

Mackerel

Scomber scombrus Linnaeus 1758

[Jordan and Evermann, 1896-1900, p. 866]

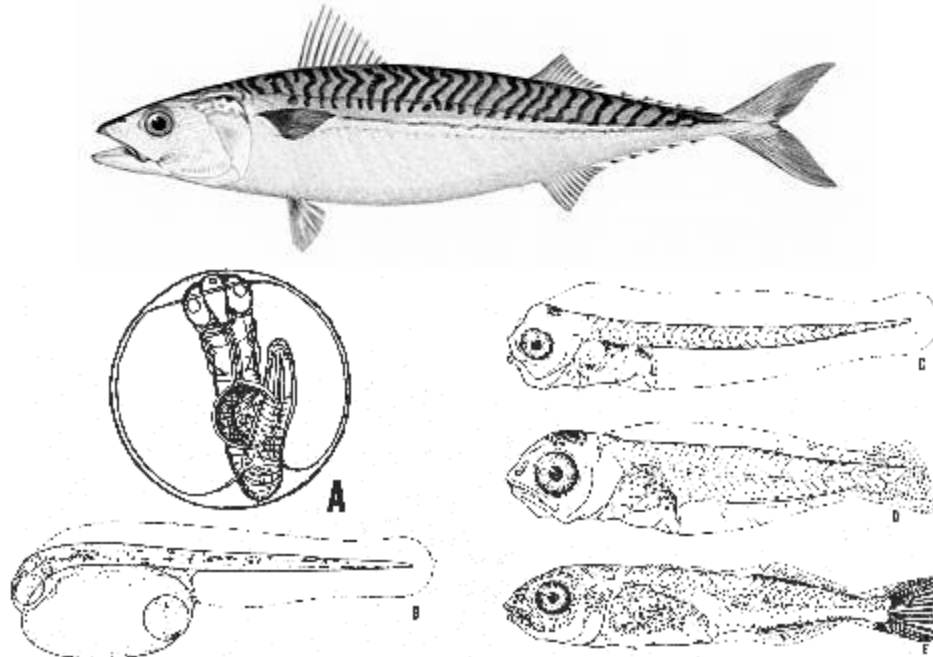


Figure 175 - Mackerel (*Scomber scombrus*).

- A, egg (European), after Holt;
- B, larva, 3.5 mm.;
- C, larva, 4.6 mm.
- D, larva, 7.8 mm.;
- E, larva, 15 mm.;
- B-E, drawings by Luella E. Cable.

Description

The mackerel is fusiform in outline, tapering rearward to a very slim caudal peduncle and forward to a pointed nose. Its body is about four and one-half to five and one-half times as long as it is deep, oval in section, thick and firm-muscled as are all its tribe. Its head is long (one-fourth of length to caudal) and its mouth large, gaping back to the middle of the eye (the premaxillaries are not protractile), while the jaws, which are of equal length, are armed with small, sharp, slender teeth. The eye is large, and the hollows in front of and behind it are filled with the so-called "adipose eyelid," a transparent, [page 318] gelatinous mass in the form of two scales, a forward and a hinder, which cover the eye except for a perpendicular slit over the pupil.

There are two large dorsal fins: the first originating over the middle of the pectoral fins when the latter are laid back is triangular, of 10 to 14 (usually 11, 12, or 13) rather weak spines that can be laid down along the midline of the back in a deep groove; the second dorsal, separated from the first by an interspace longer than the length of the latter, is smaller (9 to 15 rays, usually 12) and is followed by several small finlets, of which there are usually 5, but sometimes 4 or 6. The anal fin is similar to the second dorsal in shape and size, originates slightly behind it, and is similarly succeeded by 5 small finlets that correspond to the dorsal finlets in size and shape. The caudal fin is broad, but short and deeply forked. The caudal peduncle bears two small longitudinal keels on either side but no median lateral keel, the absence of the latter being a distinctive character. The ventral fins stand below the origin of the first dorsal and are small, as are the pectorals. The scales of the mackerel are so small that its skin feels velvety to the touch; indeed they are hardly to be seen on the belly with the naked eye, but those about the pectoral fins and on the shoulders are somewhat larger.

Color

The upper surface is dark steely to greenish blue, often almost blue-black on the head. The body is barred with 23 to 33 (usually 27 to 30) dark transverse bands[94] that run down in an irregular wavy course nearly to the mid-level of the body, below which there is a narrow dark streak running along each side from pectoral to tail fin. The pectorals are black or dusky at the base, the dorsals and caudal are gray or dusky. The jaws and gill covers are silvery. The lower parts of the sides are white with silvery, coppery, or brassy reflections and iridescence; the belly silvery white. [page 319] But the iridescent colors fade so rapidly after death that a dead fish gives little idea of the brilliance of a living one.

Size

Most of the grown fish are between 14 and 18 inches long; a few reach a length close to 22 inches. Fourteen-inch fish weigh about 1 pound in the spring and about 1¼ pounds in the fall when they are fat; 18-inch fish weigh about 2 to 2½ pounds; a 22-inch mackerel will likely weigh 4 pounds. An unusually large mackerel is taken occasionally; in 1925, for example, the schooner *Henrietta* brought in one weighing 7½ pounds.

Habits

Mackerel are a swift-moving fish, swimming with very short sidewise movements of the rear part of the body and of the powerful caudal fin. When caught they beat a rapid tattoo with their tails on the bottom of the boat until exhausted. And they require so much oxygen for their vital processes that when the water is warm (hence its oxygen content low) they must keep swimming constantly, to bring sufficient flow of water to their gill filaments, or else they die.[95]

Despite their great activity, they do not leap above the surface, as various others of their tribe do, unless perhaps to escape some larger fish.

The mackerel, like the herring, has the habit of gathering in dense schools of many thousands. It is not known how long these schools hold together; it would be especially interesting to know whether they do so through the winter when our mackerel are in deep water, but the general opinion of fishermen is that they do so throughout the migrations at least. Although the mackerel may scatter and the schools mix more or less, especially when they are feeding on the larger and more active members of the free-floating fauna as is said to happen in British waters, the members of any given school usually are all of about the same size, i. e., of the same age. Fish of the year almost always school separately from the others as Sette[96] has pointed out; he has also pointed out that this tendency of the fish to separate according to size is probably due to the fact that the larger ones swim faster than the smaller ones.

Mackerel school by themselves, as a rule. But sometimes they are found mingled with herring, alewives, or shad, as Kendall[97] described. We have yet to learn how mackerel schools hold together, whether by sight or by some other sense. And various explanations have been proposed to account for the schooling habit, such as that it is advantageous for feeding, that it is a concomitant of spawning (this would not explain its persistence out of the spawning season, however, or the fact that any given school is apt to contain green, and spent as well as ripe fish even at spawning time), or that it affords protection from enemies. But when all is said, the instinct prompting it remains a mystery. At any rate, schooling is not a necessity, though usual. When mackerel are at all plentiful, and even when they are not, numbers of single wandering fish are often hooked by persons trolling for them, and by flounder and cunner fishermen.

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. Neither do mackerel ordinarily "fin" or raise their noses above the surface, as is the common habit of the menhaden (p. 114). An observer at masthead height can perhaps see a school of mackerel as deep as 8 to 10 fathoms by day, if the water is calm, and the sun 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[98] reports one case of a school recognized by its firing as deep as 25 fathoms; but the water is seldom (if ever) clear enough in the Gulf of Maine for a submerged light to be visible from above, more than 15 fathoms down.[99] the trail of bluish light left behind by individual fish as they dart to one side or the other, while one row or sails through a school on a moonless, overcast night when the water is firing, is the most beautiful spectacle that our coastal waters afford, and one with which every mackerel fisherman is familiar.

No one knows how greatly the movements of the mackerel, from day to day, result from involuntary drifting with the circulatory movements of the water, which are different at different depths, and how greatly they depend on the directive swimming of the mackerel themselves. Our only [page 320] contribution in this regard is that we once were able to follow on foot beside a school that was advancing along the Scituate shore at a rate of about 3 to 4 miles an hour, against a tidal current of about one-half knot, until the fish swung offshore and out of our sight.

The speed at which a school travels when it is not disturbed depends, it seems, on the size of the fish of which it is composed. It has been observed by Sette that mackerel less than one year old swim at about 6 sea miles per hour (10 ft. a second) while circling inside a live car; yearlings at a rate of about 11½ sea miles per hour (19 ft. a second), or nearly twice as fast. We find no definite observations on the normal speed of the larger fish, and no one knows how rapidly a mackerel may swim for a short distance, if it is disturbed. Mackerel seen during the warmer months of the year are always swimming, but this rule may not apply in winter, when the water holds more dissolved oxygen because it is colder, and when it is probable that their demand upon it is lower.

