THE UTILITY AND METHODS OF MACKEREL PROPAGATION.

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The esteem in which the mackerel is commonly held as a food-fish and the great importance of its pursuit and capture to a large part of the population of certain sections of New England have naturally caused the welfare of the fishery to be jealously guarded. During the past decade the frequent failure of a season's fishing to earn profits has given rise to a fear that the supply is in danger of speedy exhaustion. It was this supposed danger which several years ago led those who have labored in the interests of improved fisheries to experiment with the artificial propagation of the species. It was hoped that the method which had repeopled so many depleted streams and lakes, which not only saved from extinction but extended the shad fisheries, and which is no doubt destined for still greater triumphs in the future, would be capable of rejuvenating some of our decrepit sea fisheries. Though the evidence is by no means unequivocal, these hopes appear to have had a certain warrant in the cases of two sea fishes, for which suitable apparatus and methods have been devised. It is the purpose of the present sketch to point out what appear to be the possibilities and limitations of the method when applied to the mackerel.

The subject may be stated as two principal problems, viz: (1) Is the alleged scarcity of the mackerel a sufficient reason for believing that the supply is becoming exhausted? (2) If so, can the supply be increased and maintained by recourse to artificial propagation?

A glance at the statistics covering the last twenty years may seem to confirm the gravest fears, for from 350,000 barrels in 1880 and 395,000 barrels in 1881 the catch inspected in Massachusetts fell to 75,000 barrels in 1886 and 18,000 barrels in 1891, since which year there has been some slight increase. Fortunately statistics of the catch covering a long period are available for several of the New England States. The late Dr. Goode has presented, in his "History of the mackerel," a curve showing the number of barrels of salt mackerel inspected in Massachusetts annually from 1804 to 1881, and this exhibit has been extended in the annual reports of the Boston Fish Bureau. The frequent and great changes in the course of the curve, corresponding to variations in the number of barrels, are very striking. But a remarkable regularity in the periodicity of the more important fluctuations is apparent. Thus, great catches were made at intervals of about twenty years, in 1831, 1851, about 1870, and in 1881; the smallest catches alternate with these, namely, in 1814, 1840, 1859, 1877, and 1891. Smaller variations of shorter and less regular duration occur between the larger.

By eliminating these minor irregularities, the great movements and the general tendency of the fishery become more evident. This elimination is accomplished by averaging the annual figures for overlapping periods of ten successive years, beginning with each year from 1820 to 1882. The curve plotted from these results is much more uniform than that exhibiting the annual inspection; it rises and falls regularly and gradually at long intervals above and below a line representing the mean annual inspection of about 230,000 barrels. It also shows that the fishery has not, on the whole, diminished in productiveness. We are therefore justified in assuming, though the hope may prove delusive, that the present period of scarcity will, like all similar ones in the past, be succeeded by a time of plenty. The conclusion follows that the evidence does not point to any necessary or immediate danger of the commercial extinction of the mackerel.

This conclusion may be questioned, on the ground that the catch has held its own only through the increased efficacy of the methods employed. A careful study of the results which have followed some of the more important innovations does not lead to the acceptance of this objection. Many competent authorities have expressed the opinion, which is supported by an array of convincing evidence, that man can exert but little direct influence upon the numbers of those species of fishes which inhabit the open sea. Professor Baird, in writing of the bluefish, shows conclusively that the numbers of this fish have increased and decreased quite independently of the methods adopted by man for its capture, and that man exerts an indirect influence upon its movements in but one respect, namely, by decreasing, through excessive fishing, the available food supply which it derives from the shore fishes. The mackerel, owing to the character of its food, consisting of sand-eels, small crustacea, and other forms not subject to man's direct influence, would seem to be even more independent of the methods of the fisheries than is the bluefish.

It may also be supposed that the greater or less quantities of fish annually captured have been determined by the energy with which the mackerel industry has been pushed. That some of the smaller fluctuations have been due to this cause seems evident, from the fact that during certain years, when the average fares have remained about the same, the catch has been proportional to the number of vessels employed. It is, however, also evident, from the statistics bearing upon this point, that the number and tonnage of vessels employed bear no constant relation to the quantity of fish captured. On the contrary, a very successful year has always stimulated greater interest, and has led to the employment, for several years thereafter, of an increasing number of vessels, while a year of marked failure has diverted vessels and men to other employments. This fact tends to overcome and obscure the evidence which the statistics convey of great and sudden movements in the body of mackerel.

