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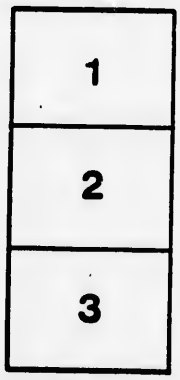

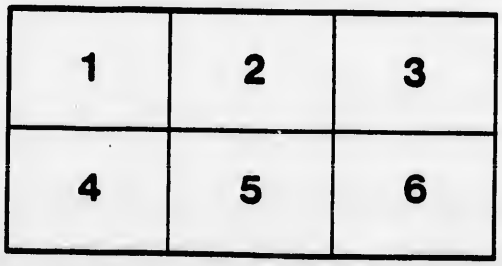

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SPECIAL APPENDED REPORTS

BY

PROFESSOR E. E. PRINCE

Dominion Commissioner of Fisheries

I. FLUCTUATIONS IN THE ABUNDANCE OF FISH

II. THE FOOD OF THE STURGEON

III. NOTES ON THE HABITS AND LIFE HISTORY OF CANADIAN SALMON

1898

OTTAWA
GOVERNMENT PRINTING BUREAU
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SPECIAL REPORTS

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II.—The Food of the Sturgeon.

III.—Notes on the Habits and Life History of the Canadian Salmon.

SPECIAL APPENDED REPORTS

I

FLUCTUATIONS IN THE ABUNDANCE OF FISH

BY PROFESSOR PRINCE, COMMISSIONER OF FISHERIES, OTTAWA.

Fisheries, through all their history have been subject to characteristic fluctuations. Uncertainty in regard to the occurrence or disappearance of fish has long been proverbial. The miner is accustomed to surprises, sometimes favourable, sometimes unfavourable, and the farmer is rarely able, with any confidence, to foretell the results of his season's labours, but the fisherman surpasses all in the uncertainty which besets his efforts to utilize the valuable resources of the rivers and the sea. The abundance of fish on the one hand, or their scarcity on the other, have resulted in those strange fluctuations, abounding prosperity and indescribable depression, which have formed the most vexing of all problems for fishery authorities and scientific economists, while their explanation has taxed the ingenuity of practical men as sorely as professional theorists. In some instances, the causes of these fluctuations are apparent and readily discoverable, in others they are problematical and difficult; but in multitudes of cases it has, in the past, been deemed sufficient to have recourse simply to the supposed erratic movements and capricious habits of the fishes themselves. "The Irish coast," says an old writer, "affords a remarkable illustration of the capricious habits of fish, for which no satisfactory cause can be assigned. The haddock and whiting, which have not, for a long time, been seen on the western and northern shores have suddenly reappeared, and are again taken in considerable quantities." To attribute the reappearance, like the disappearance, of any species of fish to mere erratic tendency or whim is contrary to all that we know of fish life, as of other animal life, though so brilliant an authority as Dr. Pouchet has maintained that this is true of the sardine, as his distinguished *confrère* Professor A. F. Marion remarks: "Je crois pouvoir conclure que, pour lui, la sardine est une espèce absolument erratique, n'abordant que fortuitement, on ne sait sous quelle impulsion, vivant d'ordinaire dans la haute mer et jusqu'aux régions les plus éloignées des côtes, descendant aussi dans les abîmes océaniques, s'y reproduisant loin de l'action de l'homme et à des moments qui n'ont rien de régulier ou du moins sans subir l'influence de la succession normale des saisons."

Hardly less difficult is the problem presented by the mackerel fishery in various countries. Take the mackerel season just closed, 1898. As one authority has pointed out: "It was a failure from the start. That is not only true of the American mackerel fisheries, but also true of the Irish and Norwegian industry. As we have frequently said, the fish crop is like the wheat crop or the apple crop; one year it is good and the next it is poor, the only difference being that we understand the conditions which make or mar a crop of wheat or apples a little better than we do the conditions that produce a good or a poor season's fishing. The total catch, including what was landed fresh at

New York and other points during the spring fishing, and at Gloucester, Newport and Boston and other New England ports during the summer, was scarcely above seventeen thousand barrels. Not more than a half-dozen of the seventy vessels that have comprised the Gloucester fleet have had a remunerative year's work. The majority have lost money. The loss falls upon men and owners alike." The phenomena of nature are only capricious and inexplicable to the ignorant, and many facts which appear irregular and abnormal to the ordinary observer, are, to the man of science, regular and necessary, and belong to a recognized order, being subject to known laws and conditions.

The study of fisheries, as a department of exact research, has been one of the last to be taken up by trained scientists, and as yet the progress made cannot, perhaps, be compared to that in other lines, such as forestry, mining, or agriculture, yet the patient and arduous labours of fishery experts in various countries have yielded most remarkable and far-reaching results. In some cases, our ideas on fishery matters have been revolutionized, and certainly many common opinions prevalent amongst fishermen regarding such questions as the spawn of fishes and the habits of the young have been entirely overturned. The causes of abundance, or of depletion, are causes which may be complex or simple, but they are causes which investigations, conducted by competent authorities, can ascertain and elucidate. The confusion in the minds of those engaged in the fisheries arises less from lack of observation than of that power of discrimination which is a result of rigid technical training. It needs only an ordinary power of observation to note a multitude of possible causes for any phenomenon, but to eliminate the secondary and non-essential from the necessary and potent causative circumstances is beyond the common practical intelligence. A few years ago it was my duty to officially make inquiries into certain fisheries in the Bay of Fundy. The herring fishery, which had long been declining off the New Brunswick shore, came in for my special attention. I obtained a large amount of evidence from fishermen, very old and experienced men, many of them, but what struck me about the evidence and the proffered information was not the lack of observation or the absence of knowledge, but the superabundance of both. There was such a plethora of explanations for a single isolated fact, that any person except a fishery expert, would have been hopelessly dazzled by the excess of light thrown upon the simple problem. Why had the herring fishery in question declined? That was the question, and the local fishermen, all men of intelligence, observation and experience, offered no less than sixteen separate and distinct solutions of the problem. The reason most generally given was this: The herring fishery has fallen off because the young fish have been so seriously destroyed in the so-called sardine weirs. You cannot have abundance of adult fish if you decimate the young immature fish further down the bay. To illustrate the difficulty of sifting evidence of this nature, and to show how varied and even contradictory such evidence is, I give a brief statement of the explanations actually offered:

(1.) Young herring destroyed wholesale in sardine weirs.
(2.) Overfishing, especially by United States fishermen.
(3.) Driven off by increased steamboat traffic.
(4.) Too many drift nets have diverted the herring schools.
(5.) Shrimp food has disappeared, which attracted herring.
(6.) Mere caprice has caused them to leave.
(7.) Winds dislodged and cast ashore the herring spawn.
(8.) The sea bottom has changed, altering the bays and inshore grounds.
(9.) Pollution of the waters of the bay by vast quantities of surplus herring, captured and thrown away.
(10.) Deforestation of land increased the silt brought down by rivers in sudden floods, and smothered the spawn.
(11.) Saw-dust and factory pollution poisoned the waters.
(12.) Gurry rotting on the sea bottom after hake fishing is over.
(13.) Bad smell from offensive lobster bait drove away herring.
(14.) Phosphorescence of decayed bait in lobster traps frightened herring.
(15.) Disturbance of water due to constant hauling and sinking of lobster traps along the shore.