The mackerel is a fish of the open sea; while numbers of them, small ones especially, often enter estuaries and harbors in search of food, they never run up into fresh water. 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 the outer part of the shelf of the continent. But they are most numerous within the inner half of the continental shelf during the fishing season, and their normal range seems not to extend oceanward beyond the upper part of the continental slope, in which they contrast with their relatives the tunas, the bonitos, and the albacores.

The depth-range of the mackerel is from the surface down to perhaps 100 fathoms at one season or another. (We recur to this in discussing the occurrence of mackerel in the Gulf of Maine, page 325.) From spring through summer and well into the autumn, the mackerel are in the upper water layers; shoaler, mostly, than some 25 to 30 fathoms, and schools of all sizes come to the surface more or less frequently then. But they frequently disappear from the surface, often for considerable periods. And it seems, from fishermen's reports, that the larger sizes tend to swim deeper than the smaller ones, on the whole, especially in mid and late summer.[1] It is probable, also, that their vertical movements during the warmer part of the year, when they are feeding actively, are governed chiefly by the level at which food is most abundant, which for the most part is shoaler than about 50 fathoms, at least on our side of the Atlantic.

The highest temperature in which mackerel are commonly seen is about 68° F. (20° C.). At the opposite extreme they are sometimes found in abundance in water of 46°-47° (8° C.); and commercial catches are sometimes made in water as cold as 44°-45° (7° C.), but odd mackerel only have been taken in temperatures lower than that[2] in American waters. Large catches of mackerel are made, however, by trawlers in the North Sea in winter in water as cold as 43°-45° (6°-7° C.). But as Sette has emphasized, the European mackerel differs racially from the American, and may differ in its temperature relations as well.

Food

We may assume that the diet of the young mackerel is at first much the same in the Gulf of Maine as it is in the English Channel,[3] namely, copepod larvae and eggs, the smaller adult copepods, various other minute pelagic Crustacea, and small fish larvae. But the young fish depend more and more upon larger prey as they grow. Our Gulf of Maine mackerel have repeatedly been seen packed full of *Calanus*, the "red feed" or "cayenne" of fishermen, as well as with other copepods (we have examined many in this condition). They also feed greedily, as do herring, on euphausiid shrimps (p. 89), 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 the dietary of the mackerel. Thus, Doctor Kendall writes 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, others were full of *Sagittae*, others, again, of *Sagittae* and amphipods (*Euthemisto*), of small copepods (*Temora*), or of red feed (*Calanus*), so that even fish from the same school had selected the various members of the drifting community in varying proportion.

Similarly, 1,000 mackerel caught near Woods Hole from June to August contained pelagic amphipods (*Euthemisto*), copepods, squid, and launce;[4] others taken off No Man's Land have been found full of shelled pteropods (*Limacina*). And 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 launce. In short, practically all the floating animals, not too large or too small, regularly serve for the nourishment of mackerel except the *Medusae* and *ctenophores*, and a diet list for any given locality would include all the local pelagic Crustacea and their larvae.

Mackerel have often been seen to bite the centers out of large *Medusae*, but, as Nilsson suggests, they probably do this for the amphipods (*Hyperia*) that live commensal within the cavities of the jellyfish, not for the sake of the latter.

Mackerel also eat all kinds of small fish, to a greater or less extent according to circumstances. In the Gulf of Maine they devour large numbers of small herring, launce, and even smaller mackerel. They likewise feed on pelagic fish eggs when available, oftenest on those of their own species. And they bite greedily on almost any bait, especially if it moves, such as a bit of mackerel belly skin, a piece of clam, a piece of sea worm (*Nereis*), a shining jig, spoon or spinner of appropriate size, or an artificial fly, white, red, or silver-bodied. Side by side with these comparatively large objects mackerel are also known to take various microscopic organisms, chiefly the commoner peridinians and diatoms, but they never feed extensively on these as menhaden do (p. 114). And copepods are so plentiful in the Gulf of Maine, and the vegetable plankton that swarms in April has so largely disappeared over most of the Gulf before the mackerel appear later in the spring, that we doubt if they are ever reduced to a vegetable diet there or anywhere in American waters.

Mackerel are also known to feed on bottom animals to a small extent. Nilsson, for example, reports various worms and hydroids and even small stones from their stomachs, but our experience in the Gulf of Maine is to the effect that this would be exceptional there, if it happens at all.

Most authors describe the mackerel as feeding by two methods: either by filtering out the smaller pelagic organisms from the water by their gill rakers[5] or by selecting the individual animals by sight. A good deal of discussion has centered about the relative serviceability of these two methods of feeding. Probably the truth is that when forced to subsist on the smaller objects in its dietary it must do so by sifting them out of the water, but that it selects the more desirable whenever opportunity offers to exercise its sight. It is not yet known how small objects the fish is able to pick out. It takes fish individually of course, and such large Crustacea as euphausiid shrimps and amphipods, just as the herring does, which evidently applies to the 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 the smaller copepods and crustacean larvae is not so clear. Captain Damant,[6] whose experience in deep-sea diving has given him an exceptional opportunity to observe mackerel feeding under natural conditions, describes fish among which he was at work 20 to 40 feet deep in Lough Swilly (Ireland), as "feeding on plankton, not by steadily pumping the water through the gill filters but snatching gulps from different directions and making little jumps here and there."

It has been a commonplace from the earliest days of the mackerel fishery that the fish are fat when last seen in the autumn, but that most of them are thin when they reappear in spring, obviously suggesting that they feed little during the winter. This is corroborated by the fact that the mackerel taken on bottom by British and French trawlers between December and March usually are empty, and that a few mackerel taken by the *Albatross II* along the continental edge off Chesapeake Bay in February 1931 were very emaciated. But mackerel taken in winter sometimes have food in their stomachs; some of them even are fat.[7]

The immature fish feed and fatten from the time they appear in spring. And it also seems that the schools of older fish destined to spawn late in the season feed until the actual ripening of their sexual products commences, for large catches of the maturing fish were regularly made on hook and line in June in the Gulf of St. Lawrence where spawning takes place in July (until the eggs began to run, in fact). But these large mackerel would not bite after that until they had spawned out (last half of July or first part of August). And available evidence, American as well as European, is to the effect that fish destined to spawn soon after their vernal appearance inshore continue their winter fast until they have spawned, when they commence feeding greedily.

Enemies

The mackerel falls easy prey to all the larger predaceous sea animals. Whales, porpoises, mackerel sharks, threshers, dogfish, tuna, bonito, bluefish, and striped bass take heavy toll in particular. Cod often eat small mackerel; squid destroy great numbers of young fish less than 4 or 5 inches long, and sea birds of various kinds follow and prey upon the schools when these are at the surface. A considerable list of parasitic worms, both round and trematode, are known to infest the digestive tract of mackerel. But they seem more immune to danger from sudden unfavorable changes in their environment than the herring are, for they are never known to be killed by cold, and they seldom strand, except when small ones are driven ashore by larger fish.

Breeding

Mackerel spawn off the American coast from the latitude of Cape Hatteras to the southern side of the Gulf of St. Lawrence. The spawning area covers almost the entire breadth of the continental shelf southward from Cape Cod, but it is confined more closely to the vicinity of the coast thence northward. 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.[8] Mackerel do not resort to any particular breeding grounds, but shed their eggs wherever their wandering habits have chanced to lead them when the sexual products ripen. It follows from this, and from the fact that mackerel vary so widely in abundance over periods of years that the precise localities of greatest egg production may be expected to vary from year to year, depending on the local concentrations of the fish.

The mackerel spawns in spring and early summer. As it does not commence to do so until the water has warmed to about 46° F. (8° C.), with the chief production of eggs taking place in temperatures of, say, 48° to 57°, 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 in the southern side of the Gulf of St. Lawrence, where eggs have been taken from early June to mid-August.[9] Mackerel have never been found spawning in autumn, so far as we can learn, though a considerable number of eggs that we towed in Massachusetts Bay early in November of 1916 resembled mackerel eggs from the hatchery so closely that we would not have hesitated to identify them as such, had they been taken in summer. They may have been the product of a belated fish, but more likely of some other Scombroid.

