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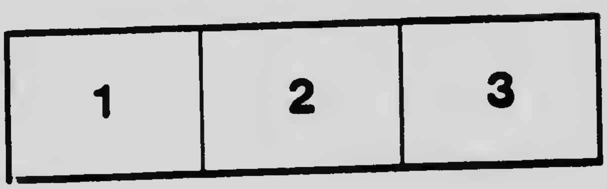

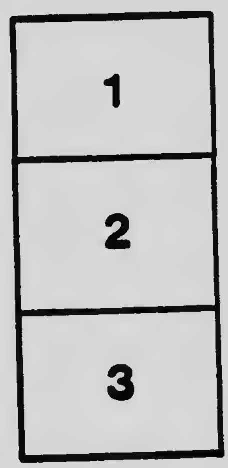

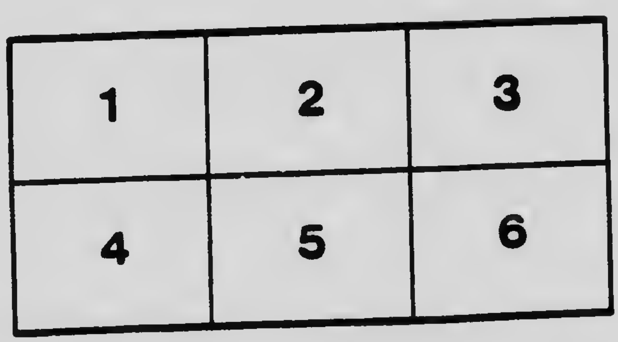

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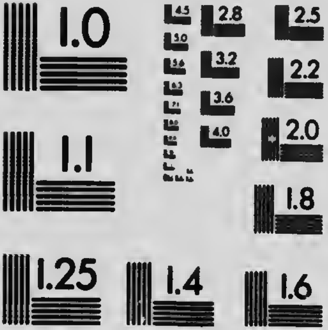

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SPECIAL

APPENDED REPORTS

BY

PROFESSOR E. E. PRINCE

Dominion Commissioner of Fisheries, Ottawa.

1. EGGS AND EARLY LIFE HISTORY OF THE COD, HADDOCK AND MACKEREL.
2. MIGRATIONS OF SEA FISH.

1907-8

OTTAWA
GOVERNMENT PRINTING BUREAU
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CONTENTS.

I.—THE EGGS AND LIFE HISTORY OF THE COD, HADDOCK AND MACKEREL.

BY PROFESSOR EDWARD E. PRINCE, COMMISSIONER OF FISHERIES, OTTAWA.

Complaint has been made that published investigations on fish life and fish habits, for popular information have been too exclusively devoted to fresh water fish and to anadromous species. The salmon, trout, whitefish, black bass and pike-perch or dore have been fully treated in reports and papers for general readers. The cod, haddock and mackerel are three examples of fishes that are of the highest commercial importance and about them readily accessible publications are wanting. It must also be added that scientific and technical knowledge concerning the life history of fishes inhabiting the deep sea is less full and complete than is the case with river and lake fishes and species like the salmon that spend only a portion of their time in fresh water. A considerable mass of information exists respecting the cod, mackerel and haddock, but to learn about the spawning peculiarities, habits of the young, rate of growth, food at different stages and migrations, it is necessary to consult difficult technical treatises and to read scientific journals which are not readily accessible. One of the very few books for general readers published in London in 1897 is the beautifully illustrated work on British Marine Food-Fishes, by Professor W. C. McIntosh and Dr. A. T. Masterman.

Little was generally known about the eggs and life history, the growth and migrations of sea fishes used for food when I began their special study in 1885 at St. Andrews, Scotland, under the guidance of Professor McIntosh, though it was already known, and had been known to specialists for nearly twenty years that cod, haddock and mackerel were wholly unlike the sea herring, and fresh water fishes, both in regard to the nature of their spawn, the features of their breeding, growth and early migrations.

Professor G. O. Sars had begun investigations in the course of which he secured small floating eggs, like minute pellets of glass, but so light and buoyant that they floated near the surface of the sea. The waters surrounding the Lofoten Islands, the famous fishing grounds of the Norwegian cod-fishermen, were filled with these small, almost invisible, floating eggs. Later Dr. Sars discovered other eggs much resembling cod's eggs, which proved to be the very similar eggs of the haddock, and later he obtained the eggs of the mackerel, also floating, rather larger than cods' eggs, and exhibiting a new feature, viz.: a glistening oil-globule. Dr. A. W. Malm, of Göteburg, likewise found the eggs of the haddock and mackerel and described them, while Alexander Agassiz, and the early scientific staff of the United States' Fish Commission (Dr. J. A. Ryder, Dr. R. E. Earll and others) confirmed previous discoveries and extended them very considerably. So inadequately was the importance of Sars' amazing discoveries realized by biologists and by the general public that at the Great International Fisheries Exhibition in London, in 1883, his drawings and descriptions of these floating sea-fish eggs attracted little attention on the whole. On my many visits to that famous and in some respects unsurpassed fisheries exhibition, I never failed to re-examine Dr. Sars' drawings with the accompanying detailed descriptions placed alongside, and on no occasion did I observe brother scientists or interested spectators paying much attention to that unique exhibit. The specimens and drawings were not only unique, they were, from a fisheries point of view, epoch-making. In the official catalogue of the exhibition it is interesting to note that they were carefully described.

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Owing to this special interest I quote from the catalogue the following notice: 'Professor G. O. Sars, development of cod (*Gadus morrhua*) explained by a series of fifty-six coloured drawings on seven plates, made by the exhibitor during his visits to the Lofoten Islands in the years 1865-69.' There were shown 56 accurately drawn figures, Nos. 1-24 showing the ovary, early ovum and first segmentation stages; Nos. 25-36, the formation of the young fish in the egg, and the features of the hatched larva and young cod up to one inch in length; Nos. 37-52, later stages of young post-larval cod, and Nos. 53 to 56, later codling up to adult cod, 20 and 33 inches in length.