(16.) Long lines left by fishermen for two weeks to two months. As there is one hook to every fathom, and 400 to 600 hooks on a "trawl," quantities of hooked fish died and decayed and did the injury.

All these reasons—some of them most plausible and ingenious, and doubtless having a basis in fact, I grouped under two heads, and whichever of these two heads embraces the true explanation will enable a solution and remedy to be reached. The reasons put forth, no less than sixteen in number, imply that the herring, formerly plentiful, have been destroyed, and that the abundant schools no longer exist anywhere: or that they still exist but have been driven to other resorts and cannot, therefore, be taken along the Bay of Fundy shores of New Brunswick. This is, indeed, characteristic of all evidence offered upon the question of depletion. On the one hand, parties interested affirm that decline and gradual extermination is the true explanation while, on the other hand, it is claimed that the fish supposed to be reduced in numbers are really as plentiful as ever, but have migrated to other regions and cannot be found in such numbers, if at all, about their former haunts. It is true that in no department of natural history has accurate information been so meagre as in the science of fish and fisheries, for the customary habits and seasonal movements of the fish could only be accurately followed in the depths of the sea, and in more or less remote areas in rivers and lakes, under conditions of the most obscure and difficult character. When the Highlanders of Scotland fancied that the herring deserted a certain coast because, in some strife of the clans, blood had been shed, or when, as Dr. C. D. Badham related, the Celts, in an obscure parish in the west of Ireland, declared that the schools of herring departed when a new clergyman announced his intention of tithing the produce of the sea, and never showed any sign of their presence during his incumbency, these supposed explanations were not more baseless than many which have been formulated in the reports and conclusions of important fishery commissions. The causes of success or decline in any particular fishery may be natural and normal or they may be due directly or indirectly to human agency. They may arise from conditions of which the student of economics can take cognizance, or they may arise from conditions of a wholly different character, and may even be dependent upon the racial and social characteristics of the people. But while to such causes and conditions the rise and fall of fisheries may, in many instances, be attributed, the most momentous of all are those which are due directly to natural or biological conditions, so often complex and profound, but always capable of being investigated, with the hope of ultimate solution, like all other problems in the domain of nature. When a particular region, fresh water or marine, is unduly strained and the fishery resources seriously impaired by fishing operations pursued to excess, there must follow a depletion which may be permanent or only transitory. Thus, a large maritime population may become dependent mainly upon one particular fishery resource, and the natural limits of a healthy industry being overpassed, a period of depression, or even of total exhaustion, may supervene. Lobster and oyster fisheries in various countries are a striking example of this last-named type. The oyster and, indeed, the mussel fisheries of the British Islands have reached a state of such absolute unproductiveness that the markets can only be kept supplied, and that inadequately, by importations from other countries. That common shell-fish, the mussel, is the principal bait used by the line fishermen in Britain. 30,000 tons are required yearly by the Scottish fishermen, and for this supply dependence is largely placed upon importations from Holland and other countries. Oysters which, 50 or 60 years ago, sold for 30 cents to 40 cents per hundred, cannot be had now for less than $1.50 per hundred, and those of the poorest quality, while the best Whitstable oysters often sell at over ten dollar a hundred at the principal oyster stores. The shad fisheries in the maritime provinces of the Dominion furnish another notable case of depletion, due mainly, possibly due solely, to overfishing. It has been argued that in the case of the shad the decline of the fishery is due to pollution of its feeding grounds, and it has been maintained that the extensive flats in the upper portions of the Bay of Fundy abounded with the "shad-worm," a favourite food of the shad, but that saw-dust and other pollutions drifting down the streams of the adjoining counties (in Nova Scotia and New Brunswick) have covered these areas and destroyed the food. Certainly the Bay of Fundy shad formerly netted in immense quantities in the fall, were fat and well fed, and apparently

schooled in those waters for feeding purposes. Those who maintain that the shad have forsaken these areas because of lack of food, have not been able to point out any other localities to which these fish now resort. Possibly there is good reason to attach weight to the contention stated above, though it cannot be ignored that excessive destruction of spawning shad took place in the spring up all the rivers emptying into the Bay of Fundy. Not only were the spawning fish mercilessly destroyed on entering the estuaries, but were slaughtered on the spawning grounds, and relentlessly pursued when poor and emaciated, and drifting down the stream, after depositing their eggs.

A decline in a fishery may prove to be due to causes deeper and more obscure than a simple decline in the supply of fish or exhaustion due to overfishing. The native character and natural aptitudes of the people may have something to do with the apparent abundance of fish and the state of their fisheries. Thus, a Select Committee of the British House of Commons, appointed in 1833, reported that the Channel fisheries off the south coast of England had been declining for nearly twenty years. The numbers of men and boats had continued to decrease, the fishermen and their families had become poorer and poorer, and had become dependent upon the parish-rates for support. The encroachments and competition of the French fishermen, aided by a substantial bounty from their Government, were claimed as the potent causes of the decline. In sea fisheries, it may often happen that a fishery which shows every sign of decay, if we have regard only to one nation, is really in a prosperous state if we take into account the extent and profitableness of the same industries pursued in the same seas by other countries. A remarkable case of this kind was illustrated by the famous bank fisheries of Newfoundland. The Newfoundland industry was in such a serious state of decline that there appeared a possibility of its total abandonment. The number of "banking" vessels declined from 330, in 1889, to 58, in 1894. The catches, which amounted to 236,821 quintals in the former year, fell to 53,824 quintals six years later, that is in 1894. So serious a falling off in an important national industry created justifiable alarm. An official investigation was authorized, but, as usual, the practical men engaged in the industry expressed the most contrary views. No less than fifty-nine separate reasons for the decline were volunteered by the owners and ex-owners of vessels and by the fishermen themselves, and it would be impossible to imagine causes more diverse and opposed than those alleged to have produced the decline. The actual scarcity of fish, or their different and more local method of schooling, the lack and the dearness of bait, the injury to the banks by offal and fish-waste, or by the periwinkle fishing carried on by the French, the inefficiency of the men and their want of navigation experience, their inefficient gear and ill-fitted vessels, extravagance in regard to ship's stores, and carelessness in keeping vessels and gear in proper trim, and hosts of other reasons, more or less remotely bearing upon the important matter at issue, were set forth as accounting for the decline of the industry. Some of the reasons practically amounted to a charge of incompetence and of idleness, while other causes adduced had reference to the weather, "natural disadvantages, such as fogs and gales," or to the proverbial "periods of plentifulness of fish, and periods of scarcity on the banks." None of the causes summarized above really touched the essential points which the commissioners referred to in framing their conclusions. Thus, it was shown that the large fleet of American bankers made on an average actually larger catches per boat than the Newfoundlanders, who were in closer proximity to the banks, and had local supplies of bait available. During the five years, 1889 to 1894, the United States boats exceeded the Newfoundland boats by about 122 quintals per vessel. The United States boats were larger and better, carried a rather larger crew, and used more gear, but had also the advantage of access to a great market, and the certainty of better prices. Success depends, said the commissioners, not only on good vessels and gear, but upon an experienced, industrious and economical skipper, and a well-managed zealous crew. "Once we have redeemed the errors of the past, a brighter future for the bank fishery will open," is the conclusion reached at the termination of the investigation. In other words, the bank fisheries, there is every reason to believe, are as prolific as ever, and any decline is due to causes which rest with the fishing population. The history of fisheries, in various parts of the world, clearly shows that this is true, and that fishing industries have declined on account of the inferior skill