The mackerel is a moderately prolific fish; females of medium size may produce as many as 400,000 to 500,000 eggs in the aggregate, according to various estimates,[10] with 546,000 reported for one weighing 17/8 pounds. But it is seldom that as many as 50,000 are set free at any one time, and often many fewer, for the members of a given school spawn over a considerable period. And recent observations[11] have shown that our earlier statement that they spawn chiefly at night was not correct.

The eggs are 0.97 to 1.38 mm. in diameter, with one large oil globule,[12] and drift suspended in the water, chiefly shoaler than the 5-fathom level. The rate of development is governed by the [page 323] temperature of the water. Recent experiments by Worley[13] (which corroborate early hatchery experience) have shown that incubation takes about 150 hours at 54°; 115-95 hours at 57°-61°; about 70 hours at 64°-65°; and about 50 hours at 70°; with normal development limited to temperatures between about 52° (11° C.) and 70° (21° C.).

Newly hatched living larvae are 3.1 to 3.3 mm. long[14] with large yolk sac, and with numerous black pigment cells scattered over head, trunk, and oil globule which give them a characteristic appearance. The yolk is absorbed and the mouth formed, the teeth are visible, and the first traces of the caudal fin rays have formed by the time the larva is about 6 mm. long. The rays of the second dorsal and anal fins and of the ventrals appear at about 9 mm. (to end of caudal fin); the first dorsal when the total length of the larva is about 14 to 15 mm. The dorsal and anal finlets are distinguishable as such in fry of 22 mm., and the tail fin has begun to assume its lunate shape, but the head and eyes still are much larger than in the adult, the nose blunter, and the teeth longer. At 50 mm. The little mackerel resemble their parents so closely that their identity is evident.

Rate of growth

The sizes of the mackerel fry taken during the mackerel survey carried out by the U. S. Bureau of Fisheries in 1932,[15] added to other available evidence show that our mackerel grow to a length of about 2 inches during the first 1 to 2 months after they are hatched, a rate about the same as in British and Norwegian waters.[16]

This size is reached earlier or later in the season, depending on the date when any particular lot of fry was hatched. Thus mackerel fry of 1¼ to 2½ inches obviously spawned that spring, have been taken at Woods Hole, both in the first half of June[17] and in the last 10 days of July,[18] fry of 2½ to 5 inches in the first half of August, and fish of about 6½ inches at the end of that month. Similarly, Captain Atwood found fry of 2 inches and shorter in July in the Massachusetts Bay region, i. e., about a month after the local mackerel schools had spawned out.

Fry of 3½ to 4½ inches (obviously of the same season's crop because too small for yearlings) have been taken at Gloucester in August, and Captain Atwood reports them as 6½ to 7 inches long, near Provincetown by October. Many of these little fish, up to 7 or 8 inches long (now large enough to be caught in the fish traps and known as tacks or spikes) are caught along the western shores of the Gulf of Maine and along southern New England during the fall. And measurements of thousands of young mackerel from the Gulf and from southern New England, compiled by the U. S. Bureau of Fisheries, have shown that the fry of the year average 8 to 9 inches, or longer, by the end of their first autumn, before they leave the coast for the winter. But broods produced in different years may grow at different rates, probably depending on feeding conditions, as well as on the dates when they are hatched. Thus fry spawned in the spring of 1927 averaged 8¾ inches in November, but those spawned in 1928 averaged 9¾ inches then.

Our mackerel run about 10 to 11 inches long in spring and early summer of their second year of growth (they are known now as tinkers), which agrees closely with Stevens'[19] estimate for mackerel of the English Channel, based on studies of scales and otoliths. They grow to about 12 to 13 inches by that autumn, or to 14 inches in years of especially rapid growth,[20] and the yearlings usually are a little longer in the Gulf of Maine than at Woods Hole, and longer at Woods Hole than off Long Island, N. Y. It remains to be seen whether these differences are due to temperature, to the varying richness of the food supply, or perhaps to crowding. It is also a question for the future whether the differences persist into later life. The brood of 1923, which may perhaps be taken as typical, averaged almost 14⅓ inches in their third autumn, about 15⅓ inches in their fourth, about 15½ inches in their fifth, about 16 inches in their sixth, 16⅓ inches in their seventh, and about 16¾ inches in their eighth years. Thus the American mackerel, like the European, grows very slowly after its third [page 324] summer, although it is long lived. The two sexes grow about equally fast.

Nilsson's studies[21] point to a slightly slower rate of growth for the North European mackerel. But American mackerel have been found to vary so widely in this respect that the reported difference may have been only an accident of observation.

A few fish of both sexes may mature sexually in their second year; about 4/5 of the males and 2/3 of the females spawn in the third year; and practically all of them do so in their fourth year, i. e., when three full years old.[22] This coincides with the transition from fast growth to slow, as might be expected, the ripening of the sexual products being so great a strain that the adult fish do little more than recover before winter. Once a mackerel has matured sexually, it no doubt spawns yearly throughout life, as most other sea fishes do.

Proportions of the sexes

In American waters males have been described as predominating largely over females.[23] But more recent observations have shown that there are about as many of the one sex as of the other, as there are in Sweden also.[24]

General range

Both sides of the North Atlantic; Norway to Spain off the European coast[25]; from the northern side of the Gulf of St. Lawrence and Strait of Belle Isle[26] to Cape Lookout, N. C.[27] off the American coast.

Migrations, and occurrence in the Gulf of Maine

The occurrence of the mackerel in the Gulf of Maine is closely bound up with the seasonal movements of the species as a whole, for this is a migratory fish wherever it occurs, appearing at the surface and near our coasts in spring, to vanish thence late in the autumn. The directions and extent of the journeys which it carries out have been the subject of much discussion ever since the fishery first assumed importance, because of their intrinsic interest, because of their bearing on the prosecution of the fishery, and because this fish has been the subject of much international dispute. The point chiefly at issue has been 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 the extensive north and south migrations in which most fishermen have long believed.[28]

The great majority of the mackerel have withdrawn from the coast by the end of December, not only from the Gulf of St. Lawrence, but from the entire inshore belt as a whole, not to be seen there again until the following spring or early summer, and it is not yet known definitely where the bulk of them go, though the subject has been widely discussed. Mackerel, it is true, have been caught, and have been found in the stomachs of cod and pollock in January, February, and early March at various localities on and around the outer Nova Scotian banks westward from Sable Island Bank; on the southern and northwestern parts of Georges Bank; in the deeper water between the latter and Nantucket Shoals; on Nantucket Shoals; and along the middle and outer parts of the continental shelf off southern New England, off New York, off New Jersey, off Delaware Bay, off Virginia, and off northern North Carolina. Most of these winter records have been along the 30-70 fathom contour zone, but sometimes as shoal as 4-5 fathoms off Nova Scotia, and as shoal as about 10-20 fathoms (near Ambrose Lightship) off New York,[29] as deep as 90 fathoms off Chesapeake Bay.[30]

Most of these winter records have been based on odd fish only, i. e., not enough to suggest the presence of any great concentration of mackerel.[31] But there were enough of them off New York in January, February, and March of 1949 for commercial fisheries to bring in what Gordon[32] has [page 325] characterized as "huge amounts." He also reports "a large body of fish" off Montauk in mid-February of 1950. Schools of "mackerel" have also been reported as sighted at the surface on several occasions in winter, but none of these seem to have been brought in.

Direct evidence carries us only this far. But the indirect evidence of temperature is suggestive. Thus, the Gulf of St. Lawrence (where ice sometimes forms), outer Nova Scotian waters, and the upper 50 fathoms or so within the Gulf of Maine which chill to 35°-39° F. (2°-4° C.) or colder, are all too cold by late winter for mackerel, which are never encountered in commercial quantities in temperatures lower than about 45° F. (7° C.). In most years this applies equally to the inner part of the continental shelf as a whole, southward as far as northern Virginia, for the water usually cools there to 37°-40° F. (3°-4° C.) at the time of the winter minimum. But the 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 44°-46° F. (7°-8° C.) the year round as far north and east as the central part of Georges Bank, and about 41° F. (5° C.) along outer Nova Scotia.

