used so salting takes place throughout the ground fish. Drying is aided by the small particle size of the ground fish which also simplifies the reconstitution of the dried product.

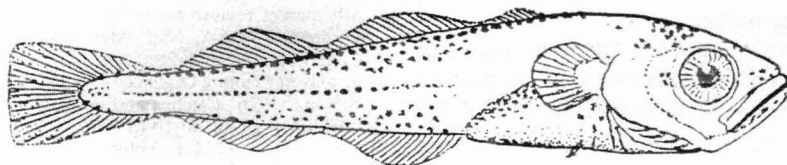


Figure 15.—Fry of Atlantic cod.

Fish Cakes

Fish cakes are prepared by soaking salt cod in cold water. The water is drained off, and the fish boiled with fresh water with about double the weight of potatoes. Beaten eggs, butter or margarine, diced onions, and pepper are added, and the mixture is formed into cakes, rolled in bread crumbs, and deep-fat fried until light brown. The fish cakes are cooled on trays, then packaged in cold-waxed cartons using waxed paper separators. The cartons are closed, then overwrapped and frozen in a plate or blast freezer. After freezing, the cartons are packed in corrugated containers for storage or shipment.

Smoked Cod

For smoking, cod fillets are normally skinned and brined in a 70-80 percent brine for 4-10 minutes depending upon size. The brined fish are allowed to stand and drip before smoking. The smoking time varies from 2 to 5 hours according to size. The temperature of the kilns is usually controlled at 80°F (27°C).

Codworm

On the Atlantic coast, the nematode *Porracaecum decipiens*, called "codworm," is often found in cod, but it may also be found in hake, flounders, and ocean perch. Generally, the infestation incidence of codworm is high in inshore areas sometimes with over 50 percent of the cod infested. The number of parasites per fish is much larger in inshore fish than in fish caught offshore. Codworm larvae range from ¼ inch to 3½ inches (6.35 to 88.9 mm) in length and are white to reddish brown in color. The larvae are usually found

burrowed into the muscle of the fillet. Candling—placing the fish fillet on a glass plate with a strong light below—is the best method of detecting the codworms. The parasite can be removed with tweezers or by cutting it out with a knife.

The life cycle of the codworm is as follows: Adult worms lay eggs in the intestines of the harbor seal, *Phoca vitulina*, or gray seal, *Halichoerus gryphus*, which then pass through the seal feces into the ocean. The eggs hatch, and the larvae are eaten by an invertebrate such as a shrimp which is then eaten by fish. In the larval form, the codworm cannot reproduce. When fish infested with these larvae are eaten by a seal, the worms mature and complete the cycle. These parasites are not harmful to humans but are considered aesthetically objectionable.

Conservation

As early as the 16th century, English fishermen complained about mesh sizes in the rough trawl nets used by other fishermen. In 1558, Queen Elizabeth I published a Royal Decree giving a minimum limit of 2½ inches (6.4 cm) mesh size. It was recognized early that trawl nets, while quite efficient, tended to catch many unmarketable, small-sized fish which represented a waste.

Early work of the U.S. Fish Commission was concentrated on increasing the number of cod in the sea by artificial propagation. Cod were first raised at Gloucester, Mass., during the winter of 1878-79. Additional hatcheries were built in Boothbay Harbor, Maine, and Woods Hole, Mass. At the Gloucester station, 217 million cod eggs were fertilized. The fertilized eggs were moved to hatching trays for further development. The newly hatched fry (Fig. 15)

were taken from the traps and released in the harbor.

The Woods Hole hatchery continued its work until World War II, but the hatcheries at Gloucester and Boothbay Harbor ended earlier.

Following the conclusion of many tagging experiments in Europe and North America and a trawling study of Georges Bank by David Belding, it was found that 14.3 percent of the cod caught in the otter trawl had to be discarded because of their small size (Jensen, 1972). Further tests by the U.S. Bureau of Fisheries found that 40 percent by weight of immature cod were caught in the otter trawl.

After widespread research by fishery scientists, a regulation was implemented banning the use of trawl nets with a mesh size smaller than 4½ inches in the cod and haddock fisheries. This mesh regulation was adopted by the International Commission for the Northwest Atlantic Fisheries composed of Canada and 11 European countries.

The establishment of 200-mile limits and their control by systems of quotas will result in the conservation of the key species of fish in the North Atlantic and Pacific fisheries, i.e., such species as cod, haddock, whiting, and pollock.

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