The collection was not an imposing display and was overshadowed by the larger and more striking objects displayed in the various sections and galleries, and sent from all quarters of the globe. At the conferences, which were held frequently during the eight or nine months of the exhibition's existence, and which I attended diligently, in order to listen to the great masters in the science of fish and fisheries, very scant reference was made, so far as I can recall, to the astonishing and revolutionizing character of Dr. Sars' specimens, and their importance as practically bearing upon the preservation and welfare of the fishing industries in the sea.

At the commencement of my researches I found that the field was regarded as virgin and practically untouched, so little was generally known about the eggs and the breeding peculiarities of the marine food fishes, which form the staple commodities in the great fish markets of the world. When Professor McIntosh and myself read at the British Association and at the Royal Society of Edinburgh the results of our investigations, they were regarded by the biologists as very novel and of altogether peculiar interest and importance. Full and adequate studies, in continuation of the pioneer work of Dr. G. O. Sars and Dr. A. W. Malm, had not been made of the lilfe histories of the marketable food fishes in the sea. Indeed, until I studied mackerel eggs in the spring of 1893 on the s.s. *Fingal,* and made drawings of the young fry immediately after hatching, no one had seen or sketched the mackerel in its first stages, and those published subsequently by a very able English authority showed colouration and other features not observed by me in the Irish mackerel eggs obtained during the official fishery cruise under H. M. Inspector W. Spotswood Green, in the year named.

The researches above referred to, with later investigations by other workers have shown that:

(1) Cod, haddock and mackerel produce spherical eggs which are typically pelagic, *i.e.,* small in size, extremely delicate in structure and appearance, of glassy transparency and so buoyant as to float freely near the surface of the sea.

(2) The young larvæ emerging from these eggs are as minute as mosquitos or midges, very buoyant and transparent, frequenting the superficial strata of the open sea, and carried helplessly about by the tides and currents, during the earliest part of their life.

(3) The young fishes, as soon as they cease to feed on their stock of food yolk, and actively capture food, migrate in schools incalculably vast, from the open waters, where they are first congregated and find safer areas inshore, often quite close to the shallow beach or the tidal rock-pools.

(4) The later post-larval and adolescent stages are marked in each species by features in their migrations and habits which are not uniform but diverse, and distinctive of the several species.

In the following summarized account I shall describe in each of the four named species:

(1) The mature ovum and its deposition.

(2) The hatching of the ovum and larval migrations.

(3) The features characteristic of the early larval stages.

(4) The post-larval or pre-adolescent stages, often embracing curious developmental transformations.

(5) The maturer stages, not yet adult, and migrations.

(6) The adult condition and habitats in the sea.

The egg of the cod is a spherical buoyant pellet 1·38 to 1·39 mm., or a little over three-fifths of an inch in diameter, and of such colourless transparency as to be practically invisible in the water. On the Banks of Newfoundland and off the Canadian Labrador, as also off the Lofoten Islands and the southwest shores of Iceland, these floating eggs may occur in quantities beyond the grasp of the human mind. Their incalculably vast myriads dancing like microscopic soap-bubbles in the sea may indeed impart a dull milky aspect to the surface waters as though a filmy stratum of mucilage floated along the surface of the sea, as described by Norwegian fishermen over forty years ago.

Each female cod produces an enormous number of eggs. Indeed, M. Petit weighed the ovary of a specimen and calculated that at least nine millions of eggs were contained in a single large fish. The female cod is, contrary to the rule in most fishes, smaller than the male when full grown. The fish congregate near the surface of the sea at the spawning time, which is during the months of midwinter, October to December, or even so late as February and May. Off the coast of Labrador and around the Magdalen Islands the spawning schools crowd so thickly that a vessel may be impeded in her progress, striving to pass through them. No well defined areas in the sea can be distinguished as cod spawning grounds; but the regions in Canada and Northern Europe vary from two to two hundred miles from the shore. Much depends on the nature of the coast and the character of the currents and tides; but it has been determined that the parent cod have a preference for warmer rather than colder areas, though the young fry are found to flourish, some months after hatching, in water of extreme frigidity as off the north coast of Iceland. The eggs scatter widely and in areas of low specific gravity they may descend to a depth of many fathoms. though the most favourable areas are those in which they float within one or two fathoms of the surface, and in extreme calms may form a smooth film quite at the surface. All the eggs are not deposited at once, but those which lose the creamy white opacity of the maturing eggs and acquire a clear glassy transparency like translucent gum, glide to the posterior end of the ovary and are shed. While the ripe female cod scatter their eggs near the surface, the male fish congregate below, and the streams of minute sperms which they eject like jets of cream. ascend and fertilize the eggs. Few eggs probably escape fertilization, as the tests in the Marine Laboratory, now the Gatty Marine Station, at St. Andrews, Scotland, proved. Dr. Schmidt, in a recent report on the cod in Iceland states that 'when maturity approaches. and the fish is preparing for reproduction, it becomes much more sensitive to external conditions. This results in the undertaking of the second great migration of its life, which having regard to the object may be called the spawning migration, and which ends in the warm water on the south and west coasts. The proportion of the sexes on the spawning grounds has not been determined, as has been done in the case of the salmon and certain other fishes; but Sars noticed in Norwegian waters more female fish near the surface than male fish.

