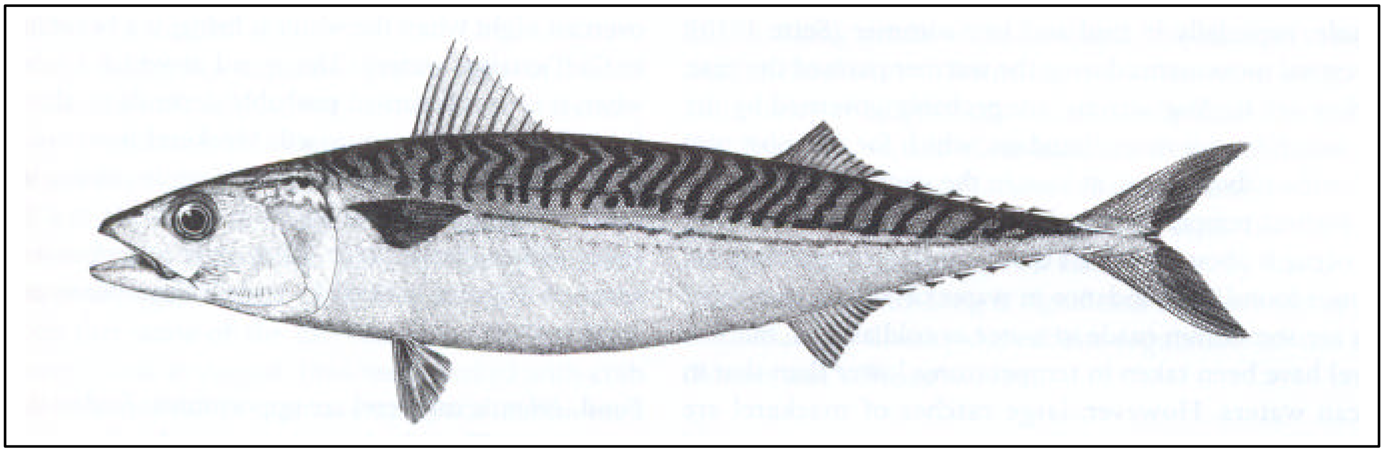
ATLANTIC MACKEREL / ***Scomber scombrus*** **Linnaeus 17;8** / Bigelow and Schroeder 1953:317-333



Description. Body fusiform, tapering rearward to a very slim caudal peduncle and forward to a pointed snout (Fig. 271). Body 4.5-5.5 times as long as deep, oval in section, thick, and firm-muscled. Head long, one-quarter length to caudal. Mouth large, gaping back to middle of eye. Jaws of equal length, armed with small, sharp, slender teeth. Eye large, hollows in front of and behind it filled with so-called "adipose eyelid," two transparent, gelatinous masses, an anterior and a posterior, which cover eye except for a perpendicular slit over pupil. Two medium-sized dorsal fins: first originating over middle of pectoral fin when latter laid back, triangular, of rather weak spines that can be laid down in deep groove along midline of back; second dorsal separated from first by interspace longer than length of latter, smaller, followed by five small finlets. Anal fm similar to second dorsal in shape and size, originates slightly behind it, followed by five small finlets that correspond to dorsal finlets in size and shape. Caudal fin broad, short, deeply forked. Caudal peduncle bears two small longitudinal keels on either side but lacks the median lateral keel characteristic of Spanish mackerels and tunas. Pelvic fins small, originating below origin of first dorsal fin. Scales so small that skin feels velvety; hardly visible on belly without magnification. Scales around pectoral fins and on shoulders somewhat larger, forming poorly developed corselet.

Meristics. Dorsal fin rays XI-XIII, 9-15 (usually 12) + 5 finlets; anal fin preceded by small but distinct anal spine, anal fin rays 1,11 or 12 + 5 finlets; pectoral fin rays 20-22; 21-28 interneural bones under first dorsal fin; gill rakers 30-36 on lower limb of first gill arch; vertebrae 13 + 18 = 31 (Collette and Nauen 1983).