and industry and lack of perseverance on the part of those engaged in them, and this was clearly the cause of the decay of the British sea fisheries in the German Ocean during the seventeenth century, when the superior enterprise of the Dutch enabled them to gradually usurp the business which had hitherto been controlled by English fishermen. Until recently, the valuable and prolific fisheries of the west of Ireland were but little utilized by the resident population along those shores, and it was not until Scotch, Manx, English and French fishermen intruded into these waters that any appropriate local attempts to stay the decline of the Irish fisheries were made. Numerous cases might be cited where the inexperience, not to say indolence and indifference of the resident people have resulted in strangers and foreigners harvesting the rich treasures of the deep, which had long invited exploitation. In addition to the factors just referred to, factors which it is needless to say are extrinsic and readily remediable, there are others which have been revealed by the arduous labours of biologists and scientific fishery experts. These factors are intrinsic and involved in the preservation or disturbance of that balance of nature which is as real and tangible in the world of waters as upon the surface of the land. Whether or not the injuries arising from these causes are remediable is another question, but, at any rate, it is possible to decide whether restorative steps are feasible if once we are able to name the cause or causes.

It is well to premise that one of the most important conclusions reached by the investigations of experts in recent years is that all important fishes are local in their range. The old idea that fish migrated over great distances has been exploded. It is becoming more and more apparent that they affect their own local areas, and that such local areas can be exhausted more or less completely. Even fishes like the herring and mackerel are by no means the erratic wanderers which they were at one time thought to be. The movements of the schools are, indeed, mainly from deep water to shallow, and back again. The herring fishery on the east coast of Britain which was long thought to clearly establish the theory of extensive migrations from the North Pole (as Pennant said) to the more temperate waters of southern England and back again, is now seen to prove precisely the opposite. It is true that the herring fleet begin off the Orkneys and Shetlands early in the summer, and, month after month, move south, finding schools of herring at every successive point, until the fishery ends off the Norfolk coast in the fall, but, as every fisherman knows, the herring found in certain localities are peculiar to those localities, either in size, shape or flavour, and are clearly not merely members of one great army, moving southwards. Were it not so, local varieties of herring would be an impossibility. As one critic has remarked, were Pennant's theory of a vast school traversing thousands of miles of ocean a true explanation, it would be essential that this moving host should, at certain seasons, make a return migration to the polar seas, but such a northerly migration has never been observed. Were fishes of great economic importance thus nomadic, they would be independent to a large extent of local conditions, and would be little affected by circumstances potent over only limited areas, yet we know that the contrary is the fact, and that herring, mackerel, haddock and cod fisheries may be a marked success in one area and a failure in another and that these states of plenty or of depletion appear to be most erratic, whereas they should be widespread and gradual or uniform were the schools the common property, as it were, of an entire length of coast. The practised eye of the fisherman will distinguish, at a glance, a fish from a particular locality, especially of certain species. It is not difficult to relegate a St. John River salmon and one from the Miramichi and one from the Restigouche, to their respective waters after carefully comparing examples. Even the herring of the Scottish coast are in many cases easily distinguishable. A menhaden caught on the coast of Maine can, with facility, be distinguished from a Long Island menhaden, a Chesapeake or a Florida one, by certain indescribable characters, easy to perceive, but difficult to define. The presence of the crustacean parasite in the mouths of southern menhaden, and its constant absence from those of the north, is a very strong argument in favour of local limitations in the range of menhaden schools. That the same schools of menhaden return year after year to the same feeding grounds is very probable. The schools in the southern waters do not re-

ceive any apparent increment at the time of the desertion of the northern coast, nor are the southern waters deserted at the time of the abundance in the north.

Most fish have their special local range. They loyally linger around their own native haunts, and only lack of food or some potent physical cause will induce them to change their ground. The late Professor Spencer Baird, in 1871, very clearly laid down the principle referred to, saying:

"In all discussions and considerations in regard to the sea fisheries, one important principle should be borne in mind, and that is that every fish that spawns on or near the shores has a definite relationship to a certain area of sea bottom; or, in other words, that as far as we can judge from experiment and observation, every fish returns as nearly as possible to its own birthplace to exercise the function of reproduction, and continues to do so, year by year, during the whole period of its existence. * * * It is an established fact that salmon, alewives and shad, both young and old, have been caught on certain spawning beds, and after being properly marked and allowed to escape, have been found to reappear in successive years in the same locality. * * * The principle is rather more difficult to establish in regard to marine fishes; but experiments have been made by competent men on our coast and elsewhere, which prove the existence of the same general principle in relation to them."

The abundance of fish in a locality may, indeed, be maintained, and yet the statistics of the fishery for one season or for many may show a falling off. The causes may be seasonal or meteorological in many cases. Thus, the smelt which enter the principal rivers of New Brunswick and Nova Scotia in incredible numbers in the fall (November and December) and again in the early months of the year, remain in those rivers, moving in and out with the tide until the ice completely roofs over the water, but a fall of snow, darkening the ice, or the appearance of the full moon, will at once drive all the schools out into the sea again. The catch for any particular season may thus rise high or fall to the lowest level with the occurrence of transient changes of the nature referred to. Winds also have great influence. Last year, for instance, the great fall herring fishery of Norway was exceedingly disappointing and poor. The catch did not exceed 106,000 barrels, as compared with the previous season's record of 282,000 barrels. Those well acquainted with the fishery claim that this serious falling off did not arise from any diminution in the herring supply, but from the fact that the herring kept off shore from 35 to 40 English miles, and the weather was too rough to permit the ordinary herring craft to venture so far out. It is said that a German steamer followed the herring at that distance from shore, and made very good hauls of fine herring. In the spring of 1808 there were no cod off the south-west coast of Nova Scotia because, the fishermen affirmed, the herring had been driven away by the unfavourable winds that prevailed.

What, then, are some of the causes which reliable evidence shows have detrimentally affected fisheries. They may be grouped under eight or nine headings.

Overfishing.—This includes not only the employment of excessive quantities of gear, but the methods of using the gear and the kind of devices or engines employed. If, as fishery experts are agreed, excessive lengths of nets are used continuously in limited fishing areas so that whole schools of fish are captured and few or none are permitted to escape, depletion must rapidly ensue. While it must be admitted that the ocean, taken as a whole, is inexhaustible, yet established fisheries are confined to specially prolific areas, and such areas will bear the exhausting process of utilization only to a limited extent, or their reproductive and recuperative capacities will be too severely taxed. Nor does the exhaustion of an area leave space for the incoming of schools from other areas. Surrounding localities have their special schools too, local races they may be called, and, in accordance with hereditary instincts they remain true to their own areas, and under normal conditions have no reason to forsake such areas in order to repeople depleted areas more or less distant. Just as on the land, each area has its own insect fauna, and an entomologist can often determine the locality of a beetle or a butterfly by slight and subordinate local features, so there is every evidence for holding that local races of fish, even those regarded as nomadic and extremely migratory, cling to the limits in which they were born and reared. Not only of crustaceans, like the lobster and shrimp, whose movements are less active and erratic, but of fishes like mackerel and cod, able to

traverse considerable distances, this is true, and generation after generation of these local races of fish linger around their accustomed haunts. Overfishing may be effected in many ways, but the principal are the too constant and uninterrupted pursuit of the fish so that when feeding and when engaged in spawning they are harried and destroyed without cessation: or the use for even short periods of time of apparatus excessive in amount or in destructive character. The decline and depletion of the Sacramento salmon fisheries on the Pacific coast of the United States was no doubt due to the latter cause. An excessive amount and extremely destructive forms of fishing gear were used for only a short period annually, and though the spawning fish in the upper waters were subject to no increased disturbance and the schools of salmon in the sea had uninterrupted course over their feeding grounds, as before, yet so completely were the migrating schools killed out when passing up the river that the fishery came to an end.