The eggs are helplessly wafted about in the water, and in a period varying from one week to four weeks, according to the temperature, the young fish, less than one-sixth of an inch long (4 mm. or ·16 in.) emerge into the open sea, floating back downwards and exhibiting four black transverse bands along the slender worm-like body. Within two or three days the young fish have vigour enough to swim in the right position, progressing by sharp wriggling motions. A swollen ball of yolk protrudes from the under side and upon that fluid yolk the fry feeds. By the end of the first week the yolk-sac has nearly disappeared and the fish is slightly longer and appears deeper in the body owing to a long fin along the back having grown in height. About this time (being now over 5 mm. in length. or ·195 in.) the eyes appear bright and silvery, a black patch appears at each side of the body and the two first cross bands of dark colour break up, but the second and third bands still remain, and the little fish descends to some depth to what is known as the mid-water habitat. Minute crab-life copepods now form the main food of the larval cod and these, when undergoing digestion, turn pinkish or red. Hence this red food visible through the transparent walls of the young fish impart to it a reddish hue. Later, when 5·6 mm. long (·226 in.) the last two bars have disintegrated, black spots appear on the head and along the middle of the under surface, while a greenish yellow tint faintly appears over the little fish. All this time the breast fins have been actively used like delicate fans, but the second pair or ventral fins now bud out, yellowish tints appear, and a length of ·332 in. or 8·25 mm. is attained at this time, viz., the third week. A little later, when the cod is ·375 in. or 9·42 mm., hard rays appear and strengthen the back fin, the anal fin and the tail fin, and the shape of the head is no longer blunt and rounded, but more pointed and cod-like. The mouth opens to the front instead of upwards, as in the earlier stages, and a little barbule or feeler appears at the tip of the chin. Myriads of these baby cod now move shorewards, and a month or five weeks later, in May, June and July, when the fish are over 40 days old (·585 in. or 14·8 mm. long) they crowd the inshore waters. They rapidly reach a length of an inch, and in company with green cod, pollock, &c., form schools in the rock pools and in shallow inlets. The cod is distinguishable by the more marked reddish hue of the top of the head, by the pearly lustre of the sides variegated with eight or nine irregular dark blotches along the sides and back, while the belly is silvery. Black spots appear on the two back fins and on the first anal fin below, but none on the tail fin, though a U-shaped band occurs marking the root of the tail.

Dr. Schmidt found that small cod in the North Sea, off the Scottish coast, were much paler in colour than the larval cod of more northern waters. Sars was the first to describe the cod at 2 inches (50·8 mm.) in early August amongst algæ along rocky shores, and states that by October they are 4 or 5 in. long, and a month later as much as 6 to 10 inches long. Their colour varied, being reddish yellow on rocky shores and greener or grey on sandy spots. When a year old, say in February or March, the young codling may be a foot in length (304·8 mm.) and in the course of the season they forsake the shore and migrate seaward. In their third or fourth year the cod is mature and they are then two feet or more in length and develop spawn.

HADDOCK.

In many respects the haddock resembles its congener the cod, yet, a careful study of their eggs, life history, habits and external features shows innumerable differences and even contrasts. Their localities for spawning are much the same as those of the cod, being out in the open sea from five to twenty, or even sixty, miles from land. The female haddock is universally smaller than the male, and the size of the egg is really the largest of the early pelagic or floating eggs. It is not readily distinguished from the spherical, transparent, buoyant eggs of the cod, but is larger, viz., ·058 in. in diameter, or 1·458 mm., and the number produced is far less than in the case of the cod viz: a quarter of a million to two million eggs. Haddock scatter their ova in the sea from January to the end of May, and the time of hatching varies from one to three weeks. The newly hatched fry are smaller than those of the cod, viz., ·14 in., or 3·5 to 4 mm., and they swim helplessly, ventral side upwards, being incommoded by the yolk sac or ball of fluid food which nourishes them for several days. There is no trace of the cross-bars so prominent in the cod, but irregular black spots occur about the shoulder, and a row on each side from the abdominal area to the tail and along the ventral line of the muscular body. After floating about for a week near the surface of the sea they appear to make for deeper water near the bottom and red-blood has been observed at that age. It is interesting to note that in these minute floating larval fish there is no red blood for some time, a delicate colourless fluid being driven by the heart over the transparent body. The jaw is turned sharply upward until the eleventh or twelfth day, when the movable lower jaw opens direct to the front. The lateral abdominal patch of colour is even more marked and dense and along the lower border of the fleshy tail a row of black stars is a marked feature. In May the young haddock from 1 inch to 3 inches in length abound in mid-water, neither at the bottom nor near the surface of the sea. They remain 20 to 40 miles out at sea, and do not migrate close inshore like the cod and the pollock and green cod. Sars described the haddock as stouter and more compact in form than the cod of the same age. The ventral pair of fins are first noticed in the fish at an inch in length, when the sides of the body are sparsely spotted with black dots, the head and shoulders included, and the specks of black colour extend over the fins; but the under surface of the fish is pale and silvery. When about one-fifth longer, *i.e.*, 1⅐ inch long (29 mm.) the larval haddock still keeps to deep water, and the two ventral fins appear exceptionally long, while the unpaired dorsal and anal fins are largely developed, but there is still no regular cross-bar or checker pattern similar to that of the cod. On reaching a length of 1½ inches (39 mm.) minute scales appear, and the characteristic 'thumb' mark or black patch behind the shoulder is quite distinctly visible. The barbule on the tip of the chin appears, but is shorter than in the case of the cod, and the mouth is smaller in proportion to the size of the fish. There is no dappled appearance as in the cod, and no dusky or speckled coloration as in the green cod or pollock. When an inch longer (2⅜ inch, *i.e.*, 60·45 mm.) the haddock 'mark' is darker and more definite, the pectoral fins are yellowish brown and speckled, uniform specks of black extend all over the head and body, the eyes are of a metallic silvery colour and the lower jaw and the mental barbel are smaller than in the cod. In contrast to the cod, no haddock appear to frequent the shore up to this age. Specimens 80 mm., *i.e.*, 3¼ inches long, exhibit a warm coppery sheen such as is so frequently observed in the large full grown haddock. Professor McIntosh in his account of the haddock, states that the bottom trawl at the end of July has secured haddock of 4 inches (101·1 mm.), and they are taken also on baited hooks, but before that stage none have been secured otherwise than in the mid-water net or in the stomachs of predaceous fishes. At that size they are no doubt about five months old. Later specimens six or seven months old, 6 inches long, have been secured, and in November and December they measure over 7 inches in length, while the following May and June they reach a length of at least nine inches and cannot be less than thirteen to nineteen months old. Thus the haddock shows rapid growth during its first summer, no less than an inch per month; but in winter its growth is slower. In the third year the haddock reaches the mature stage and is developing spawn. After spawning they are often found inshore feeding voraciously on eggs of other fishes attached to rocks, &c., and they are much more gregarious in their habits than cod, but are not abundant so far north as the related species named.

MACKEREL.