Color. Upper surface dark steely to greenish blue, often almost blue-black on the head. Body barred with 23-33 (usually 27-30) dark transverse bands that run down in an irregular wavy course nearly to the midlevel of the body, below which there is a narrow dark streak running along each side from pectoral to tail. Pectoral fins black or dusky at the base, the dorsal and caudal fins gray or dusky. Jaws and gill covers silvery. Lower parts of the sides white with silvery, coppery, or brassy reflections and iridescence; the belly is silvery white. The iridescent colors fade so rapidly after death that a dead fish gives little idea of the brilliance of a live one.

Size. Reach 56 cm FL; common to 30 cm. Most adult fish are 35-46 cm long. The all-tackle angling record is a 1.20-kg fish caught in Kraakvaag Fjord, Norway, in June 1992 (IGFA 2001). Fish about 35 cm weigh about 0.5 kg in the spring and about 0.6 kg in the fall when they are fat; 46-cm fish weigh about 1 kg; a 56-cm mackerel would likely weigh 2 kg.

Distinctions. Atlantic mackerel differ from Atlantic chub mackerel in lacking spots below the midline, in having the space between the end of the first dorsal fin groove and the origin of the second dorsal fin clearly longer than the length of the groove, in lacking a swim bladder, and in having 13 instead of 14 precaudal vertebrae.

Habits. Atlantic mackerel are fish of the open sea; although numbers of them, small ones especially, often enter estuaries and harbors in search of food, they never run up into freshwater. Neither are they directly dependent either on the coastline or on the bottom in any way at any stage in their lives. They are often encountered far out over outer parts of the continental shelf. They are most numerous within the inner half of the continental shelf during the fishing season and, unlike their tuna and bonito relatives, their normal range seems not to extend oceanward beyond the upper part of the continental slope. The depth range of Atlantic mackerel is from the surface down to perhaps 183 m at one season or another. From spring through summer and well into the autumn, mackerel are in upper water layers mostly shoaler than 46-55 m; schools of all sizes come to the surface more or less regularly. They frequently disappear from the surface, often for considerable periods. Larger fish tend to swim deeper than smaller ones, on the whole, especially in mid and late summer (Sene 1950). Their vertical movements during the warmer parts of the year, when they are feeding actively; are probably governed by the level at which food is most abundant, which for the most part is shoaler than about 91 m, at least in the western Atlantic.

The highest temperature at which Atlantic mackerel commonly occur is about 20°C. At the opposite extreme they are sometimes found in abundance in water of 8°C; commercial catches are sometimes made in water as cold as 7°C, but few mackerel have been taken in temperatures lower than that in American waters. However, large catches of mackerel are made by trawlers in the North Sea in winter in water as cold as 6°-7°C.

The Gulf of St. Lawrence (where ice sometimes forms), outer Nova Scotian waters, and the upper 36 m or so within the Gulf of Maine, which chill to 2 o--4 ° C or colder, are all too cold by late winter for Atlantic mackerel. In most years this is also true of the inner part of the continental shelf as a whole, and south as far as northern Virginia, for the water usually cools there to 3°--4°C at the time of the winter minimum. Atlantic mackerel need only move out to the so-called warm zone at the outer edge of the shelf to find a more suitable environment, for the bottom water there is warmer than 7°-8°C year-round as far north and east as the central part of Georges Bank and about 5°C along outer Nova Scotia.

Mackerel are swift-moving, swimming with very short sidewise movements of the rear part of the body and the powerful caudal fin. When caught they beat a rapid tattoo with their tails on the bottom of the boat until exhausted. They require so much oxygen for their vital processes that when the water is warm (hence its oxygen content low), they must swim constantly to bring a sufficient flow of water to their gill filaments.