The problem is, however, only shifted. We may feel satisfied that there are no indications of the speedy exhaustion or material reduction of the mackerel supply; but the fact remains that there have been periods, sometimes extending over a number of years, during which the fishery has not paid the cost of operation. It becomes, therefore, extremely important that the cause or causes of these fluctuations should be determined, in order to obtain, if possible, a constant and uniform supply of the fish. It is manifestly just as important to the fishing as to the manufacturing interests that economical regulation of supply and demand should be accomplished. The great evil of the present state of affairs is uncertainty. Capital and labor are attracted or repelled by the appearance of conditions which can not at present be calculated upon beforehand, with a consequent loss in the long run to the fishermen and an increased price to be paid by the consumer.

When the effective causes are fully known the remedy will be indicated; and should it prove to be one impossible of application, it may at least be possible to foretell the prospects of a season and thereby save those interested much disappointment and loss. Many suggestions have been made to account for the fact. Of these we shall consider but four of the most important.

I. It has been contended from time to time, during periods of scarcity, that overfishing or the employment of particular apparatus or methods was to blame. That this theory was advocated even as early as colonial times is evidenced by legislation affecting the methods of taking mackerel which we find recorded in the colonial laws of Massachusetts. With each succeeding period of wane this theory is revived, but its advocates become silent with the advent of prosperity, when the very methods complained of are plied with renewed vigor, or perhaps replaced by more effective methods. The fact that there has been no continuous diminution in the quantity of mackerel taken during the last eighty years, together with the fact of the regular alternation of large and small catches having no casual connection with the employment of new methods, seems to sufficiently dispose of this theory as the sole or even an important explanation. We may quote the weighty opinion of Dr. Goode. He says of the mackerel:

> It seems quite evident that the periods of their scarcity and abundance have alternated with each other without reference to overfishing or any other causes that we are prepared to understand.

The area within which the mackerel is subject to man's influence is but a small part of the vast expanse over which it roams, and the time but little more than half of the year. To one who appreciates the magnitude of the struggle for existence which rages in the ocean, the constant dangers and many natural enemies which beset the mackerel at all times and during every period of its life, the numbers which fall to man must seem but the merest trifle compared to the multitudes which are destroyed by other causes. We may arrive at a reasonable estimate of how insignificant human influence sometimes is by an examination into the history of man's conflicts with the rabbits in Australia, the mongoose in Jamaica, the sparrow in our own country, the locusts and other injurious insects everywhere, etc. On the other hand, there are the cases of the bison, the fur-seal, the great auk, and many other birds and mammals, as well as fresh-water and shore fishes, to bid us be cautious; and we may yet learn that the small numbers (relatively to those which naturally succumb) of mackerel taken by man may turn the balance in the direction of that fish's numerical decline.

II. Infectious diseases may decimate the ranks of the mackerel hosts periodically. This is a possible explanation for which there is absolutely no evidence. Fresh-water and anadromous fishes have been known to be thus destroyed in vast numbers by fungous and other diseases, and a great fatality among the bluefish in the beginning of the century may have had a similar cause; but the subject is an untilled field with regard to sea fishes. The mackerel is almost invariably affected by large numbers of parasites, but these appear to produce no ill effects. No bacterial or other diseases are known. That slight changes in the physical conditions of the sea may destroy life on a stupendous scale is evident from such observed cases as that of the tilefish. If such destruction of the mackerel has taken place the fact has escaped notice.

III. A third and perhaps more worthy suggestion would lead us to seek the solution of the mystery in the effect of environmental influences on the fertility of the species, the relative abundance during one season being the result of greater or less fertility in previous seasons. Or, the actual fertility of the parent fish remaining the same, the physical and other conditions may be such as to destroy the eggs and young in greater or less numbers, resulting in subsequent times of scarcity or plenty. Though there is no direct evidence of variable fertility in the case of the mackerel, many analogous instances are known of seasons of greatly increased or diminished fertility in other groups of animals, of which every observant naturalist has met with many. The young of some of our shore fishes are well known to appear in great swarms during certain seasons and to be unusually scarce in others. In some cases these swarms of young have been observed to appear as larger and larger fish for several successive years, but in other cases their very abundance has proved their destruction by attracting schools of bluefish, which very quickly depleted their ranks.