Widely differing from the cod and haddock in all the features which are regarded as important in the eyes of the naturalist, the mackerel ranks with the two valuable food-fish named on account of its importance economically, and on account of its production of minute delicate floating eggs. The salmons' eggs are large and heavy, and the eggs of the herring are dense and cling together like hard glassy pellets; but the eggs of the mackerel are extremely transparent and delicate and float buoyantly near the sea's surface. Professor G. O. Sars and Dr. A. W. Malm first described the egg, and it was my good fortune, as already stated, to be the first naturalist to hatch out and make scientific drawings of the young larval mackerel, when with Mr. Spotswood Green, investigating the west Irish fishing grounds on the ss. *Fingal*. The female mackerel produces on an average probably a quarter of a million eggs. As Drs. Jordan and Evermann say: 'The mackerel egg is exceedingly small, it being only 1/24 of an inch in diameter. The eggs average about 40,000 to the fish, but 200,000 have been taken from one fish. The largest mackerel would doubtless produce 1,000,000 eggs each.' Yarrel regards fish 14 to 16 inches long as large average specimens, such weighing about 2 pounds; but he states that in 1849 a specimen 18 inches long and weighing 2½ pounds was caught on the English coast, and in November, 1856, one was sold in London weighing 2 pounds 10 ounces; but in Canadian waters much larger mackerel are frequent, and I myself saw a Nova Scotia mackerel taken in May, 1898, which was 22½ inches long and weighed no less than 4½ pounds. In May and June the spawning schools move landward to spawn. They approach the Nova Scotian coast and move into the Gulf of St. Lawrence from a southeasterly direction. Up to the middle of July they will not, as a rule take bait, and as Professor Hind pointed out they lose all desire for bait when engaged in spawning. The deadly purse-seine introduced into the Gulf of St. Lawrence by the American schooners captures these spawning schools in immense quantities. Almost without exception these fish coming into Pleasant Bay early in July and going up the north shore (Quebec) as far as Pointe de Monts about the end of July, are spawning or partly spawned. June and July cover the period, though mackerel remain and feed in the Gulf and along the Canadian shores until the end of October. The spawning and spawned fish are very inferior, but the fall mackerel, having recovered and fed up, are firm and fat and incomparably superior in every respect.

The eggs produced by the mackerel are small translucent spheres over 1/25th of an inch in diameter (·038 in. or 1·22 mm.), and exhibit in the midst of the clear contents a cloudy, almost colourless globule 1/80th of an inch in diameter (·32 or ·33 mm.). No globule appears in the eggs of the cod or haddock, but the ling, the gurnard and other fishes exhibit in the egg a so-called oil globule. In about six days the young fish hatches out and at first, a few sparse specks of yellowish colour are seen near the eyes. The yellow specks later appear mingled with black dots on the globule and over the head and body, and form an irregular line along the back. These spots, says the well known Irish fishery authority, Mr. E. W. L. Holt, are blue black, not dead black. The young mackerel which I had under observation for over a week until accidentally killed by a cloud of hot soot showered upon them from the smoke stack of the steamer, showed no other colours excepting yellow and black, but it has been stated that bright green pigment occurs on the fifth day on the tail, and behind the eyes and on the globule. On the ninth day after hatching a length of ·19 in. or 4·88 mm. is reached and the ball of food yolk is used up. The eyes have a bright blue metallic appearance, and on the sides, the upper abdominal pigment is very marked, but there are few spots on other parts, and no cross bands or serial patches. By the tenth or eleventh day the larval appearance is gone and the post-larval stage is fully attained. Mr. Holt compares the mackerel larva at this stage to the grotesque post-larval Cottus or sea-skulpin. At this time the schools of young come inshore and vast numbers may be seen in Northumberland Straits, off Prince Edward Island, and in the Bay of Chaleur off the Bonaventure coast in August and September. Dunn, the well known English observer, speaks of young mackerel 3 inches long in bays and shallow inlets. In November, when 6 or 7 inches long, they move into deeper water, and are not observed until they reappear as 'tinker' mackerel, 8 or 9 inches long, abounding in harbours and bays. Sars held the opinion that a one-year old mackerel was as long as the finger, that at the end of the second year it was the size of a herring, and that in the third year it is full grown, though many authorities give the mackerel another year and declare a mature spawning mackerel to be in its fourth year. For the first two years the young mackerel frequent open water near shore, and as Professor McIntosh, of St. Andrews, Scotland, says, the lengths 4 inches, 8 inches and 11 inches probably correspond with successive years in the life of the mackerel.

While the mackerel schools along the various portions of the lengthy Atlantic coast of Canada have not been separated into local races or such differences noted as in European seas, yet there is no doubt that each area on the coast has its own stock and that the mackerel does not migrate over long distances, but largely confines its movements to coming into shallow waters from deeper water and *vice versa*.

II.—THE MIGRATIONS OF SEA FISH, WITH SOME RESULTS OF MARKING FISH.

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The migrations of sea fish are of importance in connection with the commercial utilization of marine fishery resources. Their determination is beset by peculiar difficulties, and the systematic marking of considerable numbers of the most valued food fishes on the plan adopted by the Marine Biological Board of Canada, to be carried out in successive seasons on the Atlantic coast of the Dominion with the Marine Laboratory at St. Andrews, N.B., as the principal station, is the first step towards deciding the seasonal movements of the schools of fish upon which Canadian fishermen depend for their catches. Just as the study of bird migrations occupied ornithologists for over a hundred years, and the accumulation of observations and tho tabulation of ascertained facts has resulted in some approach to a satisfactory understanding of the remarkable movements of the feathered tribes over the surface of the earth, though much remains still to be discovered, so tho thorough understanding of the wanderings of tho finny tribes taking place in an element which hides them more securely from continuous observation than the heights of the atmosphere hide the feathered tribes, is a subject that only the patient collection of facts, and their ascertainment both by ordinary practical as well as by scientific experimental methods can enable us to arrive at complete and adequate results. The movements of fishes in the sea vary according to the period of life of each species. Nay, even the eggs, before giving birth to the young fish, are the subject of migratory movements and add to the complexity of the subject in many species. Shore fish, which produce floating eggs, like the cod, haddock, mackerel and many flat fishes, are distributed over wide areas before they hatch out. The young fish, after hatching, are under the influence of tides and currents which effect migratory movements and transport them over great extents of sea. Later, the effects of temperature, salinity, movements of the air (winds) and of the water, are felt by the schools of small post-larval fishes, and later still the occurrence of food is a most potent factor in leading fish to take long journeys, while at maturity, besides the quest for food, the spawning instinct is powerful in causing them to move from one area to another.