Mackerel, like herring, gather in dense schools of many thousands. Members of any given school are usually all about the same size, that is, the same age. This tendency to separate according to size is probably due to the fact that larger fish swim faster than smaller ones (Sette 1950). Mackerel school by themselves, as a rule, but they are sometimes found mingled with herring, alewife, or shad (Kendall1910:287). Schools of mackerel are often seen at the surface. In the daytime they can be recognized by the appearance of the ripple they make, for this is less compact than that made either by herring or by menhaden. Mackerel do not ordinarily "fin" or raise their noses above the surface, as is the common habit of menhaden. An observer at masthead height might see a school of mackerel as deep as 14-18 m by day; if the water is calm and the sun is behind him. On dark nights the schools are likely to be betrayed by the "firing" of the water, caused by the luminescence of the tiny organisms that they disturb in their progress. Sette (1950:267) reported one case of a school recognized by its firing as deep as 46 m, but the water is seldom (if ever) clear enough in the Gulf of Maine for a submerged light more than 27 m down to be visible from above. The trail of bluish light left behind by individual fish as they dart to one side or the other, while one rows or sails through a school on a moonless, overcast night when the water is firing, is a beautiful spectacle in Gulf coastal waters. The speed at which a school travels when it is not disturbed probably depends on the size of the fish of which it is composed. Mackerel less than 1 year old swim at about 11 km.h-l (3 m.s-l) while circling inside a live car; yearlings at a rate of about 21 km.h-l (6 m.s-l), or nearly twice as fast (Sette 1950). They have a preferred swimming speed of between 0.9 and 3.5 body lengths per second (Wardle and He 1988).

Food. Atlantic mackerel are opportunistic feeders that swallow prey whole. Their food consists primarily of zooplankters captured by active pursuit of individual animals or by passive filtering (Pepin et al. 1988). Practically all floating animals that are neither too large nor too small regularly serve to nourish mackerel, and a dietary listing for any given locality would include all the local pelagic Crustacea and their larvae. The diet of Atlantic mackerel changes markedly during ontogeny (Peterson and Ausubel1984; Fortier and Villeneuve 1996). First-feeding larvae (3.5 mm in length) are phytophagous. The diet of larvae 4.5 mrn is composed of nauplii of *Acartia hudsonica, remora longicornis,* and *Pseudocalanus* sp. Larvae larger than 5 mm eat copepodites of *A. hudsonica* and 1: *longicornis* and smaller proportions of phytoplankton and copepod nauplii, and when larger than 6.5 mm add conspecifics and other fish larvae to their diet. Larval fish prey (Fortier and Villeneuve 1996) include conspecifics (66%), yellowtail flounder (18%), silver hake (12%), and redfish (4%) larvae. Stomach content weight averages 1.8% of an individual's body weight. In order to satisfy its daily energy requirement, a mackerel larva consumes 25-75% of its body weight per day. The diet of young mackerel is much the same in the English Channel (Lebour 1920).

Young fish depend more and more upon larger prey as they grow. Juveniles eat mostly small crustaceans such as copepods, amphipods, mysid shrimps, and decapod larvae. They also take large quantities of small pelagic mollusks *(Limacina* and *Clione)* when available. A series of small fish examined by Vinal Edwards contained copepods, shrimps, crustacean and molluscan larvae, annelid worms, appendicularians, squid, fish eggs, and fish fry such as herring, silversides, and sand lance.

Adults continue to feed on the same food as juveniles, but their diet also includes a wider assortment of organisms and larger prey items. For example, euphausiid, pandalid, and crangonid shrimps are common prey; chaetognaths, larvaceans, pelagic polychaetes, and the larvae of many different marine species have also been identified in mackerel stomachs.

Larger prey such as squids *(Loligo)* and fishes (silver hake, sand lance, herring, hakes, and sculpins) are not uncommon, especially in large mackerel (Bowman et al. 1984). Analysis of stomach contents of 3,617 mackerel gathered during 1963- 1983 in waters off the northeastern United States showed that the types of prey eaten by Atlantic mackerel vary enormously depending on the year, the season, and the area (Bowman et aI. 1984). Copepods, amphipods, and euphausiids can be considered staples in their diet but other prey types are taken whenever they are available.