Available evidence thus supports Sette's[33] conclusion that the bulk of the American mackerel winter on the outer edge of the continental shelf from the offing of northern North Carolina to the mid-length of Georges Bank, 30 to 100 miles off shore according to location, in depths of perhaps 50 to 100 fathoms. The few that are caught closer to land and in shoaler water in winter either represent the inshore fringe of the main population, or they are strays. Perhaps some winter off Nova Scotia as far east as Sable Island Bank. And it would not be astonishing should it prove that some winter in the deep eastern trough of the Gulf of Maine, where the temperature of the bottom water, at depths greater than 75 fathoms or so, does not fall below about 41° F. (5° C.). A few mackerel have, in fact, been caught on cod lines in deep water off Grand Manan in winter,[34] while two were found among kelp near Yarmouth, Nova Scotia, on December 28, in 1878.[35]

Sette[36] has pointed out, however, that some other factor besides temperature must have to do with the wintering habits of the mackerel, for they disappear as completely from the surface and from inshore in the southern part of their range as they do in the northern even in very warm years such as 1932, when the water (surface to bottom) was warmer than 45°-46° F. (7°-8° C.), from New Jersey southward, even at the end of the winter. On the other hand, the event (probably abnormally low temperature) that was so destructive to the tilefish in March, 1882 (p. 429), did not affect such of the mackerel as were wintering on the tilefish grounds, for they reappeared that summer in normal numbers, a point to which Sette[37] has called attention already.

Two additional facts which support the view that our mackerel do not travel very far in winter are (a) no mackerel, young or old, have ever been taken outside the edge of the continent, or anywhere on the high seas far from land for that matter; (b) their reappearance in spring takes place so nearly simultaneously along some hundreds of miles of coastline that they can hardly have come from any great distance.

Thus time and increased knowledge have corroborated the view of Captain Atwood and of Perley, of more than half a century ago that mackerel winter offshore in deep water and northward from the latitude of Virginia, not in the far south nor out in the surface waters of the warm parts of the Atlantic.

The winter home of the American mackerel appears to correspond rather closely to that of the mackerel of British seas, some of which winter on the deep northern slope of the North Sea, some in the deeper parts of the English Channel, and many on the outer edge of the continental shelf southwest of Ireland, mostly deeper than 60 fathoms.[38]

The failure of the otter trawlers to take commercial quantities of mackerel off Chesapeake Bay in winter when they fish there intensively, leads Sette[39] to conclude that our mackerel [page 326] winter in the mid-depths, not concentrated on the bottom. This, however, would imply that the wintering mackerel manage to hold position for two or three months in some way without drifting far with the movements of the water. Another possibility is that they do keep on bottom, or near it, but somewhat deeper down the continental slope than the trawlers ordinarily fish,[40] perhaps concentrated in the many gullies, large and small, with which the upper part of the slope is seamed all along from the offing of Chesapeake Bay to Georges Bank, much as the mackerel of the Celtic Sea and English Channel winter "on the sea floor, densely packed in places where its level is interrupted by banks and gullies." [41]

Whichever of these alternatives is the correct one, the oft repeated assertion that the adipose eyelids of the mackerel become opaque in winter has no foundation. And they certainly do not hibernate in thousands along the coasts of Greenland and Hudson Bay,[42] and of Newfoundland, with heads in the mud and tails protruding as a vice admiral, no less, has described them; a wholly imaginary tale, we need hardly add.[43] they may winter in a more or less sluggish state. But the presence of food in the stomachs of some of the winter-caught fish, added to the fact that some of them are fat though others are thin, shows that they move about more or less even then, and feed more or less.[44]

Most American students have looked on the vernal warming of the surface water to about 45° F. as the stimulus causing the mackerel to quit their winter quarters. European studies, however, have shown that the date of their reappearance in spring is not closely associated with any particular temperature. And if the mackerel winter on bottom along the edge of the continent, vernal changes in the temperature of the surface water nearer to land would be wholly outside their ken.

The European mackerel usually keep to the bottom on their spring migration until close in to the land before rising to the surface. But this generalization does not apply to the American fish, for while some may swim deep (so, only can we account for the fact that the first schools often show as early in Massachusetts Bay as on Georges Bank or off Nantucket) mackerel in great numbers are first sighted 30 to 50 miles offshore, and this all the way from the latitude of Cape Hatteras to the mouth of the Gulf of Maine. The first mackerel "show" off the Cape Hatteras region at any time between about March 20 and April 25, usually early in April, and by the middle of April off Delaware Bay. As the water warms they spread northward and shoreward, being joined, it seems, by additional contingents from offshore. They reach the offing of southern New England some time in May, and they are plentiful on Nantucket Shoals by the first week of that month, as a rule.

The date when they are first sighted off Cape Cod in the southwestern part of the Gulf of Maine varies from the last of April or first of May (April 29 in 1901, May 2, in 1898) to the first of June, with May 10 about the average. The earliest dates of commercial catches, for example, made in one particular set of traps near Provincetown have varied between May 14 and June 19. And the fish are plentiful in the western side of the Gulf of Maine as a whole by the end of the first week in June at the latest, if it is fated to be a good mackerel year. Mackerel (usually in smaller numbers) also appear on the Nova Scotian side of the Gulf about as early as they do in its western side; thus they were reported almost simultaneously off Yarmouth, Nova Scotia, and off Chatham on Cape Cod in 1898; in 1922 they were sighted off Yarmouth on May 7th, and off Cape Sable on the 11th. And they may appear even earlier in the season at Cape Breton, and as early well within the Gulf of St. Lawrence and in the eastern side of our Gulf. In 1894, for example, mackerel were first reported off Cape Breton on May 5 and at Gaspé on May 12, but not until May 16[45] at Yarmouth on the Gulf of Maine coast of Nova Scotia. But few of them show along the coast of Maine or in the Bay of Fundy until toward the end of June.

Sette[46] has made the very interesting discovery that two distinct populations are represented among the American mackerel, a southern and a [page 327] northern, with rather different migratory habits, and differing also in the relative success of reproduction in different years.[47] the nature of these two contingents is not known, whether genetic or environmental.

It is probable (though not proved) that the southern contingent tend to winter in the southern part of the wintering zone. The main bodies of mackerel that appear in spring along the middle Atlantic coast belong to this contingent, also most of those taken off southern New England. They summer for the most part over Nantucket Shoals; on the western part of Georges Bank; and in the western and northwestern parts of the Gulf of Maine, which they enter in the western side around Cape Cod. And they do not journey farther east than the coast of Maine. On the other hand, it seems the mackerel that appear early in the season along the Nova Scotian shore of the Gulf, to spread later to Maine, belong to the northern contingent, and also a scattering of those that enter the western side of the Gulf. These appear to winter mostly eastward from the Hudson Gorge, and their vernal migration carries most of them past our Gulf, to pass the summer along outer Nova Scotia, and in the southern side of the Gulf of St. Lawrence.[48]

A few mackerel (mostly small) from the southern contingent remain all summer in the coastwise belt from Long Island to Nantucket. Apart from these, however, the whole body of American mackerel have deserted the southern grounds altogether by the early summer, to spend the later summer either in the region of our Gulf, off Nova Scotia, or in the Gulf of St. Lawrence.[49]

If the view now held is correct as to their migratory routes, some of the mackerel that summer in our Gulf may come from as far as the offing of North Carolina; others from as nearby as the offing of New York or of southern New England. The vernal journey of the Gulf of St. Lawrence mackerel may be anywhere between, say 300 to 350 miles, and 700 miles, depending on whether they have wintered off outer Nova Scotia or as far west as the western slope of Georges Bank.

It seems certain that some of the mackerel that are first sighted on Nantucket Shoals and on Georges Bank in May remain on these offshore grounds all summer, both spawning and feeding there, for they provide good fishing there any time from June to September or October, in some years. The farther advance of such of them as continue northward into the Gulf of Maine covers a period of some weeks, with the first-comers followed by other schools later. And it seems certain (as just remarked) that fish resorting to our Gulf, do so summer after summer, never visiting the outer coast of Nova Scotia, much less a region as far afield as the Gulf of St. Lawrence. But it is an interesting question for the future, whether a given school returns to the same part of the Gulf, year after year.