The methods of marking fish are important, but owing to the variety of devices adopted by different observers in Europe and on this continent I shall deal with the subject of modes of marking fish in a special paper in the journal of the Biological Stations of Canada, Part III. of which appears at an early date. The mode of marking is one of more serious moment in the work of deciding the migrations of fishes than may, at first sight, appear. Observers have found, for example, that while a large number of fish have been found to move over a limited area in some definite direction single individuals or three or four individuals have taken to roaming, and in a short time have migrated to very long distances in the most diverses directions.* Thus in Mr. James Johnstone's experiments in the Irish sea, with the valuable flat fish the plaice (*Platessa*), out of 35 fishes marked and liberated on the Lancashire coast, about 40 miles northwest of Liverpool, one wandered past the Isle of Man round the Mull of Galloway to Corsewall Point, near the southwest corner of Ayrshire, a distance of 110 miles, while another was recaptured near Dundalk, in Ireland, having traversed a

*The irritation caused by the tag may in some cases keep the fish continually on the move, just as the migrating herds of Barren Ground caribou, annoyed by the constant attacks of large deer flies in summer, never cease to move onward over long distances.

distance of more than 120 miles, the former occupying over 14 months in the journey, while the latter took between nine and ten months to cross the Irish sea, whereas most of them were recaptured within a few months at distances of eight to twenty or thirty miles from the spot where they were marked and placed in the sea. Similar peculiar wanderings have been noticed in the United States' experiments with lobsters, rare examples wandering upwards of a hunudred miles from thee locality of liberation.† Dr. Johs. Schmidt, in his experiments with Icelandic plaice, found that most of them in 10 or 11 months (July, 1905, to May and June, 1906), moved 200 miles; one plaice reached a point about 280 miles, one about 250 miles and two about 220 miles from Vopnafjordhr, where they had been placed in the water, the one travelling the longest distance (from July to January following) in six months time. There is, however, an inshore and offshore movement, apart from definite lengthy linear migrations, mainly connected with spawning. Thus small flat fishes which very early in the year frequent the shallow inshore grounds move with the approach of summer and, as they grow larger, move into deeper water. Most fish in their early life after their larval life is over and they have assumed the form of the adult, though their dimensions are small, exhibit this habit of leaving the shallows. This movement is no doubt connected with a change in feeding habits as well as with a view to greater security and protection from enemies. In all experiments with marked fish there is a preponderance observed in the fish taking some definite direction. Johnstone's experiments showed, in the North Wales plaice, a movement westward along the northeast shore of Anglesey, a migration similar to that observed at two stations further north, viz.: off the Ribble Estuary and off Lancaster Bay, where the migration west and southwest was marked. Professor McIntosh was the first observer to indicate the main facts. viz.: the migration of the floating eggs inwards, the hatching of the young and their distribution over the inshore shallows, after drifting it may be for over a month in the same direction as the eggs, and then after reaching maturity, moving into deeper water. In the deeper waters the plaice move as in the Irish sea, or off the Scottish shores, westerly; but must, of course, vary on other shores with the geographical contour of the different localities. Indeed, as Schmidt shows, adult plaice liberated on the north coast of Iceland moved westward more than a hundred miles, while other batches of adult plaice, deposited on the east coast of Iceland, all migrated southwards. The authority named decided that the reason of this definite migration was to reach areas of warmer water 'with the exception of the few retaken close to where they were liberated, none of the plaice were retaken on the east coast. It is only right down in the south . . . . that the most were retaken.' Moreover the plaice from the north moved much slower than those from the eastern station, due, it may be, to the rougher and more irregular nature of the shore and the bottom. A similar west and south movement of the cod was also observed by the Danish authority referred to. By this movement of the adult cod warmer areas are reached suitable for the hatching of the floating eggs. But after hatching the small cod, not more than ⅕th or ⅙th of an inch in length, are borne by currents north and east so that these cold northern areas are crowded with cod fry and pass their first winter in those frigid surroundings. Schmidt found as early as April (in 1904) vast swarms of young cod 'whilst the south and southwest coasts of Iceland are washed throughout the whole year by warm Atlantic water, this is not the case on the east and north coasts, where the influence of the polar water is felt.' Few cod fry are found in the warmer south and southwest waters where the spawning takes place, but they abound in the cold northern areas where the temperature rarely rises for most of the year above freezing point. There they remain until a year old or even two years old. Young cod when 1¼ or 1½ inches long are no longer found swimming at the surface, but seek the bottom, and when from 1½ inches to 2 inches in length crowd inshore and abound in rock pools, and when 8 or 9 months old (6 to 10 inches long move out again to greater depths. When about a year old they are a foot long, and do not migrate until they are mature and ready to breed, usually when nearly

†See my special Report, 1907, p. lxi.

2 feet in length. Up to that time they are stationary and only migrate to warmer areas in the early part of the year, January to April, for spawning purposes.

The recent experiments of the Marine Biological Association, England, shows that in the cod marked on the steamer *Huxley* most of them appeared not to have wandered far, these being below 2 feet in length. As the brief note in the recent journal of the association states:—

'The report is based on the 252 cod marked on the *Huxley* and the 42 recaptures recorded up to the date of writing. Most of the recaptures, constituting 13 per cent of the healthy fish liberated, took place within six months of liberation.

'The fish below 60 cm. (24 in.) in length remained in water of depth similar to that in which they were first caught, and had not travelled far. Most of those which had moved some distance from the liberation point were recaptured south or west of it.'