The great lakes of the North American continent, Ontario, Erie, Huron, Superior and Lake Winnipeg reveal the same unwelcome facts. Overfishing has effectually reduced the once wide-spreading schools of lake whitefish, lesser whitefish (called lake herring), and pickerel or doré, and great as the fisheries still are, they are unmistakeably depleted and decaying fisheries. Even species like the black bass, maskinonge and other valuable forms, never regarded as of prime commercial importance, are now scarce, where they were, 10 or 20 years ago, abundant. The vicinity of the Thousand Islands, the prolific stretches in and adjacent to the Bay of Quinté, and similar favoured resorts are largely bereft of the innumerable fishing population which once delighted the net-fisherman, and the sportsman with his hook and line. The angler, so-called, whose ambition was to make, in a day, a record catch, did much of the slaughter; but illegal netting has been a grave factor, too. One of the ablest officers in the Dominion service reported some years ago that illegal trap-nets set in some depth of water, especially in the channels extending into Lake Huron, were decimating all the better kinds of fish. One trap-net contained, after being set only a few hours, no less than 500 pounds of black bass, besides lake whitefish, yellow pickerel, and other kinds. Some of these traps were large and most destructive, measuring fourteen feet in depth, and though prohibited by the Dominion Government, were extensively set in the waters of Georgian Bay and the North Channel, Lake Huron.

The history of lobster fisheries in most countries illustrates the same type of fishery destruction. It is true that new forms of traps have been invented more murderous and exterminating in effect than the old kinds of wickerwork lobster pots, or of oblong lath-traps; but it has proved possible, by the use of these comparatively inoffensive forms of traps to almost absolutely clean out vast areas where lobsters were once incredibly abundant. The kind of trap remained the same, but the number used was increased five hundred fold, and this enormously increased amount of gear, used during a portion of the year only, achieved the same evil result. Ice on our own coasts and stormy weather in the fall and spring and the migration of the lobster schools into deeper water after spawning afforded some protection; but these natural safeguards proved ineffectual against the influx of destructive agencies that were multiplied year by year. Of the valuable menhaden (a kind of large inferior herring) the late Professor Browne Goode said that it could not withstand the tremendous strain of overfishing. He said:

"It is the commonly received opinion that purse-net fishing is destined evidently to destroy all the menhaden in our waters. * * * The same may be said regarding pound-net fishing. It is doubtless true that the fisheries in a given locality may deplete the immediate region in which they are prosecuted. The cod and halibut may be fished for upon a single bank until the local supply is exhausted."

No doubt there is great truth in Professor Marion's claim that the explanation of the movements of migratory fish may be found, as he says in regard to the sardine, in two great impulses, hunger and reproduction: "La sardine," he says, "est, dans la Méditerranée comme dans l'océan, un poisson nomade, dont les déplacements doivent nécessairement être déterminés par les deux grandes causes qui régissent les actes de toutes les autres espèces, la recherche constante de la nourriture et les obligations temporaires du frai."

The history of oyster beds in most countries, with certain remarkable exceptions in the United States and in France, exemplifies exhaustion due to constant unremitting fishing without regard to ice, spawning, size or any other condition presented by the beds. Fishing for oysters through the ice is destructive on account of the waste it involves. Small oysters and spat brought up with the adult shell-fish are frozen in our climate, and to return them to the water dead would be of no benefit. Thousands of tons of immature oysters have thus been wilfully wasted, left to die and decay to the injury of the live beds below when the ice melts in spring. The marketing of small oysters in their first and second year has been most inimical, and car-loads of oysters are even now shipped west from the Atlantic coast of the Dominion which prove to be unsaleable on account of their insignificant size, and are dumped upon the waste heap in the cities of Ontario, Quebec and the west. Norway, so careful and wise in her utilization of many of her resources, has ruined her oyster fisheries by carelessness and reckless depletion, and annually yield only $2,000 or $3,000, though the molluscs readily sell at $10 per barrel.

Disturbance and Destruction of Spawning Schools.—There is no more pernicious method of fishing, as a rule, than that of capturing fish when in the act of spawning or immediately prior to it. Two remarkable exceptions occur, however, which constituted a somewhat difficult problem until fishery experts were able to offer a solution. These exceptions are the cod and herring, both fish being in most countries largely captured just about the spawning season when they are schooling in vast hordes in their accustomed breeding areas. Reference will be made to the peculiar and exceptional conditions connected with the two fish mentioned and there are others.

The decay of the mackerel fishery in the North Atlantic, and especially in the Gulf of St. Lawrence, can be traced to the use of most destructive gear precisely when the fish were schooling for spawning purposes. In spring and early summer an examination of specimens of schooling mackerel shows how near ripeness these myriads of fish are. When the eggs are perfectly translucent they are cast out in the surface waters of the open sea where they are fertilized and float for a week or two until the young fish are formed and burst out of the thin transparent shell. Every adult female mackerel produces not less than 750,000 eggs on an average and as the purse-seiners were able to inclose entire schools of these breeding fish, numbers of eggs beyond human computation were destroyed, and the mackerel population cut off more or less completely. Other methods of fishing, gill-nets, inshore traps, jigging, hook and line though formerly remunerative enough were comparatively harmless compared with the total and completely exterminating character of the purse-seine which was used out in the open sea precisely where the mackerel finds the appropriate conditions; clear, rippling sea-water of some depth, absence of rocks, hurtful objects, pollutions, &c., access to sunlight and the necessary modicum of heat, all necessary for the incubation of these most delicate floating ova.

The disappearance of that small smelt-like salmonoid, the caplin, from considerable stretches of the coast of Canada may be attributed to destructive methods of capture. The cod regularly came close inshore along the Labrador and northern coasts of the maritime provinces, in order to feed on their favourite food the caplin. When the caplin no longer appeared the schools of cod disappeared too. Now, along the shores in question, especially along the estuary of the River St. Lawrence traps or weirs built of fine brush or wickerwork were placed at every available point. These became filled to excess with hosts of caplin which crowded in with the flowing tide, and were left high and dry when the tide receded. These valuable little fish were used for manure to some extent, but visits to these weirs or *pêches* showed that for one ton of dead fish thus utilized twenty tons were left to rot and waste away. Masses of decayed caplin several yards deep were thus piled up day by day, involving not merely the grossest and most criminal waste of fish, but the production of wide-spreading pollution in the neighbourhood and the cutting off of supplies of natural food which brought the valuable cod almost up to low water mark. So eager were the schools of cod in their quest for caplin that large fish were continually running on shore and were left stranded when the caplin were moving along. It may be added that the caplin

came close inshore for the purpose of spawning as an examination of caplin from the Labrador coast showed.