Many of the mackerel that summer in our Gulf have already spawned farther south (p. 322). Others, however, are still hard, but they are soon taken there with eggs or milt running. Spawning in the Gulf of Maine is at its peak in June in most years, with the proportion of spent fish increasing through July, and only an occasional ripe fish as late as the first of August. But a year comes occasionally, such as 1882, when spawning is not at its height in the Gulf until July, with ripe fish continuing plentiful until August. And our towings there have yielded a few mackerel eggs as early as May 6, as late as September 1.[50]

The spawning season is at its height in the Gulf of St. Lawrence during the last half of June and the first half of July, continuing into August, a fact well known by the hook-and-line fishermen of half a century ago, because the ripe fish will not bite at that time, and more recently corroborated by the egg catches of the Canadian Fisheries Expedition.[51]

It seems from the relative numbers of eggs taken from place to place, that Cape Cod Bay is the only subdivision of our Gulf that has rivaled the more southern spawning grounds in egg production during the particular years when intensive studies [page 328] have been made.[52] Mackerel also spawn to some extent thence northward, as far as Casco Bay, but we believe very few do so farther east than that along the coast of Maine. Neither is it likely that mackerel breed successfully in the northern side of the Bay of Fundy for neither eggs nor larvae have been taken there though some production may take place on the Nova Scotian side for Huntsman reports eggs at the mouth of the Annapolis River. And while a moderate amount of spawning takes place along the outer coast of Nova Scotia,[53] it seems that the eggs do not hatch in 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 (p. 322).

Since the large adult mackerel tend to keep farther offshore than the small ones (p. 328), such of them as spawn in our Gulf do so at least a few miles out. Very few eggs, for example, were found in 1897 (a year of plenty) in the inshore parts of Casco Bay,[54] though this was formerly thought to be a productive spawning ground.

Once the mackerel have entered our Gulf, schools are to be expected anywhere around its coastal belt, at any time during the summer- also on Nantucket Shoals, on the western part of Georges Bank, and on Browns Bank, as just noted (p. 327). And while adult fish seldom venture within the outer islands or headlands, good catches of them have been made well up Penobscot Bay, and young ones 6 to 10 inches long often swarm right up to the docks in various harbors in summers of plenty.[55]

Mackerel are proverbially unpredictable in their appearances and disappearances at any particular place, hence the common saying that "mackerel are where and when you find them." This is partly because the schools are constantly on the move, but partly because it is only while they are schooling at the surface or near it that they are seen.

When they sink to lower levels in the water, as they often do, they drop out of sight entirely, unless some of them chance to be picked up by drift netters. Large mackerel are more prone to disappear in this way than small ones, especially in late summer or early autumn. In 1906, for example, the schools of large fish vanished from the Massachusetts Bay region in June, to reappear the 27th of July, on which date 28 seiners made catches ranging from 18 to 250 barrels each. And in 1892, a year of abundance, they disappeared (that is, sank) in August, not to appear again in any abundance anywhere in the Gulf of Maine until October.

The view has grown that when this happens the mackerel have deserted the Gulf for the time being. But it was common knowledge in the days before the introduction of the purse seine, when it was the regular practice to lure the fish to the surface by throwing out ground bait, that large mackerel summer as regularly in the Gulf as small, and that good hook-and-line catches of large fish could be made in one or another part of the Gulf through the season from June to October, even when none showed at the surface.

Their disappearances in summer merely mean that the fish have sought lower levels in the water; that they have wandered to some other part of the Gulf; or perhaps that the schools have dispersed more or less. When they sink in summer in our Gulf, it is not likely that they descend very deep. In the first place the water deeper than about 40 to 50 fathoms is colder than 46°-47° F. (8° C.), i. e., than they seem to prefer; in the second place the planktonic animals on which they feed are more concentrated above the 50-fathom level than deeper. And a year comes, now and then, when mackerel of all sizes school at the surface all summer long.[56]

Sette's[57] painstaking analysis of the relative frequency with which schools are seined in different localities has shown that mackerel are seen far the most often in the southwestern part of the Gulf and out along the western part of Georges Bank, with the chief concentrations in one part or another of Massachusetts Bay and off the outer shore of Cape Cod to Nantucket Shoals, though great numbers are also caught along the Maine coast, close inshore.

Mackerel contrast in an interesting way with herring in this respect, the latter being caught in by far the greatest numbers in the northeastern corner of the Gulf, i. e., just where there usually are fewest mackerel. But there is much variation from year to year in their relative abundance from place to place as appears from the following table of catches, made in two successive years when the total landings from the Gulf, as a whole, did not differ greatly (landings at Boston, Gloucester, and Portland by the vessel fishery, stated in pounds).

Fishing grounds	1916	1917
Georges Bank	3,701,597	624,086
South Channel	77,157	13,600
Nantucket Shoals	2,516,414	6,277,830
Off Chatham	2,017,753	3,938,452
Off Race Point	99,250	621,751
Stellwagen Bank	1,559,972	519,550

In some years few mackerel are seen at the surface in the Gulf eastward of the Isles of Shoals, 1926, 1927, 1933, 1934, and 1935 were examples. In other years, however (e. g., in 1928, 1929, 1930, 1931, and 1932) many schools are sighted and seined along the coast of Maine as far eastward as the vicinity of Mount Desert Rock (see fig. 176, based on Sette's painstaking analysis). But the experiences of the old time hook-and-line fishermen suggest that the mackerel tend to move northward and eastward in general from the Massachusetts Bay region, for they made their best late-summer and early-fall catches between Cape Elizabeth and Mount Desert Rock in most years, notably about Monhegan Island. And the results of hook-and-line fishing are a far better clue to the presence or absence of mackerel than the seine catches are, since they draw from the fish that are deep down, as well as from those that may chance to be at the surface.

The Nova Scotian side of the Bay of Fundy has been a profitable mackerel ground, occasionally, but only for short periods and at long intervals. Thus good catches were made there for some years previous to 1876, but this fishery was abandoned a few years later for want of mackerel. There were enough fish there again in the early 1900's to yield about 7 million pounds in the 6-year period 1901 to 1906.[58] But we have not heard of any large catches made anywhere in the Bay of Fundy since that time, so events of the sort must be out of the ordinary. And very few mackerel are ever reported along the New Brunswick side of the Bay.

In most years, mackerel are few over the central deeps of the Gulf (fig. 176), but a year comes now and then when they are plentiful there, as happened in 1882 (a year of great abundance), when great numbers were caught between Georges Bank, Browns Bank, and Cashes Ledge, and thence northward to within 40 miles or so of the Maine coast. Most of the early season catch, in fact, was made in this deep water region that year, and in the weirs along the west coast of Nova Scotia. But the fish disappeared thence later in the season. And large catches have never been reported from the eastern part of Georges Bank to our knowledge.

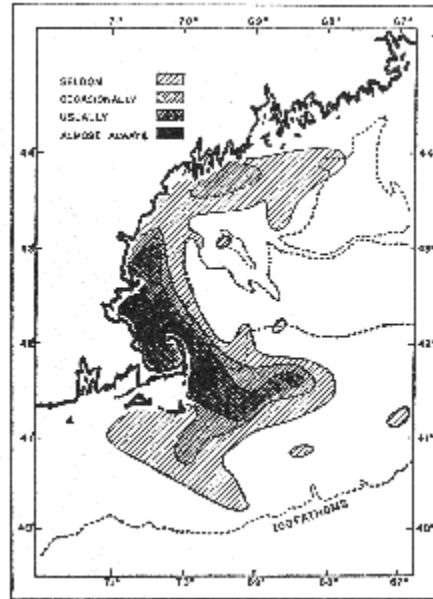


Figure 176. - Average distribution of mackerel in the Gulf of Maine, July through September, based on relative frequencies of catches recorded for each 10-mile rectangle, 1926 through 1935. After Sette.

As a rule, the schools tend to stay nearer the coast in years when small (i. e., young) fish dominate the population. The entire Gulf of Maine catch, for example, was taken within 45 miles of [page 330] land in 1926, when the stock was dominated by fish hatched in 1923, i. e., were in their third year. In years of this sort, anglers fishing in harbors, or going out in charter boats for the day, do well, catching the smaller sizes chiefly. But in 1928, when the same year class dominated as had in 1926 (i. e., fish now in their fifth year), only about two-thirds of the catch was made that close in, with about one-third of the catch taken more than 45 miles out at sea. Nineteen twenty-nine may serve as another example, with more than one-half (57 percent) of the large fish caught more than 45 miles out, but less than 1 percent of the small ones, and a few large ones, taken as far out as 80 miles. But even the fully grown fish do sometimes come close inshore; we have ourselves caught mackerel within a few yards of the beach in the southern side of Massachusetts Bay, as large as any that we have seen taken anywhere.