Now in the Atlantic waters of Canada the cod taken in June and July and on to September or later are the cod which have spawned in deep water and resort to shallow inshore waters for food or find it on the rough and rich ground known as the banks. The fishermen speak of the cod moving north after the capelin and the swarming of immense schools of large cod on the Labrador shores is due to the presence of the smelt-like capelin upon which they feed and grow fat. These coast migrations during the summer months are limited and, we may almost say, with the late Professor Hind, that the 'schools of cod frequenting a particular coast may be said to be indigenous to it.' The late Professor Spencer Baird came to the same conclusion: 'The cod' he says (U. S. Comm. Rep., 1889) 'is a local fish, and the different schools have their different habitats.' Nielsen, in his report (Rep. Newfoundland Fish Comm., 1889), expresses the opinion that the cod is a local fish as well as the salmon, and indicates with some detail that each group has its local resort and the local varieties can be readily distinguished, a George's Bank fish being known from any other kind of cod on the other 'banks.' So can a Cape St. Mary's fish be distinguished from any other kind of cod in Newfoundland, and a Trinity Bay fish from a Placentia fish.' The view has even been expressed that in the sea, as in salmon and shad rivers, each area or locality has its own local variety of the same species, and Professor Baird went so far as to assert that deep sea fisheries depleted in any particular locality will not be restored. 'No fish' he ventured to declare 'will come from surrounding localities to take the vacant place. Fish bear a particular relation to particular spots and fishing out one locality is thus like emptying a keg of lard, the space left does not become again occupied.' Valid objection may be justifiably raised to a view so extreme as that, but it is nevertheless true that in different localities the same species of fish may exhibit distinctive features, and demonstrate the existence of local races. Even so migratory a fish as the mackerel, if we accept Professor Garstang's views, shows marked local variations, so that different areas may be said to be peopled by different local races.

The floating eggs of most sea fishes of value for food purposes may be carried over great distances as already pointed out, and the young larval and post-larval stages are similarly transported from one area to another so that local varieties must cross each others' boundaries and interdigitate or intermingle, nevertheless the fact is that in some localities valuable fish have been so persistently destroyed that their almost total depletion has been accomplished and their former abundance, even after many years, has never been restored. The cod fisheries on many parts of the Atlantic coast of Canada have been destroyed, and the mackerel, once abounding all along the eastern shores of the Dominion, have become largely a thing of the past, while the once marvellous shad fisheries of the Bay of Fundy are not one-thousandth the value and extent they were 30 or 40 years ago. The disappearance of fish may be the result of many and various causes, but the restoration by incoming schools from other non-depleted areas is either very slow, or does not take place to any appreciable degree. Fish may migrate from an accustomed locality to another new locality, attracted there by more abundant food, and the disappearance of fish and decay of important fisheries may often be traced to that cause. It has even been claimed that the decline 18 or 20 years ago of the Gulf of St. Lawrence mackerel fisheries is due not merely to the wholesale destruction of the schools of fish just before spawning, but to the increasing scarcity of the food which brought them into the inshore waters. Lobsters were formerly incredibly abundant and each summer the inshore waters were alive with incredibly vast numbers of the surface swimming fry of the valuable crustacean. These crowded young lobster fry were the chief food of the mackerel, and with the destruction of the lobsters and consequent scarcity of the free swimming young, the mackerel found their food gone and they sought food elsewhere. This may be true in a certain degree, and the sudden and unexpected appearance of large schools of mackerel last season supports it. The balance of nature once seriously disturbed has wide and lasting effects. But the physical conditions in the sea may change, currents and particular seasonal streams may so vary as to affect the salinity and temperature of the water. Temperature is a potent factor in determining the movements of fish.* Thus, as Dr. Wemyss Fulton, ten or eleven years ago announced, the gurnard (*Trigla*), an esteemed food fish in Britain, moves inshore from deeper water about the end of March and in April and especially in May. Most of them are breeding fish and they spawn from April until July or August, thus seeking the warmer inshore waters at the spawning time. Temperature brings in these adult fish, but large numbers of small immature gurnards also move inshore from May onwards. With them it cannot be the spawning instinct, but must be due to the increasing temperature and possibly also to a greater plenitude of food. The gurnard thus presents a feature quite the reverse of that of the cod, in the young stages, for the small gurnards appear to be most sensitive to a higher temperature and forsake the deeper, colder water; whereas the cod, in its young stages, spends its first year at least in the most frigid surroundings in the waters of northern Iceland. While cod, haddock, plaice, &c., seek the deeper waters and spawn offshore, the gurnard moves closer into shallower water to commence spawning in April and May. But anadromous fishes, which annually ascend rivers, like the smelt, striped bass, shad, alewife or gaspereau and salmon, are not content to move into shallow inshore areas of the sea, they pass up into the brackish waters of rivers, like the smelt, or ascend, like the striped bass, to tidal limits, or move further up entirely above the influence of the tide, like the shad and gaspereau, or like the salmon migrate hundreds or even thousands of miles to the head-waters of the noblest and longest continental rivers. 'Leaving their home in the far deep, the shad, in beginning their annual pilgrimage,' says a popular writer on the migration of the shad, 'rise to the surface, and then direct their course landward, the earliest emigrants being those in which the propagative function is most advanced. Pursuing their way over the comparative shallows that widely fringe our continent, and joined by other communities bent upon the same devoted errand, they gather in our estuaries and about the mouths of our rivers, and there they linger until the effluent waters are warmer than those of the sea.' The opinion prevails that the schools of shad resorting to a certain river are the fish originally hatched in that river, and attracted by some peculiarity in the water flowing out of the mouth of their native stream, and influenced by the degree of temperature favourable for their entrance into fresh water, return once more to the upper waters. Thus in the Bay of Fundy the spawning fish in the St. John river are not the schools native to the Annapolis or the Avon of Minas Basin, nor are any of these fish which were hatched from eggs deposited by parent fish in the Stewiacke, Shubenacadie or the Petitcodiac rivers. When shad were taken from the Atlantic to the Pacific by the United States Fisheries Bureau, certainty was felt that the shad planted in the Sacramento would return to that river only. As the writer already quoted says:—

* Thus on the north shore of the Gulf and Labrador it was reported in 1867 that there were 'no cod to be caught for there was no bait' that is the herring and caplin did not come inshore as usual; whereas in 1884 the small catches of cod were attributed to the severity of the season the ice remaining until nearly the end of May. The cod fishery was a failure.