A great run of cod, usually called the "caplin school" as a rule, touched the Labrador coast about the middle of June, near Natashquan, and moved east to disappear from the shore a month later. In 1898 no sign of this school was apparent, and the total absence of the caplin may be regarded as a sufficient explanation. Oddly enough the schools of caplin, which had been absent for many years at the Magdalen Islands, appeared in 1898 along the south shore, and the local fishermen regarded these as the north shore or Labrador caplin which had erratically forsaken their usual resorts. This is wholly improbable and it is far more likely that the conditions which were unfavourable for the incubation and hatching of the Labrador caplin (whether due to natural causes or to offal pollution, abnormal destruction and the like) were favourable on the Magdalen Islands and the fish once more became numerous there.

The gaspereaux (also known as alewives or kiacks) attracted the cod inshore in western Nova Scotia in a way similar to that of the caplin schools referred to, and the disappearance to a considerable extent of the cod from the littoral waters south of the Gut of Canso is no doubt largely due to the destruction of the gaspereaux, a destruction due to causes described on another page. The well-known case of the Dublin Bay haddocks doubtless comes under this category. In the early seventies the Dublin haddock schools disappeared for four or five years and all kinds of explanations were adduced, but the question of undue destruction of the spawning fish, or the loss of ova due to storms or other causes was not thought of. Some such unfavourable circumstances no doubt were the cause, for the haddock again appeared in numbers and the Dublin fishery resumed its former prosperity.

Natural Enemies.—The life of all fishes is a perpetual warfare with enemies, and the carnage of the sea apart from man's destructive operations exceeds that amongst the terrestrial tribes. The Royal Commission on British Fisheries, 1863, attempted to graphically picture this slaughter by natural enemies in the case of the herring. Allowing to one cod only two herring per day for seven months in the year, and assuming that an average fisherman takes not less than fifty cod in that time, it appears that the cod caught by the 40,000 or 50,000 Scottish fishermen if left in the water would have eaten more herring than the whole catch of the herring fleet. There were in 1861 40,000 tons of cod and ling taken in Scotland representing, say two millions and a half of codfishes and the calculation is easily made which establishes the contention that the herring fishermen take but a fraction of the fish which migrate along the shores, and are daily and hourly destroyed by predacious foes. Were not this destruction to continue "the population of the sea," as one writer has remarked, "would soon become so immense that, vast as it is, it would not suffice for its multitudinous inhabitants." An increase in the number of sharks and dogfishes in a particular area may have the most baneful results, entailing not merely the wholesale slaughter of valuable fish, but their dispersion and flight to other areas, and frequently extensive injury to the nets and other fishing gear. Over thirty years ago while mackerel were schooling in vast numbers in Massachusets Bay, great schools of blue fish, 16 to 20 pounds weight, suddenly made an incursion and devoured in quantity the smaller fish. The blue fish had been scarce for many years, and their unexpected advent had a most disastrous effect upon the mackerel fishery. Possibly a scarcity of food elsewhere had caused these larger fish to forage in this way.

The splendid fishing grounds off Grand Manan, N.B., deteriorated some years ago on account of the inroads made by sharks, dogfish, &c. An official report (1893) states the matter as follows :—

"The decrease in the cod catch has been gradual for the last ten years, which can only be attributed to the marvellous increase in the schools of dogfish and sharks in the Bay of Fundy.

"The hering fishery is one-third less than last year, not from a scarcity of herring, but from the manner in which they have been harassed by the dogfish, pollock and silver hake. Herring have been driven ashore by pollock and silver hake on many occa-

sions. The weirs at Whitehead did not fish at regular times as in former years, that at 'weir times' the hake and pollock would rush through Cow Passage with a sound like Niagara Falls, and all the herring taken there were caught at times that the tide did not serve.

"The pollock have been so well fed by the herring that they did not take the hook, and this fact explains the decrease in the pollock catch."

Pernicious Chemical Influences.—Chief stress has been laid upon causes which are biological in their nature, but there are others purely chemical and physical. Of the purely chemical causes which control the appearance and movements of fishes one of the principal has been found to be the abundance or scarcity of oxygen mingled with the sea water. The absence of herrings from the Arctic seas has been frequently commented upon. The minute crustacean life which is so attractive, and so essential, it may be added, to the vast schools of herring, is extremely rich in the cold northern waters, yet herring do not appear to resort to those regions, whereas on both sides of the Atlantic the waters, adjacent to this continent and to the British Islands and the European continent, herring abound. The Atlantic is more richly oxygenated than the Arctic seas, and this comparative lack of oxygen is no doubt the main factor in deterring the herring from migrating thither. Experiment has clearly demonstrated the dependence upon temperature of the absorbtive power of sea water. Barometric pressure too is important in determining the amount of atmospheric air absorbed, and as this air loses its oxygen far more rapidly than its nitrogen in its descending passage to deeper strata of water, these deeper strata are of necessity imperfectly oxygenated, and unless disturbed by moving currents, unable to support the higher forms of animal life. As was shown by observations in the Swedish fisheries, the presence or absence of the usual schools of certain fish was almost solely influenced by the greater or less amount of water rich in oxygen pouring into the Baltic Sea from the open ocean. Active migratory fishes, such as mackerel and herring, must be largely controlled by these conditions, especially in waters more or less inclosed or separated from the open oceanic areas.

That artificial chemical impurities directly affect fish-life has become almost axiomatic in the science of the fisheries, and many of the more delicately organized species no doubt succumb to pollutions poured from factories, gas works and the like. These pollutions, if they spread over spawning beds, or affect shallow areas which are the favourite resort of the delicate fry in the early stages of their existence, must be a far-reaching injury; but actual observations appear to demonstrate the comparatively innocuous nature of such impurities so far as relates to robust and actively migratory fish like adult salmon. That a river like the Tay in Scotland should continue to hold its own as one of the most famous and prolific of salmon rivers, although Dundee, with its large population, pouring out the filth and waste associately with a busy and dirty industrial centre is but a few miles from its mouth; and Perth, a city of nearly 40,000 inhabitants, with its dye works and other enterprises producing a vast amount of injurious impurities is only 30 miles from the estuary, demonstrates the resisting power which salmon trout have, physiologically speaking, in the midst of poisonous and hurtful surroundings.

The Aroostook River in the State of Maine, a tributary of the Canadian St. John River, still has its quota of salmon, although the pollution of St. John city, and the sawmill waste poured in all along the banks to Fredericton and up to Woodstock would seem sufficiently inimical, while in the Aroostook itself the abuses are if anything intensified not merely by the greater accumulations of debris, but by the erection of millsdams apparently of an impassable character. The salmon are not to be daunted, and a few years ago after it had been commonly held that salmon had been wholly destroyed, fine examples were seen leaping near Houlton and migrated as far as Presqu'Isle. In the Canadian tributaries, like the Tobique, the conditions are wholly different as the primitive favourable conditions still obtain, and the salmon which reach these rivers find themselves in the midst of the congenial surroundings, remote from populous hives of industry.