Besides the lemmings, locusts, army-worms, and many other species among land animals, we may also mention the great swarms of jelly-fishes, salpæ, etc., which appear periodically on our coasts, and the oyster, which, even aside from the question of the fixation of spat, differs greatly in this respect in different seasons. Some of these cases can be proved to be owing to the production of eggs or young in greater or less numbers, others to the greater or less destruction, through unfavorable circumstances, of eggs or young. The records of surface towings made in the neighborhood of Casco Bay show that the number of mackerel eggs present varies greatly. In 1894 they were very plentiful, while during the summer of 1897, although the eggs of other species were present in great numbers, those of the mackerel were almost entirely absent. And this was in spite of the fact that schools of mature fish entered the bay during that time. This result may have been due to the mackerel having spawned further off the coast in 1897 than in 1894. The winds influence the distribution of the eggs by moving the surface waters, but this and similar factors were eliminated in the investigations of 1897.

IV. The last theory to be considered in this connection is one deduced from the well-known wandering habits of the mackerel. Besides periodic movements toward and from the shore, and coastwise migrations which occur in spring and fall, this fish, like many other active pelagic organisms, is in the habit of wandering far and wide over the broad expanse of the North Atlantic Ocean. How extensive these more irregular movements may be in the case of particular schools of fish is not known, but it is supposed that during the periods when our fishermen meet with a scarcity the great body of fish may remain in some region hitherto unknown or inaccessible. They may either be in the open sea far off the coast or remain submerged and hidden.

Everyone knows that within the actual limits of the fishing-grounds the schools are very sensitive to changes in conditions, and so long as many of the influences which affect them remain unknown their movements seem to us to be mysterious and capricious. The fishing, both with line and seine, may be exceedingly good in certain localities for a few days, when suddenly, even in the midst of their abundance, the fish may "strike off" almost without warning, and either totally disappear, or apparently the same school reappears at some distant point.

Mackerel may be present in abundance, but refuse to school or to take the hook; or no mackerel may be visible at the surface, yet the occasional rush of schools before the onslaughts of larger predaceous fish or mammals, or other signs, may betray their whereabouts, and though plenty, none will be caught. These conditions may characterize a part or the whole of a season. During particular seasons the best fares may be taken in the spring; during others, in the fall or in midsummer. Sometimes the great catches, which have made the total for a season large, have been taken in a few weeks; sometimes the entire season has been uniform in its results, either good or bad, as the case may be.

Again, seasons may be characterized by marked differences in the distribution of the fish. One time the best catches will be secured in the Gulf of St. Lawrence; at another time in the Gulf of Maine, and, again, in the waters about Cape Cod. Sometimes the best fishing may be inshore, and the trap-owners will reap a harvest; sometimes it will be farther off the coast, and the seiners will enjoy a monopoly. It has frequently happened that for a period of years one part of the coast has been affected very differently from others. For many years the Gulf of St. Lawrence was a favorite resort of American mackerel men, but it now seldom repays the trouble of a visit. The Bay of Fundy, though formerly productive, has not supported a mackerel fishery for twenty years.

All of these facts and many others show that the movements of the mackerel are as changeable as the weather and in the present state of our knowledge just as uncertain. The success of the fleet in any given year is no certain criterion of the abundance of mackerel during that year, and it is only by taking the averages for a number of successive years that the real state of the fishery can be apprehended. There is also some direct evidence of the existence of large numbers of mackerel even in seasons which have been failures. The summer of 1877 will be remembered as one of the most disastrous that the mackerel men have known since the beginning of the century; yet in that year was seen what was probably the greatest single body of mackerel ever recorded, estimated by an experienced captain to contain 1,000,000 barrels, a number about twice as large as the entire fleet has ever taken in one year. This would seem to indicate that instead of the schools being scattered so as to come under the observation of fishermen, many of them were congregated into this vast, roving body. A few similar bodies, which might easily escape observation, would explain the apparent scarcity that year, and the successful spawning of these would account for the great host which visited Massachusetts Bay in 1880 and spread along the New England coast in the following year, when the catch was unprecedented.