'Until the Pacific coast plantings it was assumed that the shad invariably returned to the stream that gave them birth, and this, as a rule, is perhaps correct. The conditions of the California coast evidently operate, however, to the diffusion of the fish, they having in many instances established themselves in rivers far from the Sacramento. This movement may be due to the balmy Japanese current, the Gulf Stream of the Pacific, which laves its northeastern shore and agreeably tempers its climate. Influenced by its genial flow and pursuing its track, the shad have wandered northward, and, if they maintain their advance, as they probably will, their ultimate establishment in the river system of Asia may be regarded as assured. Owing to various favourable conditions, the shad not only multiplies rapidly in its new abode, but in some localities has modified its habits, being found in varying abundance throughout the year. Moreover, it attains an exceptional size; seven and eight pound fish are common in California, but are almost unknown with us, and there have been exposed for sale in the San Francisco market shad of a weight as high as twelve and thirteen pounds. This superiority in size is not unlikely due mainly to a less actively prosecuted fishery, for shad of equal weight were known to our fathers. The heaviest fish are probably the growth of a number of years, and an exhaustive fishery that each season leaves but few survivors necessarily tends to eliminate the larger individuals.'

It is reported that some of the shad resulting from the stock originally placed in the Sacramento have been captured in Alaska, and certainly in the Fraser river, Rivers inlet and even the Skeena river, in British Columbia quite a number of shad have been taken by the salmon fishermen, several hundreds in all. How does this affect the prevalent theory that such fish are true to their own native river? There is abundant evidence that salmon return to their own rivers. This is seen in the differences almost sufficient to justify the establishment of sub-species, difference not only of external form, and of internal characteristics of the flesh (texture, colour, &c.), but of anatomical and skeletal features. A Godbout salmon of the north shore is distinguishable at once from the typical Restigouche salmon, while neither resemble in size and conformation the salmon of the Miramichi. The Peticodiac salmon are different from the St. John River fish, so that one may say of the Canadian salmon rivers of the Atlantic shore that a different variety of *Salmo salar* is characteristic of each of these rivers. Certainly, as Professor Starr Jordan has said, nearly all salmon return, as a general proposition to the region in which they were spawned, but that famous authority qualifies the opinion by indicating that the schools may also resort to other rivers to which they were not native, and adheres to his original view expressed in 1880. He says: 'It is the prevailing impression that the salmon have some special instinct which leads them to return to spawn in the same spawning grounds where they were originally hatched. We fail to find any evidence of this in the case of the Pacific coast salmon, and we do not believe it to be true. It seems more probable that the young salmon hatched in any river mostly remain in the ocean within a radius of twenty, thirty or forty miles of its mouth. These, in their movement about in the ocean may come into contact with the cold waters of their parent rivers, or perhaps of any other river, at a considerable distance from the shore. In the case of the quinnat and the blueback, their 'instinct' seems to lead them to ascend these fresh waters, and in a majority of cases these waters will be those in which the fishes in question were originally spawned. Later in the season the growth of the reproductive organs leads them to approach the shore and search for fresh waters, and still the chances are that they may find the original stream. But undoubtedly many fall salmon ascend, or try to ascend, streams in which no salmon was ever hatched. In little brooks about Puget Sound, where the water is not three inches deep, are often found dead or dying salmon, which have entered them for the purpose of spawning. It is said of the Russian river and other California rivers, that their mouths, in the time of low water in summer, generally become entirely closed by sand-bars, and that the salmon, in their eagerness to ascend them, frequently fling themselves entirely out of water on the beach.'

The conclusion is then stated that it is rather a search for fresh water simply rather than a desire to reach their native head-waters which impels the salmon to act in the way stated. Of course, there is the analogy of the migration of other animals, notably birds, in respect to which the late Professor Alfred Newton, of Cambridge, England, did not hesitate to speak of the 'pertinacity with which birds return to their accustomed breeding places and the force of this passionate fondness for the old home,' (Dict. of Birds, p. 556). No doubt the parents are in most cases the birds which return, otherwise it is difficult to understand the case of a pair of stone-curlews (*Œdicnemus*) which bred for many years on the same spot, as Newton stated, even after the surroundings had been completely changed, an original barren rabbit warren having become a thick and flourishing bush or plantation. That it is the same pair of birds which return in such cases is difficult to prove, but as Newton pointed out, the alternative raises much greater difficulty 'for then we have to account for some mode of communicating precise information by one bird to another.' But the young as well as the parents are prone to return to the original haunts, as it has long been known that birds of prey drive away their offspring from their own haunts. 'The practice, however,' said Newton, 'is not limited to birds of prey alone, but is much more universal (*op. cit.* p. 554). There is much ground for believing that one of the main causes of migration in fishes is due to an hereditary tendency, an 'instinct' it may be called, for want of a better term, which is so strong, that even temperature of the surrounding water is less potent as a stimulus, and apart from the question of food and of breeding, this tendency to move over geographical areas with unerring certainty as to time and direction is one of the most perplexing and powerful that the scientific student can contemplate. It is true that, as Professor Hind stated, 'the question of inshore and offshore mackerel fishing grounds becomes, in a great measure, reduced in the Gulf of St. Lawrence, to the different conditions of marine climate which prevail where the Labrador current is the controlling agent, or where the Gulf stream asserts its power and influence during the summer season,' but an inherent tendency exists also.

Dr. W. Bell Dawson has for successive seasons covering a number of years carried on elaborate and accurate investigations in the Gulf of St. Lawrence, and though it is early yet to attempt any generalizations between the results of these current and tide observations, and the movements of the great schools of fish in the Gulf, such as cod, haddock and mackerel. The general result, however, is to show that the outflow from the Gulf is compensated by an inflow both in the Straits of Belle Isle and Cabot straits and that the changes effected by this compensating circulation are what may be called superficial rather than deep-water. At greater depths than 50 or 60 fathoms these important currents have probably little or no effect. As Dr. Dawson has reported: 'In reviewing the movements of the water, with a view to tracing the general circulation of the Gulf, it is the principle of the balance of flow which is the most evident. Wherever a current of a constant character occurs, there is a corresponding return current to make up for it. Thus in Cabot strait, the outflowing water in the Cape Breton current is balanced by the inflow at Cape Ray; the northeastward current on the west coast of Newfoundland is balanced by the contrary direction of the movement on the opposite shore; and we have fairly good indications of a return flow to compensate for the Gaspé current.