Destructive Physical Causes.—Reference has already been made to unfavourable circumstances affecting fish-life which are of a physical rather than a chemical nature. The two are interwoven as a rule, but in themselves they are entirely distinct. Thus the floating saw-dust which will choke a shad, a gaspereau or other clupeoid whose branchial apparatus is provided with a cage of gill-rakers, will hardly have any evil effect upon a salmon or striped bass. A powerful fish like the sturgeon, however, is at once injuriously affected, but mainly on account of the fermented saw-dust lodged at the bottom, which not only is sucked in by the funnel mouth of the sturgeon when feeding on the bottom, but is most deadly in its effects upon the sand-shrimps, river mussels and shell-fish generally which so largely constitute the food of that fish. The decline of the herring and other fisheries in the Firth of Forth, Scotland, has been attributed to the hill drainage which has affected the specific gravity, purity, and temperature of the water so that the herring, especially, deserted this shallow estuary about forty years ago. Since then schools of herring come in for a short time, but not in their former immense numbers, showing that the physical conditions and possibly the food affected thereby are detrimental and drive the fish out again. Aquatic vegetation is, of course, affected, and the dependent animal life, of a microscopic character, perishes with the disappearance of plant life. All fish culturists are aware of the necessity of encouraging the growth of suitable water plants, on which minute water insects live and multiply, in order to fatten and keep in health the growing fish. In trout ponds is this especially necessary. It is the same in rivers, in lakes and in the sea. If the plant life be injuriously affected fish-life suffers too. What hope is there of the existence of fish in waters polluted by poisonous sewage, &c. ? The appalling state of things described in the following extract, and referring to the Kent River in the north of England, shows to what an extent these deadly agencies may poison and contaminate fine salmon and trout rivers: "Below the point where the refuse was discharged, the clean water from above and the filthy liquid from the sewers could be seen running side by side for several yards till they at length commingled, the result being a black turbid stream, on whose surface floated a scum formed of the lighter particles of filth and whose bottom was a dense black mud, thickest wherever an eddy or a pool facilitated precipitation, but always entirely covering the natural bed of the river. This sediment was exactly similar to the mud which had collected in the hollows. This state of things existed along the entire length of the channel of the river below the outlets referred to above." (From Mr. C. E. Fryers' Report, Salmon Fisheries, &c., of England, 1895.)

In his interesting account of that increasingly valuable fish, the sturgeon, the late Prof. Ryder pointed out that the very young stages subsist upon small animalcule, which in turn live upon minute forms of plant life. Even the sturgeon are found to devour large quantities of small plants. "The story of the life of a sturgeon (as the author named pointed out) is seen to be bound up with the lives of vast myriads of organisms in no way related to it in the system, but only as sources of nutriment. It is quite certain that.....if the minute life upon which the young sturgeons subsist were exterminated, the sturgeon would also become extinct. It follows from this that whatever affects the relative abundance of the minute life of rivers and estuaries where sturgeons are found, must also affect the survival and abundance of the latter."

Reference has already been made to the effect of cold and barometric pressure upon the chemical contents of water in which fish live. The amount of oxygen dissolved may be reduced to a minimum by unfavourable physical conditions. It has long been known that herring as a rule make their appearance on the coast when the water is about 55° F. or rather 55·5° F., and on the east coast of England it was held that the Yarmouth schools only came in when the incoming stream from the Atlantic Ocean had swept round Sutherlandshire and joined the North Sea waters reducing the temperature of the east-coast waters to the desired 55½. So long as the temperature is higher so long the schools of herring remain in deeper water. The surface temperature has not, as was at one time thought, a direct influence on the movements of the herring though relatively warm currents appear to deter and relatively cold temperatures seem to attract the

moving schools. The precise conditions involved under what may be called favourable and unfavourable physical circumstances in relation to the movement and distribution of fishes are too complex and numerous to detail here; but while temperature and the chemical results dependent thereon are of first importance the further physical character, viz., density is hardly less so. But density depends upon conditions chemical and thermal. If the incoming water from the Atlantic (reverting to the herring question in the North Sea) be of great density, a cold current and of considerable salinity, its admixture with the less saline and less dense water of the German Ocean will raise its temperature, and as observations have shown that about the middle of August 55½° F. is found to be the surface temperature—the temperature particularly favourable for the herring. As it progresses this colder bottom current is pictured as at every stage sending up columns which mingle with the warmer surface water, and in this way the schools of herring out in deeper water are attracted inshore, offshore winds prevailing, and great catches are made in the vicinity of the "patches of water welling up from the bottom." The fact that fishes, as a rule, possess an organ on each side of the body (the sensitive lateral line) enables us to understand how temperatures, densities and chemical changes profoundly affect them. But it must not be forgotten that it is these conditions, favourable for depositing and hatching the ova, as well as suitable for the microscopic animal life necessary for adults and young fish, that are vitally important. The regular migrations of fish as affected by physical and chemical conditions lose all their meaning unless their biological significance (food, propagation, &c.) be fully taken into account. We owe to Sars an ingenious explanation of the bearing of meteorological, current, and the temperature changes upon the abundance, not merely the presence or the movements but the numbers of herring which appear in a specified locality. The distribution of minute crustacea, especially copepods and decapod larvæ is regulated mainly by the weather and will differ indefinitely in successive years. The herring schools will linger where appropriate food abounds and those nearer the inshore waters will arrive in the littoral fishing grounds earlier than those schools further out in the sea. The movement coastward, which is annual, no doubt occurs in the open sea at about the same approximate date each season, some time before the roe and milt of the parent fish are attaining ripeness. Hence the early spring herring which are adjacent to abundant food and stay longer near the coast, are in better condition and of better quality than those that were more remote from this plentiful nutriment, and had a longer, more exhausting journey to make. The earlier fish, too, will be able to penetrate further into the fjords and sounds. In other words, the fishery will yield a much better, richer, and safer result than in the opposite case, when the herring only remains for a season near the outermost coast, and is much thinner and more exhausted, and when only occasionally a small school is chased near the land by large fishes of prey. The herring-fishery may therefore yield a very different result, even if the same mass of herrings has year after year been outside the coast and has produced the same quantity of young ones. The final cause of the irregularity in the spring-herring fisheries must therefore be sought in the changes of weather, current and temperature of the water in the outer sea, not so much during the fishing season as during the rest of the year, particularly during the preceding autumn and summer.

Whether there is in this respect a periodicity which corresponds with that of the herring-fishery will be more satisfactorily explained by future observations than by the study of the past. For the present, it cannot be denied that such a thing is possible. It is well known that salmon linger about the mouths of rivers until the temperature is favourable for their entrance. So long as the temperature of the water flowing out of the mouth of a salmon river is above 58° or below 38° the schools of fish are unwilling to ascend. The facts in regard to other fish are not so generally known, especially such a fish as the sturgeon, which is so abundant and of such value in Canadian waters. The late Prof. Ryder said of this fish: "The upward movements of the schools seem to be affected to some extent by a rise of the prevalent temperature of the water and air, thus making the fishing for the time more profitable. Conversely, a decline in the

prevailing temperature is often apparently followed by a diminution in the numbers of fish on their way up the river, and a cold, late season retards the appearance of the fish from the salt waters farther south. A very rainy season, which has caused an unusually abundant flow of fresh water down the river, also interferes with their early appearance in the waters above Delaware City. This is supposed to be due to the fact that the water becomes fresh farther south than usual where the schools then remain to discharge their spawn. The fishing season at Delaware City is at its height during the months of May and June, but fish are caught during the summer and autumn and until as late as September and October."

When ultimately analysed we find that the abundance of fish, their migrations and the biological conditions upon which their well being and increase depend, above all the food supplies so essential to their existence, rest upon causes and circumstances which are largely physical.