Bigelow and Schroeder examined many Gulf of Maine mackerel packed full of *Calanus,* the "red feed" or "cayenne" of fishermen, as well as with other copepods. Mackerel also feed greedily; as do herring, on euphausiid shrimps, especially in the northeastern part of the Gulf, where these crustaceans come to the surface in abundance. Various other planktonic animals also enter regularly into their diet. Kendall wrote in his field notes that some of the fish caught on the northern part of Georges Bank in August 1896 were packed with crab larvae and others were full of sagitta, amphipods *(Euthemisto),* small copepods *(remora),* or red feed *(Calanus),* so that even fish from the same school had selected members of the drifting community in varying proportions. Similarly; 1,000 mackerel caught near Woods Hole from June to August contained pelagic amphipods *(Euthemisto),* copepods, squid, and sand lance; others taken off No Mans Land have been found full of shelled pteropods *(Limacina).*

Mackerel have often been seen to bite the centers out of large medusae, but they probably do this for the amphipods *(Hyperia)* that live commensal within the cavities of the jellyfish, not for the jellyfish themselves (Nilsson 1914). Under laboratory conditions, mackerel feed on *Aglantha digitale,* a small transparent medusa common in temperate and boreal waters (Runge et al. 1987).

Most authors describe mackerel as feeding by two methods: either by filtering smaller pelagic organisms from the water using their gill rakers or by selecting individual animals by sight. Mackerel have long rakers with spines on the foremost gill arch only; and these are not fine enough to retain the smallest organisms (see Bigelow 1926: Fig. 42C,D for photographs of the gill rakers). Much discussion has centered on the relative serviceability of these two methods of feeding. It is not yet known how small an object a fish is able to

select; they do take fish individually; as well as such large Crustacea as euphausiid shrimps and amphipods, just as herring do, and also larger copepods, to judge from the fact that mackerel stomachs are often full of *Calanus* or of one or two other sorts in localities where indiscriminate feeding would yield them a variety. Whether they select smaller copepods and crustacean larvae is not so clear.
In laboratory experiments, adult mackerel acclimated at 17.5°C cleared their stomachs of fish (silverside, *Menidia menidia)* in approximately 38 h independent of ration size or body weight (Lambert 1985). Assimilation efficiency was high.

Predators. Mackerel fall prey to all the larger predacious sea animals. Whales, porpoises, sharks, tunas, bonito, bluefish, and striped bass take a heavy toll. Atlantic cod often eat small mackerel; squid destroy great numbers of young fish less than 10 or 13 cm long, and seabirds of various kinds follow and prey upon the schools when these are at the surface. Other predators include bigeye thresher, thresher, shortfin mako, tiger, blue, spiny dogfish, and dusky sharks, thorny and winter skates, silver, red, and white hakes, pollock, goosefish, weakfish, and king mackerel (Maurer and Bowman 1975; Bowman and Michaels 1984; Rountree 1999; Bowman et al. 2000). Summaries of NEFSC food habits data indicate that spiny dogfish, Atlantic cod, and silver hake are the most important fish predators on Atlantic mackerel (Langton and Bowman 1980; Bowman and Michaels 1984; Bowman et al. 1984; Overholtz et al. 1991a; Rountree 1999). Cannibalism by larval Atlantic mackerel 3-14 mm long is significant but does not appear to contribute to density-dependent regulation of the species (Fortier and Villeneuve 1996).

Parasites. One species of parasitic copepod, *Caligus pelamydis*, is found on Atlantic mackerel (Cressey et al. 1983). A considerable list of parasitic worms, both round and trematode, are known to infest the digestive tract of mackerel.