Now, it has very justly been pointed out that these known facts respecting the more local movements of the mackerel, which are the cause of many of the minor variations in the catch, argue forcibly that similar fluctuations of larger degree are explained by migrations of greater scope. When the center of distribution of the mackerel hosts falls within our waters, there is a plenty; when it falls elsewhere, the degree of scarcity corresponds with its remoteness. In this connection it remains to point out that the mackerel, unlike anadromous species, is not constrained to visit the coasts by the impulse to spawn, but that this process may and frequently does take place in the open ocean, far from land.

Some of the factors which determine the movements of the great body of mackerel are known, some are unknown. Of the known factors the most important is the distribution of the pelagic organisms which serve as food for the species. But this again is determined by temperature, winds, currents, precipitation, and many other factors. Though the incompleteness of our knowledge leaves the question of variable numbers still open, we are probably safe in the tentative conclusion that migrations and variable fertility are two of the more important factors which enter into the solution of the problem. If these are among the causes, have we the remedy? We can not hope to control the migrations, though we may learn how to follow the mackerel in its wanderings or to take it from the depths. The possibility of developing new local schools by artificial means may be suggested, but this would be a weighty task, and, moreover, the same influences which led the old schools to migrate would probably affect the new. But if we set this supposition aside it remains for us to inquire if there is any probability that the desired result of uniformity in the supply can be effected by artificial propagation.

The problem is a complex one and difficult of adequate treatment. In the first place, if the truth of the above contention, that the mackerel has probably adjusted itself to the fisheries and that its numbers have in consequence maintained a fairly even balance be admitted, then it follows that each generation must produce a number of eggs sufficient, when all deductions for casualties are made, to give rise to an equal number of mature breeders. That is, the number of breeders must remain practically constant in successive generations. As in the mackerel the two sexes are about equally divided in numbers, it also follows that from all of the eggs annually produced by a female but two on the average grow to be breeding fish. The total number of eggs produced by a mackerel during the spawning season has been variously estimated at from 363,000 to 680,000. Let us fix the average number near the lower limit. There results the conclusion that about 200,000 eggs are required, under natural conditions, to produce one breeding fish.

The average annual catch of the Massachusetts fleet is about 230,000 barrels, representing roundly, according to a somewhat hasty estimate, about 32,000,000 fish of three years and older, 23,000,000 of two years, and 12,000,000 of one year. The first are all fish of breeding age, and perhaps some of the two-year-olds also are. The poor catch of the year 1877 fell below this average to the extent of about 21,000,000 fish of the largest size and 8,000,000 two-year-olds, while of younger fish the average was just equaled. Suppose that the problem is to make good this deficit by artificially propagated fish and that for the sake of clearness we leave out of consideration any disturbing factors. In order to produce this result, a sufficient number of eggs must have been handled in 1874 to produce, three years later, 21,000,000 mature fish; and in 1875 to produce, two years later, 8,000,000 fish of the size usually classed as No. 3's. And this leaves out of consideration the number of fish which would have been destroyed by the fisheries and other causes in the interval between 1874–1877, as well as the obvious fact that of those which survived only a small part would be taken by the fishermen. To make good this shortage for 1877 by the natural processes of spawning, under average conditions would require a number of eggs equal to 21,000,000 multiplied by 200,000.[1]

The year taken (1877) is, of course, an extreme case, though the present decade has seen much worse; but the goal which should be aimed at in our fishery development is to supply the entire quantity consumed in this country. Besides, the year 1874, when this hypothetical experiment in practical propagation is supposed to have been begun, was particularly favorable to its successful issue. The Massachusetts inspection passed 180,000 barrels of Nos. 1 and 2, or about 50,000,000 of fish large enough to be breeding. Now, suppose that one-half of these were males and that one-third of the fish were taken in actual spawning condition. Let us further assume that all of these 8,500,000 spawning females were actually stripped and the entire yield of eggs utilized. It is peculiar of the mackerel and many other active fishes that only a portion of the eggs produced in the season mature at one time. The mackerel yields on the average, when stripped, about 40,000 eggs. This would give a total number of eggs secured of 8,500,000 multiplied by 40,000, or 340,000,000,000.