'It is this balance of flow which points to the nature and direction of the circulation of water in the Gulf. If we begin to trace it from Cabot strait, where the balance between the gulf and the ocean takes place, the inflow at Cape Ray appears to diffuse itself more or less widely over the central part of the gulf, but it regains its strength further north on the west coast of Newfoundland, and makes a deep bend into the northeastern angle of the gulf, and returns westward along the north shore. On reaching Cape Whittle, it still makes westward; and, whether as an actual set, or by displacing water which comes more directly from Cape Ray, it appears to work around the eastern end of Anticosti, and so compensates for the outflow of the Gaspé current from the estuary of the St. Lawrence. This current after rounding the Gaspé coast, makes southeastward as a general set or drift across the gulf to the western side of Cabot strait; and its waters there leave the gulf in the outflow of the Cape Breton current.

'It also appears that the whole of the balance or compensation in the gulf currents takes place at the surface and in ordinary under-currents, which do not probably extend to a greater depth than some 50 or 60 fathoms. There is nothing, therefore, to show the necessity for any appreciable movement in the deep water from 60 to 80 fathoms downward, which lies in the deep channels of the gulf. Where direct observations have been obtained, this deep water appears to lie quiescent, without any movement that can be detected.'

But to the ordinary mind the outflow of such a vast river as the St. Lawrence, the largest river in North America, must appear to profoundly affect the gulf waters, both as to salinity, temperature, &c.; but Dr. Dawson has pointed out that the 'volume discharged by the St. Lawrence has been measured above Lake St. Peter at different seasons; and with the addition of the Richelieu, St. Maurice, Saguenay, and other tributaries along its estuary, the total volume of fresh water discharge would probably amount in all to 340,000 cubic feet per second. This volume of fresh water will mingle with sea water for which we may assume a density of 1·0240, as this may be taken to represent either the mean density of Atlantic coast water to a moderate depth, or the density of the salter water in the gulf itself. Under these conditions, the fresh water of the St. Lawrence would be sufficient to furnish a stream of water reduced to the lower density of 1·0230 which would be twelve miles wide and 68 feet deep, and moving with a speed of one knot per hour. This would represent the average density of the Gaspé current, and would probably be an approximation to its average speed and its volume;' but the outflow known as the Gaspé current is immensely greater than the volume of the St. Lawrence river outflow. As Dr. Dawson has estimated 'such a current has a volume forty-three times greater than the St. Lawrence river. The volume of the Cape Breton current also, is probably much the same. These outflows must therefore be replaced by a return movement at the entrance of the lower St. Lawrence; somewhere in the Anticosti region, and also by a return flow from the ocean into the gulf area; as the discharge of the St. Lawrence furnishes less than 3 per cent of the amount required in either case.'

The north shore current as well as the current flowing direct from Cabot strait must be taken into account in explanation of this vast volume of outflow. Dr. Dawson, indeed has pointed out that while 'the volume of fresh water from the St. Lawrence, as already explained, may be sufficient to dilute the sea water to the low density found in the Gaspé current or in the corresponding current flowing outward through Cabot strait, the total volume of water which actually leaves the gulf is vastly greater than the volume of fresh water which it receives from the St. Lawrence river. The volume so leaving the gulf must, therefore, be replaced by water which enters it from the ocean

'The current which usually makes inwards on the east side of Cabot strait, may be sufficient to compensate for the outflowing water of the Cape Breton current; although it is also possible that the outflow from the gulf may be partly made up for, by the difference of flow in the inward direction through Belle Isle strait; which in some years may be considerable in the early spring. The relation of the current in this strait to the gulf as a whole, has already been explained; as well as the probable amount of inflow at Cape Ray, in continuation of the general westward tendency of the water along the south coast of Newfoundland. The quiescence of the deep water in Cabot strait has also been pointed out, in this connection.' The general result of these counter currents, as affecting the distribution of floating ova and young of cod, haddock and mackerel, would appear to be that the spawn is kept inside the gulf limits and not swept out into the open ocean, while the young fish are probably carried in circular courses in local areas, never very distant from the hatching areas.

I have the materials well advanced for a report on the results of this system of currents on the distribution of floating ova which vast schools of cod and mackerel deposit in the surface waters. The movements of the early fry must of necessity be more complex and vastly less easy to ascertain than is the case on the north and west shores of Iceland or the corresponding Norse shores in both of which regions elaborate scientific results have been published.

It is well known that spawning fish refuse to readily take bait and the early schools of cod captured in June have already spawned, some of them probably a month or six weeks earlier, while the fall cod, especially the deep water fish, are undoubtedly the fish that have left the shallower waters and the surface waters to feed on the rich fauna on the floor of the sea. Nor is it very different with the mackerel which early in June are distended with ripe spawn, and refusing to take bait, as all spawning fish do, were mercilessly slaughtered by purse-seines, &c. By the end of July spawning is over, and the fish commence to feed up from that period, though their condition is not favourable for a month or more, or not until the first ten or twelve days of August. Such being the facts regarding the gulf mackerel and cod it is easy to see that both these fisheries can be restored where decayed, or preserved permanently when the abundance of fish has been maintained by as far as possible securing that the main fishery shall be after the spawning is over, and if possible after the fish have been feeding for three or four weeks and have recovered their condition. Inshore fishing for cod very early in the season is not to be encouraged, and early destruction of the spawning schools of mackerel is likewise unjustifiable. The millions of spawn produced by one female cod or mackerel indicates how easy restoration is, if only a sufficient number of spawners be allowed undisturbed to perform their spawning functions. The eggs and young are of course destroyed in quantity by their natural enemies, and these are, therefore produced on a large scale, but the balance of nature is such that if not too seriously disturbed by such exterminating instruments as the exhausting purse-seine, scooping in complete schools of spawning fish, there is no fear for the continued abundance of such marine fish. The aid of fish culture and the operation of marine fish hatcheries being too problematical and uncertain to solve the difficulty, the protection of the breeding schools when they migrate and reach their spawning areas is the only sure and safe step on which reliance can be placed.