Fishermen have long realized that mackerel are most likely to be found where there is a good supply of "red feed" (copepods) or other small animal life in the water. A relationship has, in fact, been found to hold in the English Channel between the catches of mackerel and the numbers of copepods present.[59] And while no attempt has been made yet to relate the local abundance of mackerel in our Gulf, or the depths at which they swim with the supply of food on a statistical basis, the mere fact that they do fatten in our waters is evidence enough that they manage in some way to congregate where food is plentiful. But it appears that their vernal journey, from their wintering grounds to the Gulf and to Nova Scotian waters, is directed by some impulse to migration more definite than the mere search for food. Thus while a large proportion of the mackerel did travel along the zone of abundant plankton in the only year (1930) when their advance along the coast has been compared with the quantitative distribution of the animals on which they prey,[60] they deserted the waters south of New England that year while the food still was abundant there, for regions (Gulf of Maine and eastward) where there is no reason to suppose that feeding conditions were any better at the time.[61]

As autumn draws on, the fish that summer along the Maine coast (chiefly belonging to the southern contingent) seem to work back southwestward toward Cape Cod, for catches were made successively off Portland, near Boon Island, and off Cape Ann, in the days when mackerel were caught on hook and line. It is probable, too, that such of the fish from the northern contingent as have entered the Gulf in the eastern side join in this general autumnal movement around the coast to the westward and southward, rather than that they leave by the route along which they enter, for schools have often been reported, and actually followed, swimming southward at the surface across Massachusetts Bay. And while reports of this sort are likely to be based on misconception,[62] they are corroborated in this instance by the fact that the latest catches are always made either in or off Massachusetts Bay, along the outer shore of Cape Cod, or on the neighboring parts of Nantucket Shoals, never either on Georges Bank, which would be on the direct route of any fish swimming westward from Nova Scotia, or in the inner parts of the Gulf of Maine.

Sette's studies indicate that the bulk, at least, of the mackerel of the southern contingent have moved out of the Gulf around Cape Cod and past Nantucket Shoals by late September or October in most years. But many of the fish of the northern contingent coming from Nova Scotia, and perhaps even from the Gulf of St. Lawrence, usually provide good fishing off Cape Ann and southward through October and late into November,[63] with good commercial catches until mid-December in some years. In 1913, for example, 1,200 mackerel were caught off Gloucester on December 10; 3,000 off Chatham, Cape Cod, a day or two earlier; and nearly 1,000 barrels (200,000 pounds) were seined off the Massachusetts coast during the early part of that month in 1922. In mild winters schools of mackerel are sometimes reported and even caught off the outer coast of Nova Scotia as late as Christmas time; i. e., somewhat later than off Cape Cod. But the [page 331] whole body of Gulf of Maine, Nova Scotian, and Gulf of St. Lawrence mackerel have withdrawn thence by the end of December at the latest, except for odd stragglers. And when they do depart, they must sink at once to lower levels in the water, for schools are never sighted on their journey offshore and southward; they simply drop out of sight.

Abundance

It has been common knowledge since early colonial days that mackerel fluctuate widely in abundance in our Gulf from year to year, perhaps more widely than any of our other important food fishes, with periods of great abundance alternating with terms of scarcity, or of almost total absence. In good years the fish may appear in almost unbelievable numbers; schools or associations of schools, miles in length, are reported; and it is common to see 50 or more separate bodies of fish from the masthead at one time. Mackerel, in short, seem to be everywhere, and a tremendous catch is made. But perhaps only an odd school will be seen here and there the next year, and the fishery will be a flat failure.

The period from 1825 to 1835 was one of abundance. In 1831, for example, more than 380 thousand barrels (76 million pounds) of salt mackerel (in those days most of them were salted) were landed in Massachusetts ports. But mackerel were scarce for the next 8 years (1837-45), only 50,000 barrels being landed in Massachusetts in 1840. The Massachusetts catch then fluctuated violently from 1851, when the landings rose once more to 348,000 barrels, down to 1879. The fleet brought in something like 294 million fish from Nova Scotian and United States waters combined in 1880. And this introduced a period of extraordinary abundance, culminating in 1885 when the catch reached the enormous total of 500,000 barrels (100,000,000 pounds). But this was followed in its turn by a decline so extreme, so widespread, so calamitous to the fishing interests, and so long continued, that the catch was only about 3,400 barrels (equivalent to 582,800 pounds of fresh fish) for the entire coast of the United States in 1910 (when the stock of mackerel fell to its lowest ebb) with almost none reported in Massachusetts Bay or along the Maine coast.

Mackerel then increased again in numbers; slowly at first, then more rapidly, as appears from the fact that the catch for the Gulf of Maine and for the banks at its mouth was about four times as great in 1911 (about 2½ million pounds) as it had been the year before, rising to about 41/3 million pounds in 1912, 5 million in 1913, 7½ million in 1914, to something more than 11 million in 1915, and 16 to 161/3 million each for 1916 and 1917. But this period of multiplication fell far short of equaling the banner years of the 1880's. And the catches fell off again so rapidly after 1917 that the Gulf of Maine yield for 1919[64] was only about one-quarter as great as it had been in 1917. Although 1920 saw some slight recovery, 1921 (with a local catch of only about 1 million pounds) proved the worst mackerel season for our Gulf since 1910. The stock then built up enough (following the familiar seesaw pattern) for the Gulf to yield about 25 million pounds of mackerel in 1925. Since that time down to 1946, the Gulf of Maine catch has ranged between a low of about 20 million pounds (1937) and a high of about 59 million (1932). Thus the catch of mackerel in our Gulf may be 50 to 100 times as great in a good year as in a poor. The average Gulf of Maine catch for the period 1933-1946 was about 37 million pounds, yearly.

Various far-fetched explanations have been proposed for these astounding ups and downs in the catches from year to year, such as that the fish have gone across to Europe; have sunk; or have been driven away or killed off by the use of the purse seine. Actually, these changes reflect the ups and downs in the numbers of the fish that are in existence from year to year. Mackerel, in short, were extremely plentiful in 1885, very scarce in 1910, moderately plentiful in 1916 and 1917, very scarce again in 1921, and they have been moderately plentiful since about 1925, but probably not so plentiful as they were in the 1880's.[65]

It has long been known for the herring and for some other species that the prime factor in determining the abundance of the fish is the comparative success of reproduction from year to year, years favorable to the production and survival of larvae presaging several seasons of abundance, or vice-versa. And comparison of the relative proportions of mackerel of different sizes (that is, of different ages) in the total catches from year to year has shown that this is equally true of the [page 332] mackerel.[66] When there is an abundant crop of young mackerel, the fishing is good during the next several years, but the catches then fall off, if another good brood does not soon appear upon the scene. The course of events since the low point in 1910 may then be reconstructed about as follows:

In 1910, when the stock of mackerel was at its lowest, most of the fish caught were large, suggesting that few young had survived for several years past. Unfortunately, no information is available as to the composition of the population from the point of view of size for the next three years, when the catch was progressively somewhat larger, but great numbers of small fish, (apparently yearlings), were reported in 1912, pointing to a good breeding season in 1910, in 1911, or in both. In 1914 fish smaller than 1½ pounds again formed nearly 60 percent, by weight, of the catch in and off the Gulf of Maine, and approximately 80 percent in 1915, with an even greater preponderance in actual numbers between small (young) fish and large (old). These little fish, hatched during the period 1910 to 1912 or 1913, were responsible, as they grew, for the fairly good catches made in the Gulf in 1916 and 1917.[67] But the production of fry must have been very poor in 1916 and 1917, for the Gulf of Maine catch was only about one-seventh as great in 1919 as it had been in 1916. And reproduction must have practically failed in 1918 or in 1919, for the mackerel caught in 1920 ran very large, both south of New York that spring, and in our Gulf during that summer and autumn.

The population was now back again in about the same state as it had been in 1910, the cycle having run through a period of 10 years. The parallel goes further, too, for 1921 must have seen a wave of production to account for the swarms of small fish that appeared along the New England coast from Woods Hole to Mount Desert during the summer of 1922. This again presaged a great increase in the catches of mackerel for the next few years to come (more than 11 million pounds were taken in the Gulf of Maine in 1923). And Sette's studies show that 1923 was another productive year, resulting in a catch more than twice as great in 1925 as it had been in 1923, and about 3 times as great in 1926.[68] the very large catch of about 59 million pounds in the Gulf in 1932 was preceded similarly by the presence of great numbers of yearlings in 1929, evidence of successful reproduction in 1928.

Thus, it seems that the proportion of fish of different ages in the catch in any one year may be used as a basis for predicting the success or failure of the run of mackerel for the next year; such predictions have in fact been attempted by Sette[69] with fair success.