[1] It is, of course, understood that the 21,000,000 includes fish of several ages. In the calculation all are regarded as being 3 years old, owing to the absence of any data upon which to base a separation among those of 3 years and older. The writer's personal examinations of mackerel for several years past convince him that the number of mackerel of 3 years of age captured is at least equal to all those of greater age combined, making a very liberal allowance in favor of the latter. The result of the calculation would not, therefore, be materially affected.

Now, suppose that all of these eggs were hatched, which would be a triumph of fish-culture beyond our wildest dreams, and that the 340,000,000,000 of larvæ were liberated under the usual conditions; it is evident that from now on they must be beset by the same dangers and suffer the same losses as their fellows hatched under natural conditions. In the latter case it has been shown that it takes 200,000 eggs to produce one breeding fish. As we do not know just in what period of life this destruction of 199,999 out of every 200,000 takes place, we are forced to make a guess. Let us make one which can be proved to be liberal, and suppose that 75 per cent of it occurs while the embryo is developing in the egg, during a period at most of six days, and only 25 per cent during the remainder of the three years. According to this, 50,000 newly hatched larvæ would produce one mature fish of the average spawning age. Dividing the 340,000,000,000 by 50,000, we get 6,800,000—a figure which, even under a series of hypothetical conditions ridiculously favorable, is below the desideratum. The figures given are, of course, only approximate, and in one case a liberal guess, but they give some idea of the magnitude and difficulties of the undertaking.

Let us now see what has actually been accomplished. Repeated experiments have been conducted—both abroad and especially by the United States Fish Commission for several years past—in the hope of successfully propagating the mackerel. The eggs, like those of the cod and other marine fishes, are buoyant in water of the density of the open ocean, and the same apparatus has been used in this country as for the very successful cod hatching. The several forms of Chester and McDonald tidal boxes have been used with results which have been practically uniform for all. For the purpose of automatically changing and freshening the water, the principle of a tidal rise and fall induced by an intermittingly acting siphon is used. The eggs after fertilization are placed in a receptacle, either an open box the bottom of which is made of cheesecloth, or a cylindrical jar the open end of which is closed by cheesecloth, while the bottom is perforated by a hole which permits the ingress and egress of air. The cheesecloth end of either box or jar is supported on a frame fixed at a proper point (about 2 inches below the lowest point to which the water falls) in one of the tidal boxes. By this arrangement the water within the jar or box containing the eggs is made to partake of the same movement, and part of it is drained off and replaced by fresh water with each complete tidal oscillation, while the buoyant eggs float in a layer at the surface. They do not, however, long remain so, but during the course of development become—apparently because of the gradual absorption of the oil drop—gradually heavier, and sink slowly toward the bottom. Here they lie in the midst of a mass of filth, which quickly collects, and, cut off from the light and air, sooner or later succumb. A few will usually hatch, but the larvæ do not long survive. Attempts have been made to overcome this difficulty by increasing the density of the water, or by the use of shallow dishes in which the eggs are more directly exposed to the light and air. Both of these methods gave somewhat encouraging results, but the experiments could not be carried to a conclusion. Experiments with the ordinary tidal apparatus have been frequently repeated under varying conditions, but have almost always resulted in complete failure.

The only important exception to this statement is to be found in the results reported during the past summer by Mr. Corliss, of the United States Fish Commission station at Gloucester. According to this statement, out of about 1,000,000 eggs handled 450,000 were hatched. To explain the mortality it has been suggested that this result is due to imperfect fertilization, itself the outcome of some lack of vitality in the egg or spermatozoan; and while this is generally attributed to injuries received in capture, attention may be directed to the suggestion that the periods of scarcity may be in part due to lowered vitality and fertility of the fish. In this case it is obvious that to attempt artificial propagation while the condition lasts would be a waste of time.

But this explanation probably fails to reach the root of the matter, as a study of the spermatozoa and eggs before and immediately after fertilization indicates, by the activity of the former and the response of the latter, a good vital condition. Fertilization is very easily accomplished, and the rhythm of development is strikingly constant and simultaneous in all of the eggs of a batch. The unfavorable condition must be sought in the method of propagation, and many facts point to the conclusion that the shore waters utilized for the purpose lack the physical qualities, and the apparatus fails to supply certain important conditions requisite to the healthy development of the eggs. To this conclusion are opposed the results reported from Gloucester Station, and these, together with the partial success of experiments with water of increased density, lead to the hope that the mackerel may some day be successfully hatched.