Blasting, Loud Reports, &c.—Fishermen have in numberless cases attributed the disappearance of fish in waters adjacent to forts, &c., to loud reports and explosions. On the Berwickshire coast in Great Britain this idea prevails everywhere, and as the auditory organs of fishes are very sensitive and complicated there is some reasonable ground for these views. Certainly blasting operations under water have the most disastrous results, and two or three years ago a certain part of the St. Lawrence River appeared like a moving stream of dead and dying fish after some explosions of dynamite. On the Detroit River the noise and bustle of the shipping and traffic generally is regarded as responsible for the decay of the once prolific lake whitefish fisheries, though doubtless the garbage and noisome pollutions of Detroit City have had no less evil effects. Oddly enough certain fishermen along the sea coast of Quebec attribute the decrease in the lobsters in some of the bays to the noise of occasional steamboats, especially paddle boats, but the increase in lobster traps and the unlimited capture of spawning lobsters must have contributed to the exhaustion of the valuable crustacean in those localities. Perhaps the most novel of all reasons is that urged by old fishermen on the Delaware River to account for the scarcity of shad. They allege that the electric lights on the bridges terrify the schools of shad and cause the fish to disappear. The opposite effect might have been more easily anticipated, for bright lights as a rule have an attracting and fascinating influence upon most fishes.

The disappearance of the valuable tile-fish which for three years (1879-82) was very abundant on the north-east coasts of the United States, was attributed by some American authorities to volcanic causes. Almost in a single night this fine market fish was completely destroyed and the vessel, authorized by the U. S. Government to investigate this remarkable occurrence, found the sea for over 150 miles in a direct line crowded with the floating bodies of these dead fish. Between six and seven thousand square miles were covered by this wave of destruction, and the schools of tile-fish appear to have been entirely cleaned out of that region, though stray groups of them have been reported occasionally, though not to be compared with the millions that for the period named abounded in these waters.

Destruction of eggs or fry.—The eggs and fry of fishes are so delicate that in unfavourable seasons it is no matter of surprise to learn of their widespread destruction. We know that along the shores of Gloucester and Northumberland Counties herring-spawn is heaped up for miles after storms and is largely used for manure under such circumstances. In many salmon rivers a season of drought or an unusually severe spring may result in the death of vast quantities of eggs and alevins. In the Restigouche River some years ago sheets of ice floated down from the redds or spawning beds which were packed so densely with eggs as to appear quite orange-coloured. The ice had crushed down upon the eggs and gravel and lifted them in masses so that they were killed and carried down over a hundred miles to the sea. The phenomenal periods of plenty and of scarcity in the salmon rivers of British Columbia largely arise, there can be little doubt, from natural unfavourable conditions in the upper waters hundreds of miles away. A dry season and insufficient water on the spawning beds or a protracted season

of cold in spring may effect widespread destruction of eggs and young fish ; but three or four years must elapse before this will be apparent. When the time arrives at which the schools of adult fish should ascend, had they not been so seriously destroyed at the headwaters when young, no ascending schools appear or a mere fragment of the expected schools, then the effect is apparent. The so-called cycles of plenty (four or five years it was generally thought) find their explanation in this way. Of course, over-netting, and the slaughter of fish by Indians must have their baneful results, but the seasons of abundance and scarcity, common to all the Pacific rivers, may be traced to unfavourable conditions prevailing during spawning or incubation of the eggs. Unless sufficient fry are hatched the usual runs of adult fish cannot be secured. Cod, haddock, mackerel and other fish whose spawn floats at the surface of the sea are peculiarly endangered. Ice, rain, surface pollutions, &c., must in some seasons destroy the eggs in countless quantities while the delicate fry, also in the surface waters for many weeks, are equally susceptible to these unfavourable conditions. There is no difficulty in explaining in this way many of the otherwise inexplicable cases of erratic decrease or total disappearance of such species of fish. Some authorities attribute the decline in the great lake fisheries, especially lake whitefish and herring, far less to overfishing than to the destruction of fry especially by the use of drag seines. These nets are used upon flat, smooth shores, free from stumps, boulders and debris, and it is precisely in the clear shallows along the lake shores that the schools of fry congregate. The net is, as it were, thrown around the fish within a short distance of shore, and is pulled to land. Before being hauled in both ends are secured on shore, and the net forms a complete inclosure, capturing everything within its sweep and extending in some cases as much as 1,000 feet, with 12 feet depth in the middle, though the dimensions are often less than these. Captures in the seine are of a very varied nature, and as the meshes are loose, and not usually fully open, as in a fixed net, like a pound, many fish are entangled which are of no value for market purposes. Young fish, included in this mixed catch, are mostly injured, and may be thrown ashore as useless. Further, the constant use of seines, sweeping over the shallows, has a very unfavourable effect on the shoals of small fish. They are disturbed in their migratory movements and driven into deeper water, where they are exposed to the attacks of larger fish. Indirectly, as well as directly, the schools of fry are injuriously affected. Professor Ramsay Wright, and other authorities with special knowledge of the inland waters of Canada, have described the capture of immature whitefish by herring seine-nets, and pointed out that the surplus fish are used as manure when the market is glutted. Similarly, Dr. H. M. Smith speaks of ground where whitefish formerly spawned in considerable numbers and, where the young now appear to congregate at times, on which quantities are taken for bait, measuring 1½ to 3 inches long. The fishermen when using the seine can hardly know the extent of injury they inflict ; for when very young, our valuable good fishes are transparent, minute, and almost invisible in the meshes of the net.

That valuable fry are thus disturbed, injured and destroyed, there can be no doubt. It is impossible to avoid this where seining is carried on. But the destruction of the young of inferior species, usually regarded as worthless, is most harmful. These small fishes, or minnows, are the favourite food of pike-perch or pickerel, salmon-trout and other predaceous fish. The abundance of these more valuable kinds depends largely on the abundance of smaller varieties on which they largely live. The term minnow applied to these small fishes is used indiscriminately and embraces nearly twenty species, including some of the more valuable food fishes.

As compared with the fixed pound-net, inshore, through the meshes of which the very small fry mentioned readily pass without injury, or again, with the gill-net hanging with fully extended meshes in deeper water, the seine is by far the most injurious from the point of view here considered.

It may be that the supply of whitefish would have fairly well withstood the drain of the net fishery had it not been that they were so seriously decimated in the young larval stages. Certainly the former abundance of whitefish in Lake Ontario is astonishing.

At present the lake is regarded as not a whitefish lake at all, the catch of over 620,000 pounds in 1870 had fallen to about 400,000 pounds in 1890 and in 1895 reached the low level of about 126,000 pounds. Yet 40 years ago on Wellington Beach at the east end of the lake, where whitefish are now exceedingly scarce, single hauls of nearly 500,000 large whitefish are recorded (viz., 400 barrels). At Burlington Beach in 1856, at the west end of Lake Ontario, the men netted 86,400 whitefish and nearly 2,000,000 lesser whitefish or lake herring.

At Port Credit, near Toronto, and other places, equally large catches were made, and the Superintendent of Fisheries for Upper Canada (Mr. John McCuaig) felt justified in 1859 in describing these fishery resources as "literally inexhaustible riches."