No record has been kept, so far as we know, of the relative numbers of mackerel of different ages, of late years. But a failure of reproduction, followed by a slump in the catch, may come at any time, for history has a way of repeating itself, especially where fishes are concerned.

Nothing definite is known as to what determines the success or failure of reproduction of the mackerel in any given year. Towsings by the U. S. Bureau of Fisheries make it likely that the actual production of eggs is usually sufficient. But the vitality of the eggs spawned in any given year goes back to the physiological condition of the parents. And studies of the composition of the stock of fish in periods of high production and of low suggest that there is some correlation between the number of adult mackerel existing in the sea at any time, and the success with which they breed, for it seems that years when great numbers of fry survive always fall when the parent fish are scarce, average large, and also average very fat (by general report).

One hypothesis is that the mackerel tend to grow fast when there are only a few of them and go into the winter in excellent condition, hence are able to produce eggs of high vitality and in abundance; but they do not fare so well individually when plentiful, hence, do not emerge from their winter quarters in as good physiological condition in spring, so that fertilization and incubation may be less successful, and such larvae as hatch may be less strong. On the other hand, all this may be insignificant as compared with the success or failure of the larvae in surviving the dangers and difficulties of subsistence that confront them. Onslaughts by enemies, [page 333] abundance and ready availability of food, temperature, and salinity of the sea water all act upon the young fish to make their existence precarious; a favorable environment depends on a happy combination of all these.

Importance

The mackerel is a delicious fish, but it does not keep so well as some other fishes that have less oil in their tissues. When mackerel are rather plentiful they are one of the four most valuable fishes of our Gulf commercially, surpassed in dollar value only by the haddock, cod, and rosefish, as appears from the following table of landings in New England for the years 1943-1947.

When the fishery fails, as it does periodically through periods of several years (p. 331), the value of the catch decreases accordingly, and to a point where it is only a negligible fraction of the total yield and value of the Gulf of Maine fishery.

Species	1943	1944	1945	1946	1947
Haddock	\$8,650,000 (1.1)	\$7,550,000 (1.2)	\$7,000,000 (1.4)	\$8,800,000 (1.2)	\$8,900,000 (1.3)
Cod	\$4,000,000 (1.2)	\$3,500,000 (1.5)	\$4,280,000 (1.3)	\$3,940,000 (1.4)	\$2,780,000 (1.4)
Rosefish	\$4,350,000 (1.1)	\$4,300,000 (1.1)	\$3,840,000 (1.3)	\$4,750,000 (1.7)	\$4,200,000 (1.4)
Mackerel	\$3,180,000 (1.1)	\$2,400,000 (1.3)	\$3,160,000 (1.3)	\$2,340,000 (1.1)	\$2,000,000 (1.2)

Note.- the total value of the catch landed in Maine, New Hampshire, and Massachusetts, including fish from grounds outside the Gulf of Maine, as well as from within the Gulf, may be obtained by multiplying the values by the figures in parentheses.

Most of the mackerel were caught formerly with hook and line, ground bait being thrown out to lure the fish close enough to the vessel.[70] But this way of fishing was gradually given up about 1870, when the use of the purse seine became general. And practically the entire catch of mackerel of the past 70 years has been made with purse seines, with pound nets, weirs and floating traps coming second, and gill nets a poor third. In 1943, for example, when the total Gulf of Maine catch was between 53 and 54 million pounds, about 80 percent was taken in purse seines; between 12 and 13 percent in pound nets, weirs, and floating traps; and between 3 and 4 percent (between 1 and 2 million pounds) in gill nets (anchored or drifting), but only 1,700 pounds on hand lines. Otter trawlers, too, bring in scattering mackerel from the offshore banks: 2,400 pounds, for example, in the year in question.

Many anglers, also, troll or bait-fish for mackerel all along the coast from Cape Cod to Penobscot Bay; as far as Mount Desert if mackerel are on the coast that far east. In good years it is not unusual for 3 or 4 anglers fishing from a party boat to bring in one or two hundred fish. And 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 pickerel spinner, No. 3, 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 a white piece of clam, a piece of mackerel belly, or on a sea worm (*Nereis*), especially if attracted by ground bait.

[94] Hunt (*Copeia*, No. 117, pp. 53-59, April, 1923) describes the variations in these stripes among young mackerel.

[95] This interesting fact seems first to have been reported by Hall (*Amer. Jour. Physiol.*, vol. 93, 1930, pp. 417-421), and we have observed the same thing in the aquaria at the Woods Hole Oceanographic Institution.

[96] *Fish. Bull. U. S. Fish and Wildlife Service*, vol. 51, Bull. 49, 1950, p. 264.

[97] *Bull. U. S. Bur. Fish.*, vol. 28, 1910, Pt. I, p. 287.

[98] Fish. Bull. U. S. Fish and Wildlife Service, vol. 51, Bull. 49, 1950, p. 267.

[99] For observations on the visual transparency of the water of our Gulf, see Bigelow, Bull. U. S. Bur. Fish., vol. 40, Pt. 2, 1927, p. 822

[1] See Sette, Fish. Bull. U. S. Fish and Wildlife Service, vol. 51, Bull. 49, 1950, p. 267, for further discussion of this point.

[2] Sette (Fish. Bull. U. S. Fish and Wildlife Service, vol. 51, Bull. 49, 1950, p. 257) mentions one winter record from about 40° (4.5° C.) on Georges Bank.

[3] Lebour (Jour. Mar. Biol. Assoc. United Kingdom, vol. 12, N. Ser., No. 2, 1920, p. 305) gives diet lists for 90 larval mackerel ranging from 5 mm. to 13.5 mm. in length, taken in the English Channel.

[4] Nilsson (Publ. de Circ., Conseil Perm. Internat. Explor. Mer, No. 69, 1914) gives a similar list for Swedish waters.

[5] the mackerel has long rakers with spines on the foremost gill arch only, and these are not fine enough to retain the smallest organisms. See Bigelow, Bull. U. S. Bur. Fish., vol. 40, Pt. 2, 1926, fig. 42 C, D for photographs of the gill rakers.

[6] Nature, vol. 108, 1921, pp. 12-13.

[7] Sette (Fish. Bull. U. S. Fish and Wildlife Service, vol. 51, Bull. 49, 1950, pp. 259, 262) reports some fat mackerel in winter.

[8] See Sette (Fish. Bull. U. S. Fish and Wildlife Service, vol. 50, Bull. 38, 1943, pp. 158-164, and especially fig. 3) for discussion of spawning seasons and temperatures, and the relative importance of different spawning areas.

[9] See Sette (Fish. Bull. U. S. Fish and Wildlife Service, vol. 50, Bull. 38, 1943, pp. 158-163) for a more detailed statement.

[10] Brice, Manual of Fish Culture, 1898, p. 212; Moore, Rept. U. S. Comm. Fish. (1898) 1899, p. 5; Bigelow and Welsh, Bull. U. S. Bur. Fish., vol. 40, Pt. 1, 1925, p. 208.

[11] Sette, Fish. Bull. U. S. Fish and Wildlife Service, vol. 50, Bull. 38, 1943, p. 165.

[12] A series of Gulf of Maine eggs measured by Welsh were about 1.1-1.2 mm. in diameter, with an oil globule of 0.3 mm.

[13] Jour. Gen. Physiol., vol. 16, 1933, pp. 841-857.

[14] they shrink somewhat when preserved.

[15] See Sette (Fish. Bull. U. S. Fish and Wildlife Service, vol. 50, Bull. 38, 1943, pp. 173-178) for detailed statistical analysis of these.

[16] See Ehrenbaum (Rapp. et Proces Verb., Conseil Perm. Internat. Explor. Mer. vol. 30, 1923, pp. 21, 25) for a discussion of the early growth rate of the European mackerel.