Breeding Habits. Median lengths at maturity of female and male Atlantic mackerel from the northeast coast of the United States were 25.7 and 26.0 cm FL, respectively (O'Brien et al. 1993). Median age at maturity was 1.9 years for both sexes. Mackerel sampled in Newfoundland waters had higher median lengths at first maturity: 34 cm for females and 35 cm for males (Moores et al. 1975).
Spawning of Atlantic mackerel in the northwest Atlantic occurs from April to August and progresses from south to north as surface waters warm and the fish migrate (Sette 1943). There are two spawning contingents. The southern contingent spawns from April to July in the Mid-Atlantic Bight and the Gulf of Maine and the northern contingent spawns in the southern Gulf of St. Lawrence in June and July (Berrien 1982; Morse et al. 1987; O'Brien et al. 1993).
Most spawn in the shoreward half of continental shelf waters, although some spawning extends to the shelf edge and beyond (Berrien 1982: Map 12; Morse et al. 1987: Fig. 16; Berrien and Sibunka 1999: Fig. 79). Available data point to the oceanic bight between Chesapeake Bay and southern New England as the most productive area, the Gulf of St. Lawrence as considerably less so, and the Gulf of Maine and coast of outer Nova Scotia as ranking third (Sette 1950:158-164; Morse et al. 1987). Maximum concentrations of Atlantic mackerel eggs in the Gulf of Maine occur in May and June (Berrien and Sibunka 1999: Fig. 79).

Mackerel do not begin spawning until the water has warmed to about 8°C, with the chief production of eggs taking place at temperatures of 9°-14°C, so the spawning season is progressively later, following the coast from south to north.

Thus the chief production takes place as early as mid-April off Chesapeake Bay; during May off New Jersey; in June off southern Massachusetts and in the region of Massachusetts Bay; through June off outer Nova Scotia; and from late June through early July on the southern side of the Gulf of St. Lawrence, where eggs have been taken from early June to mid-August (Sette 1943:158-163).
It seems from the relative numbers of eggs that Cape Cod Bay is the only subdivision of the Gulf that has rivaled the more southern spawning grounds in egg production during the particular years that intensive studies were done. Subsequent information and especially the results of early tow-nettings on the southern grounds (Sette 1943) have shown that the Gulf of Maine as a whole is much less productive than the more southern spawning grounds, not more so as Bigelow and Welsh (1925:206) believed. Mackerel also spawn to some extent northward, as far as Casco Bay, but Bigelow and Schroeder believed very few do so farther east than along the coast of Maine. It is also unlikely that mackerel breed successfully in the northern side of the Bay of Fundy; as neither eggs nor larvae have been taken there; however, some production may take place on the Nova Scotian side, as Huntsman reported eggs at the mouth of the Annapolis River. While a moderate amount of spawning takes place along the outer coast of Nova Scotia (Sparks 1929), it seems that the eggs do not hatch at the low temperatures prevailing there, for no larvae have been found. But the southern side of the Gulf of St. Lawrence, where the surface waters warm to a high temperature in summer, is an extremely productive spawning ground.
Estimates of fecundity range from 285,000 to 1.98 million eggs for southern contingent mackerel between 307 and 438 mm FL (Morse 1980). Analyses of egg diameter frequencies indicate that mackerel spawn between five and seven batches of eggs per year.

Early Life History. The eggs are 1.09-1.39 mm in diameter, have one oil globule 0.19-0.53 mm in diameter, and generally float in the surface water layer above the thermocline or in the upper 10-15 m (Berrien 1975, 1982; Markle and Frost 1985). Incubation depends primarily on temperature; it takes 7.5 days at 11°C,5.5 days at 13°C, and 4 days at 16°C (Worley 1933).
Newly hatched larvae are 3.1-3.3 mm long and have a large yolk sac. Numerous black pigment cells are scattered over the head, trunk, and oil globule. The yolk is absorbed and the mouth formed, teeth are visible, and the first traces of the caudal fin rays form by the time the larva is about 6 mm long. Rays of the second dorsal, anal, and pelvic fins appear at about 9 mm TL and those of the first dorsal when the larva is about 14-15 mm. Dorsal and anal finlets are distinguishable in fry of 22 mm, and the caudal fin has begun to assume its lunate shape, but the head and eyes are still relatively much larger than in the adult, the snout blunter, and the teeth longer. Studies on development were summarized by Fritzsche (1978:116-120). At 50 mm, little mackerel resemble their parents so closely that their identity is evident. Late-stage eggs and early yolk-sac larvae have fewer melanophores on the yolk surface than s. *colias*, and larvae during and at the end of yolk absorption have several dorsal trunk

melanophores, whereas few s. *scombrus* at this stage have any such pigmentation (Berrien 1975, 1978).