There is, however, a further serious practical difficulty to be encountered. Even were artificial propagation as successfully accomplished with the mackerel as with the cod, and 50 per cent of the eggs handled turned out as fry, could the demands imposed by the figures given above be met? During the season of 1896 the collection of mackerel eggs was pushed with great vigor by the United States Fish Commission, with the result that about 23,000,000 eggs were taken, a number which, even if all were hatched and deposited under the most favorable conditions, would fall many times short of producing 21,000,000 fish three years later. In 1897 less than 4,000,000 were obtained, although every effort was made to conduct operations on a large scale.

These difficulties have led to the proposal that suitable arrangements be made with the captains and owners of seining vessels by which one or more spawn-takers (probably members of the crew would serve) would accompany each vessel during the spawning season. Upon the capture of a spawning school vast numbers of eggs could be taken, immediately fertilized, and turned overboard under the best natural conditions for further development.

The method has several obvious advantages—(1) great numbers of eggs which would otherwise be destroyed would be started on the way to future usefulness; (2) it could be applied at small cost, and (3) in one respect it would be a gain over the natural deposition of eggs, in that more certain fertilization would be insured. The facts upon which this last statement is based are founded not upon investigations of the mackerel, but of the cunner, where the gain is about 30 per cent.

One disadvantage of the method would be that the eggs would be endangered by contact with the waste thrown overboard during the splitting operations, and from predaceous fishes thereby attracted. Moreover, in view of the above figures, it seems futile to hope that operations could be conducted on a sufficiently large scale to be of any considerable benefit. If it ever becomes possible to confine the fry until they reach a considerable size, say until after they have assumed the adult form, then it may be possible to secure the supply of eggs in this way, to transport them to a station of great capacity and operating under conditions most favorable to the development of the species, such as would be obtainable upon an ocean-going steamer or an outlying island, and thus to bring about the desired result. But in view of the great area covered by the wanderings of the mackerel, of the vast numbers which inhabit the ocean, and of the peculiar difficulties which have to be overcome, it seems unlikely that propagating operations conducted at a few points along the shore can ever reach that magnitude demanded in order to make them effective.

The conclusions arrived at may be summarized in the following propositions:

1. The total mackerel supply has not been proved to have diminished materially within the present century.

2. The abundance of mackerel has varied greatly within the area of operation of the American fishing fleet.

3. The minor annual variations in the catch are in part due to the local migration of the schools, and in part to the activity with which the fishery is prosecuted.

4. The more important fluctuations are of long interval, and may be represented as waves of elevation and subsidence having a period, during the present century, of usually 20 years. They are normal, in the sense of being independent of the fisheries.

5. The causes of these more important fluctuations are not fully known, but the most probable which have been suggested are, *first*, extensive migrations which carry the body of the fish to and from our shores, and *second*, variable fecundity. These, again, are the result of complex cooperating factors, some known and some unknown.

6. The need is, therefore, not to increase the total number of mackerel, but to render available a uniform portion of the supply each year, or at least to furnish a means of forecasting the prospects of each season—that is, to determine the laws of this periodicity.

7. The method of artificial propagation, even if successfully conducted, is not of proved utility for the mackerel.

8. If artificial propagation is to be of any benefit, it must be practiced on a vast scale, commensurate with the great area over which the American school of fish roams.

9. Owing to the capricious roving habits of the mackerel, it is doubtful if local schools could be established and maintained by the deposition of artificially-hatched fry in the desired localities.

10. With our present knowledge of the subject, the mode of procedure which promises the best practical results with the least expenditure would be to deposit in the water immediately after fertilization the enormous numbers of eggs which can frequently be obtained from spawning schools captured in purse seines. This would at least avoid the most serious injury which falls upon the mackerel as a result of the modern methods of fishing.

11. The problem of the mackerel can not be divorced from the problems of pelagic life in general. When the latter are solved the former, together with many other practical fishery problems, will disappear. The scientific labors of the Fish Commission and of individuals have accomplished much toward this end, but much more remains to be done. In the specific case of the mackerel there is scarcely an important question of its economy upon which fuller knowledge is not required for the practical benefit of the fisheries.

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