- [17] Bigelow and Welsh, Bull. U. S. Bur. Fish. vol. 40, 1925, p. 204.
- [18] Sette, Bull. U. S. Fish and Wildlife Service, vol. 50, Fish. Bull. 38, 1943, p. 178, fig. 8.
- [19] Jour. Marine Biol. Assoc. United Kingdom, vol. 30, No. 3, 1952, pp. 549-568.
- [20] Fry spawned in 1927 averaged about 13¾ inches but those spawned in 1928 averaged only about 12¼ inches in their second November according to Sette.
- [21] Publ. de Circ., No. 69, Cons. Perm. Internat. Explor. Mer, 1914.
- [22] Sette, Fish. Bull. U. S. Fish and Wildlife Service, vol. 50, Bull. 38, 1943, p. 156.
- [23] Smith, Report U. S. Comm. Fish (1900) 1901, p. 128.
- [24] Nilsson, Pub. de Circ. No. 69, Cons. Perm. Internat. Explor. Mer, 1914.
- [25] there is a fairly constant racial difference between American and British mackerel (Garstang, Jour. Mar. Biol. Assoc. United Kingdom, New Ser., vol. 5, No. 3, 1898, pp. 235-295), the latter showing a larger number of transverse bars, being more often spotted between them, and more often having 6 dorsal finlets instead of 5.
- [26] Jeffers (Contr. Canad. Biol., N. Ser., vol. 7, No. 16 [ser. A, General No. 13], p. 207) reports that several mackerel were caught in 1929 at Raleigh, on the Newfoundland coast of the Strait of Belle Isle, where none had been seen in recent years.
- [27] Coles, Copeia, No. 151, February 1926, pp. 105-106 records a three-quarter pound mackerel taken at Cape Lookout in February 1925.
- [28] the literature dealing with this subject is very extensive. See especially Goode, Collins, Earll, and Clark (Rept. U. S. Comm. Fish. [1881] 1894, p. 91); Tracy (37th Annual Report, Rhode Island Commissioners of Inland Fisheries, 1907, p. 43); and Sette (Fishery Bull. U. S. Fish and Wildlife Service, vol. 51, Bull. 49, 1950, pp. 268-313) for the American mackerel.
- [29] Gordon, Marine Life, Occ. Pap., vol. 1, No. 8, March, 1950, p. 39.
- [30] Sette (Fish. Bull. U. S. Fish and Wildlife Service, vol. 50, Bull. 49, 1950, pp. 260-261, table 1) lists several such instances besides those cited previously by Bigelow and Welsh (Bull. U. S. Bur. Fish. vol. 40, Pt. 1, 1925, p. 196).
- [31] Three hundred pounds seems to be the largest winter catch definitely reported up to 1951.
- [32] Marine Life, vol. 1, No. 8, 1950, p. 39.
- [33] Fish. Bull. 49, U. S. Fish and Wildlife Service, vol. 51, Fish. Bull. 49, 1950, p. 261.
- [34] Collins, Rept. U. S. Comm. Fish (1882) 1893, p. 273.
- [35] Goode, Collins, Earll, and Clark, Rept. U. S. Comm. Fish. (1881) 1884, p. 98; cited from the Yarmouth, Nova Scotia, Herald, January 2, 1879.

[36] Fish. Bull. U. S. Fish and Wildlife Service, vol. 51, Fish. Bull. 49, 1950, p. 527.

[37] Sette, Fish. Bull. U. S. Fish and Wildlife Service, vol. 51, Bull. 49, 1950, p. 257, Footnote 3.

[38] Ehrenbaum (Rapp. et Proc.-Verb. Cons. Perm. Internat. Explor. Mer, vol. 18, 1914) summarizes what was known of the life history of the European mackerel up to that time. And Steven (Jour. Marine Biol. Assoc. United Kingdom, vol. 27, 1948, pp. 517-539) has recently outlined the chief wintering grounds.

[39] Fish. Bull. U. S. Fish and Wildlife Service, vol. 51, Bull. 49, 1949, p. 261.

[40] the southern trawl fishery is mostly shoaler than 70 fathoms.

[41] Steven, Jour. Marine Biol. Assoc. United Kingdom, vol. 27, 1948, p. 537.

[42] Mackerel do not range that far north.

[43] Cited from Lacépède, Hist. Nat. Poissons, vol. 3, in Buffon, Hist. Naturelle, 1802, p. 32.

[44] Ehrenbaum (Rapp. et Proces Verbaux, Cons. Perm. Internat. Explor. Mer, vol. 18, 1914, p. 13), whose studies of the fish entitle his view to great weight, thinks that the mackerel of northern Europe probably are torpid during part of their stay on the bottom.

[45] Huntsman, Canadian Fisherman, vol. 9, no. 5, 1922, pp. 88-89.

[46] Fish. Bull. U. S. Fish and Wildlife Service, vol. 51, Bull. 49, 1950.

[47] This conclusion, seemingly conclusive, is based on analysis of the size (i. e. age) composition of the mackerel population at various times and places, with some evidence from tagging experiments. The data are too extensive for discussion here.

[48] For further information as to migrations of the northern contingent, see Sette, Fish. Bull. U. S. Fish and Wildlife Service, vol. 51, Bull. 49, 1950, pp. 269, 285.

[49] We have found no positive record of mackerel taken in late summer anywhere south of Delaware Bay, although they are plentiful off this part of the coast in spring. Bell and Nichols, it is true, speak of "mackerel" as found in tiger shark stomachs off North Carolina (Copeia, No. 92, 1921, pp. 18-19), but Dr. Nichols writes us that these were "just Scombroids and probably not *Scomber scombrus*."

[50] See Bigelow and Welsh (Bull. U. S. Bur. Fish., vol. 40, Pt. 1, 1925, p. 206), for details.

[51] Dannevig, Canadian Fish. Exped. (1914-1915); 1919, p. 8.

[52] Subsequent information, and especially the result of tow nettings on the southern grounds in 1929, 1930, 1931, and 1932 (Sette, Fish. Bull. U. S. Fish and Wildlife Service, vol. 50, Bull. 38, 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 (Bull. U. S. Bur. Fish., vol. 4, Pt. 1, 1925, p. 206) believed.

[53] Sparks, Contrib. Canadian Biol. and Fish., N. Ser., vol. 4, No. 28, 1929.

[54] Moore, Rept. U. S. Comm. Fish. (1898) 1899, p. 16.

[55] Sette (Fish. Bull. U. S. Fish and Wildlife Service, vol. 51, Bull. 49, 1950, p. 297) discusses this point further.

[56] 1882 was an example of this.

[57] Fish. Bull. U. S. Fish and Wildlife Service, vol. 51, Bull. 49, 1950, p. 297, fig. 17.

[58] Sette and Needler, Inv. Rept. 19, U. S. Bur. Fish., 1934, pp. 1-48.

[59] Bullen, Jour. Marine Biol. Assoc. United Kingdom, vol. 8, 1908, pp. 269, 302.

[60] Bigelow and Sears, Mem. Mus. Comp. Zool., vol. 54, No. 4, 1939, pp. 259-261.

[61] See Sette (Fish. Bull. U. S. Fish and Wildlife Service, vol. 51, Bull. 49, 1950, p. 302) for a further discussion of the influence of feeding conditions on the movements of the American mackerel.

[62] the successive approach of one school after another to the coast often suggests a long-shore movement of the fish. Thus Kendall (Bull. U. S. Bur. Fish., vol. 28, Pt. 1, 1910, p. 287) tells of an instance when seiners reported "following" the schools continuously eastward along outer Nova Scotia, although the fish taken off Liverpool proved to be of quite different sizes from the catch made later about Cape Breton.

[63] In 1922, for example (Gloucester Times of April 26, 1923), mackerel netters fishing near Cape Ann did well right through November, with a catch of about 1,200,000 pounds (6,000 barrels) for the month.

[64] In 1919, 4,091,345 pounds.

[65] See especially, Sette, U. S. Bur. Fish., Fishery Circular No. 4, 1931.

[66] See especially Sette, U. S. Bur. Fish., Fishery Circular No. 4, 1931.

[67] Gulf of Maine catch, 16,391,095 pounds in 1916; 16,021,619 pounds in 1917.

[68] Gulf of Maine catch, 11,007,676 pounds in 1923; 25,475,876 pounds in 1925; 33,152,766 pounds in 1926.

[69] U. S. Bur. Fish., Fish. Circ., No. 4, 1931; No. 10, 1932; No. 14, 1933; No. 17, 1934; Fishing Gazette, vol. 50, No. 5, 1933, pp. 9 and 21.

[70] See Goode and Collins, Fish. Ind. U. S., Sect. 5, vol. 1, 1887, pp. 275-294, for an excellent account of the hook and line fishery.

Fishes of the Gulf of Maine by Bigelow & Schroeder is the seminal work on North Atlantic fishes. It was originally published in 1925 with William Welsh, a Bureau of Fisheries scientist who often accompanied Henry Bigelow on his research cruises. In the late 1920's, Bigelow began a long association with William C. Schroeder, publishing a number of papers and reports on fishes of the North Atlantic, including the first revision of *Fishes of the Gulf of Maine*. This excerpt is from that 1953 edition.

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