Age and Growth. Aging methods for Atlantic mackerel were first described for mackerel from the English Channel and Celtic Sea (Steven 1952). Growth patterns on mackerel otoliths are not as complex as those of some other fish species but older mackerel (>10 years) can be difficult to age because annuli are extremely thin and closely spaced near the edge of the otolith (Dery 1988b). Calculated growth curves and von Bertalanffy growth parameters from several previous studies were compared by Anderson and Paciorkowski (1980). A length-at-age graph is presented in Fig. 272.

Atlantic mackerel are about 3 mm long at hatching, grow to about 50 mm in 2 months, and reach approximately 20 cm in December, near the end of their first year of growth (Berrien 1982). Gulf mackerel run about 25-28 cm long in spring and early summer of their second year of growth (known then as tinkers). The brood of 1923 averaged almost 36 cm in their third autumn, about 38 cm in their fourth year, about 39 cm in their fifth, about 40 cm in their sixth, 41 cm in their seventh, and about 42 cm in their eighth year. Fish 10-13 years old reach a length of 39-40 cm. Thus American mackerel, like European, grow very slowly after their third summer, although they are long-lived. The two sexes grow about equally fast.

MacKay (1967) studied growth in several year-classes of Atlantic mackerel in Canada and theorized that growth is population density--dependent; that is, abundant year-classes grow more slowly than less abundant year-classes. Moores et al. (1975) did not find this relationship for the same year-classes of Newfoundland fish. Overholtz (1989) found the 1982 cohort to be one of the slowest growing on record and it is also one of the largest recruiting year-classes that has been observed. Early growth may be related to year-class size, whereas stock size may be more influential after juveniles join adults further offshore.

General Range. North Atlantic Ocean, including the Baltic Sea; eastern Atlantic including the Mediterranean and Black seas; and western Atlantic from Black Island, Labrador (Parsons 1970) to Cape Lookout, N.C. (Collette and Nauen 1983:59).

Occurrence in the Gulf of Maine. Once mackerel enter the Gulf, schools are to be expected anywhere around its coastal belt and on Nantucket Shoals, the western part of Georges Bank, and Browns Bank (Map 32). Their presence in the Gulf is closely related to seasonal movements for this is a migratory fish, appearing at the surface and near the coasts in spring and vanishing late in the autumn. There has been much discussion as to whether the main bodies of mackerel merely sink when they leave the coast in autumn and move directly out to the nearest deep water or whether they combine their offshore and onshore journeys with extensive north and south migrations. The literature dealing with this subject is extensive (see Goode et al. 1884; Tracy 1907; Sene 1950:268-313; Berrien 1982). Most mackerel withdraw from the coast by the end of December, not only from the Gulf of St. Lawrence, but also from the entire inshore belt, not to be seen there again until the following spring or early summer.

Migrations. Based on separation of spawning areas, tagging studies, and the size and age composition of commercial catches, Sette (1950) described northern and southern population contingents with different spring and autumn migration patterns and summer distributions. Apparent mixing of the two contingents during migrations led him to suggest that they may not be genetically distinct. Subsequent biochemical and meristic studies did not detect significant genetic differences between the two groups (MacKay 1967; MacKay and Garside 1969). However, there are significant genetic differences between Atlantic mackerel from the eastern and the western Atlantic (Scoles et al. 1998).

Atlantic mackerel apparently overwinter in moderately deep water, 70-200 m, along the continental shelf from Sable Island Bank, off Nova Scotia, to the Chesapeake Bay region (Sette 1950; Leim and Scott 1966; MacKay 1967). In spring there is a general inshore, then northeastward migration, and in autumn the pattern is reversed (Berrien 1982: Map 44).

The southern contingent begins the spring spawning migradon by moving inshore between Delaware Bay and Cape Hatteras, usually between mid-March and mid-April. They then move northeast along the coast, continually joined by schools from the northern contingent also moving inshore. The overwintering area and timing of spring migration varies from year to year, probably owing to differences in the water temperature and rate of warming. Peak spawning takes place off New Jersey and Long Island in late April and May; By early June, schools are off southern Massachusetts and by later in June and July have moved to the western side of the Gulf of Maine, where they remain for the summer. The southern contingent leaves the Gulf of Maine in October and returns to deep water to overwinter, apparently near the shelf edge, where the bottom temperature is above 7°C, probably between Long Island and Chesapeake Bay (Sette 1950; Berrien 1982).

The northern contingent usually begins to move inshore off southern New England in late May; mixing temporarily with part of the southern contingent. Northern fish then migrate eastward along the coast of Nova Scotia, are joined by other mackerel schools from offshore, and move into the Gulf of St. Lawrence, where they spawn in June and July and then spend the rest of the summer there. Small fish (>30 cm) tend to lag behind large ones during the spring migration and spawn later (MacKay 1967; Stobo and Hunt 1974; Moores et al. 1975). Some northern fish separate from the main body and remain along the coasts of Maine, Nova Scotia, and Cape Breton Island for the summer. The main body of northern fish leaves the Gulf of St. Lawrence in September and October via Cabot Strait, moves west along Nova Scotia, and passes through the Gulf of Maine from October to December, where northern and southern contingents again mix temporarily; Northern fish leave the Gulf of Maine near Cape Cod in December and are assumed to overwinter in deep water over the outer shelf between Sable Island Bank and Long Island; further mixing probably occurs then (Sette 1950; Parsons and Moores 1974; Moores et al. 1975).

Tagging experiments on Atlantic mackerel have demonstrated extensive movements (Sette 1950; Moo~es et al. 1975; Berrien 1982). Tagged fish have moved from Newfoundland to southern New England, New York Bight, and Maryland.

Mackerel tagged in the Gulf of St. Lawrence in October were recaptured on Georges Bank and off New Jersey and Delaware in winter. Mackerel tagged off Nova Scotia were recaptured off New England, off Sable Island and Delaware in winter, and off New Jersey. One Atlantic mackerel tagged near Woods Hole in June was recaptured in Nova Scotian waters. Recapture south of Long Island of an Atlantic mackerel tagged in Newfoundland waters represents the farthest doaimented migrant in the northwest Atlantic, at least 2,260 km between 30 August and 28 December 1972 (Parsons and Moores 1974). These studies indicate probable mixing of fish from different contingents during the winter.

Importance. Mackerel are delicious fish, but they do not keep as well as fishes that have less oil in their tissues. When mackerel were plentiful they were among the most valuable fishes of the Gulf commercially, surpassed in dollar value only by haddock, cod, and redfish for the years 1943-1947.

It has been common knowledge since early colonial days that mackerel fluctuate widely in abundance in the Gulf from year to year, perhaps more widely than any other important food fishes, with periods of great abundance alternating with terms of scarcity or almost total absence. Bigelow and Schroeder reviewed fluctuations in catch of Atlantic mackerel in the Gulf of Maine. From 1925 to 1946, catch ranged between a low of about 9,090,900 (1937) and a high of 26,818,000 kg (1932). Average annual Gulf of Maine catch for the period 1933-1946 was about 16,818,000 kg.

Formerly; most mackerel were caught with hook and line, ground bait being thrown out to lure the fish close enough to the vessel (Goode and Collins 1887:275-294). This way of fishing was given up about 1870 and replaced by the purse seine. Practically the entire catch of mackerel in the northwest Atlantic for the past 100 years has been made with purse seines, pound nets, weirs and floating traps, and gill nets. In 1943, for example, when the total Gulf of Maine catch was about 24,000 mt, about 80% was taken in purse seines; 12-13% in pound nets, weirs, and floating traps combined; and 3-4% (450-900 mt) in gill nets (anchored or drifting), but only 770 kg on handlines.

In the mid-1960s, an extensive offshore otter trawl fishery began in the northwest Atlantic by distant-water fleets, chiefly from Europe. They began fishing on mackerel, partly because of its high abundance and partly because of declining herring stocks. The estimated total mackerel biomass (age 1 and older) in the northwest Atlantic increased from about 600,000 mt in the early 1960s to a peak of 2.4 million mt in 1969, and then declined rapidly to less then 500,000 mt in 1978 (Fig. 273). The big rise and fall in abundance was due chiefly to the recruitment of four consecutive strongyear-classes in 1966-1969, particularly the extraordinary one of 1967, followed by a series of relatively small year-classes from 1970 to 1977, generally less than half the strength of those of 1966, 1968, and 1969 and less than one-quarter the size of the one from 1967 (Anderson and Paciorkowski 1980). Total commercial landings from this stock increased from only 7,300 mt in 1960 to a peak of 419,000 rot in 1973, and then declined rapidly to 77,000 mt in 1977, the first year of management under extended jurisdiction in both u.s. and Canadian waters inside the 200-mile zone and then declined further to 27 ,400 mt in 1995 (Overholtz 1998b). The bulk of this harvest came from the area between Georges Bank and Cape Hatteras (e.g., 90% during the peak 1970-1974 period). For the same period, about 60% came from the Mid-Atlantic Bight alone. In 1978 the commercial catch from the Bight dropped to about 1 ,000 mt, most of which was taken by u.s. fishermen. Coincident with the extension of u.s. management responsibility to 200 miles offshore, the Mid-Atlantic Fishery Management Council established controls on the fishery in the early 1980s under authority of the Magnuson Fishery Conservation and Management Act (Overholtz et al. 1991a). The fishery management plan for the United States developed by the Management Council in 1984 relies on annual catch quotas developed from an assessment of the stock based on a virtual population analysis and an estimate of incoming recruitment at age 1 (Overholtz 1993).

Fluctuations in mackerel year-classes are believed to be due to variations in larval survival (Sette 1943). Factors influencing mortality of larvae may include water temperature, predation, zooplanlkton abundance, wind-driven surface currents, epizootics, and abundance of mackerel larvae relative to their prey (Sette 1943; Taylor et al. 1957; MacKay 1967; Berrien 1982). Average recruitment levels may be reduced when the spawning stock drops below some critical level. There was concern that heavy fishing coupled with poor recruitment in the 1970s would drive the spawning stock down below such a level, and catch restrictions have been imposed since 1976 to promote rebuilding of the stock (Anderson and Padorkowski 1980).

Recreational Fishery. Many anglers troll or baitfish for mackerel all along the coast from Cape Cod to Penobscot Bay; as far as Mt. Desert if mackerel are on the coast that far east. In good years Bigelow and Schroeder reported that it was not unusual for three or four anglers fishing from a party boat to bring in 100 or 200 fish. In summers when young tinkers are plentiful inshore many of them are caught from the wharves in various harbors. If one chooses to troll, an ordinary no.3 pickerel spinner serves well, especially if tipped with a small piece of pork rind or with mackerel skin, a small metal jig similarly adorned, or any small bright spoon. Mackerel will also take a bright artificial fly and bite greedily on almost any bait, such as a piece of clam, a piece of mackerel belly, or a sea worm *(Nereis)*, especially if attracted by ground bait.

The U.S. recreational catch of Atlantic mackerel is substantially greater than the u.s. commercial catch, averaging 13,600 mt.year-l (1960-1977) compared to only 2,200 mt.year-l for the commercial fishery (Anderson and Paciorkowski 1980). The estimated sport catch has also followed major trends in mackerel abundance, rising from 5,000 mt in 1960 to 13,000- 16,000 mt in 1969-1972, then declining to the lowest estimated catch of 522 mt in 1977 (Overholtz et al. 1991b). The recreational catch stabilized to between 3,000 and 5,000 mt.year-l in the next decade. U.S. recreational catches are made mainly from April to October, whereas catches in Canadian waters off Nova Scotia and Newfoundland have typically been from May to November.