Lack of Food.—There is no doubt that the abundance or deficiency of food is most potent in affecting the movements of fishes. Scientific research has shown that each species of fish so far as ascertained lives upon special and peculiar food. Just as a lion requires a diet wholly different from that of a horse, and a squirrel would starve where the others would find abundant food, so the various fishes in rivers and sea live upon kinds of food which are wholly dissimilar. The mackerel prefers the small shrimp-like crustaceans, especially copepods and larval crustaceans which abound within a fathom or two of the surface of the open sea, the cod on the other hand seeks his food on the bottom or along the rocks and banks near shore so that small fishes, crabs, shell-fish, worms, zoophytes and other forms of bottom life are appropriate to his needs; while some of the flat-fishes, and species with massive crushing teeth, like the sea-wolf, prefer molluscs and sand-loving crabs and crustaceans. While it is in a vast number of cases easy to trace to the presence or absence of their special food the fluctuations in the abundance of certain fish, it is far less easy to account for the paucity or plenty in the occurrence of the animals which constitute the food. Many years ago some apparently unusual currents brought incalculable quantities of a small sessile-eyed crustacean to the eastern shores of Scotland. For some time the shores were clothed with these strangers, a small shrimp-like creature, unfamiliar to Scottish observers. At the time of this influx and while these interesting crustaceans were occupying some of my attention, my friend Dr. Fritjof Nansen, distinguished at that time as a brilliant young zoologist, prior to his winning fame as the intrepid hero of the Polar regions, being on a visit to Scotland at once identified the species as one found in peri-arctic waters and known on the coast of Norway. Doubtless some unusual disturbance of oceanic circulation had wafted these vast hosts of small shrimps from the north and no doubt attracted in their train quantities of northern fish. These erratic appearances of unfamiliar animals are related it can hardly be questioned to the converse disappearance of other animals upon which certain species of fish feed. The excessive drain upon the lobster supply in Dominion waters, and especially the relentless slaughter of spawning lobsters involving the loss of incalculable numbers of fry, just about to hatch, must have affected the characteristic surface fauna of the territorial waters. Areas like the waters immediately adjacent to Cape Sable and the neighbouring Nova Scotia shores, or the shallow stretches embraced in the Straits of Northumberland and around Prince Edward Island must at one time have been alive with larval lobsters swimming for more than a month in June or July, or even later, in the surface strata. There may be some basis for the contention that the schools of mackerel no longer come into certain of their accustomed resorts because this food supply consisting of young lobsters has been cut off. The excessive destruction of berried or seed lobsters must have vastly diminished the numbers of the swimming infant lobsters, and the decrease or disappearance of these would lead to the non-appearance of the feeding mackerel. While this may be so there appears far more reason to attribute the loss of the mackerel to the decimation of the adult fish when crowded together at the spawning period in the open sea. This extermination of food may be due, as pointed out, to natural causes or to artificial causes directly resulting from man's operations. Peculiar ground currents, excessive undertow, the grinding of the bases of ice-bergs and moving bodies of ice are known to wholly change the nature of the sea-bottom over extensive areas. Sand-banks and gravel become heaped

up or strewn over a soft bottom, or a hary rocky ground: and sea-weeds as well as animals, indeed the entire flora and fauna may become suddenly changed. Such changes at once affect the schools of fish. At times changes of an analogus character are attributed to artificial or human agency. Thus the schools of splendid shad which once swarmed up the New Brunswick and Nova Scotia shores to the head of the Bay of Fundy in the fall are practically a thing of the past. Instead of catches of 3,000 to 5,000 barrels in Minas Basin and Chignecto Channel, at one time famous resorts, the quantity of fine fat shad taken in the late summer in the counties of Cumberland, Colchester and Hants barely reaches about 1,000 barrels. These shad, it is alleged, after having ascended the St. John River and other larger or smaller rivers pouring into the Bay of Fundy, and having gone through the exhausting process of spawning in the upper waters in early summer descended in an emaciated condition and made for the feeding grounds, the sandy flats and soft muddy areas in the open bay which extend up into Chignecto and Minas Channels. These sandy flats, it is affirmed, abounded with food peculiarly nutritious for the fish and they rapidly recuperated, and appeared in fat and perfect condition. Every river and stream, however, poured upon these feeding grounds, decayed saw-dust, mill-waste and pollutions so that the food, it is claimed, died off, the shad were no longer attracted as they once had been, and the autumn fish which were so prized and plentiful as a food commodity, have become scarce in the extreme.

It is extremely likely that the disappearance of mackerel from certain bays and coves along the coast east of Halifax, N.S., may be due, not as many suppose to the fouling of the water by mining pollutions, but to the destruction of the food which no doubt attracted in the schools. In such inshore and comparatively shallow bays it is improbable that the mackerel would spawn, indeed some of the finest schools were fall fish. As one local authority stated not long ago injury has arisen from the "tailings" resulting from the crushing operations in the quartz mills at the neighbouring gold mines. Mercury, dynamite, &c., were used, and the tailings and waste generally were carried out into the sea. This bay (the bay referred to is Salmon River Bay, St. Mary's Co., N.S.) was exceptionally good for mackerel, but they like pure water and for eight or nine miles out from shore the muddy pollution from the mines can be seen. Where there used to be five fathoms of water in the bay there are now not more than five feet, because of the deposits referred to and the accumulation of tailings. The crusher has been idle, however, and recently (October) there was quite a large body of mackerel, indeed several bodies of mackerel in the bay. The fishermen unfortunately were not prepared, and could not seine the fish which were moving towards western Nova Scotia.

Periodical or erratic times of food scarcity must of necessity occur, and even the Norwegian waters so prodigal of animals on which fishes feed are no exception, for the takes of codfish some seasons, while enormous as they proverbially are, realize far less value on account of their thin and poor condition than in normal seasons. The want of food explains their emaciation; but the causes for this scarcity of nourishment are more difficult to trace. The ill-fed condition of the fish directly affects the character of the liver and other organs, and this is seen in the decreased production of the fish oils which are of such great market value.

Dr. Fredrik Wallem has pointed out that "on an average 400 Lofoten codfish will give one barrel of liver, and two barrels of liver will give one barrel of medicinal cod-liver oil. But in seasons when the cod is of poor quality, as in 1882, 900 and even 1,200 codfish are required to yield one barrel of liver; and this liver itself was rather poor, so four barrels instead of two are required to make one barrel of medicinal cod-liver oil." In cases where appropriate food conditions prevail throughout the year a fish essentially nomadic like the herring may become stationary for the year and practically stationary for the year like the Loch Fyne herring of Scotland or the local varieties in the fjords of Norway. The absence of food is the negative force, while abundance of food is the positive force directing the movements of fishes, and the interesting details given by Prof. G. O. Sars may be here referred to. He points out that in exceptional cases, schools of herring remain in the deep fjords for a whole year and longer, and such herrings will naturally assume

a character of their own, so as to pass for a special variety or coast-race. Although we know all the stages in the life of the herring near the coast of Norway, and would, therefore, reasonably suppose that its whole youth, till the period when it spawns for the first time, was spent near the coast, Sars remarks expressly that, on the whole, the occurrence of the summer-herring near the coast must be considered as altogether temporary. It comes, like the older herring, (the spring herring) from the open sea, but not from such a distance as this one. "Some time before the large masses of summer-herring came to Espevær, in 1873, the mackerel fishers often caught considerable quantities of large and fat summer-herrings in their nets at a distance of from five to six miles from the coast, and schools of large and small herrings could often be observed from the mackerel boats. Soon afterward the current, on account of a very sudden change in the weather, turned with unusual violence toward the islands near Espevær, and carried with it enormous quantities of small crustaceans, which were closely packed in all the neighbouring bays and sounds; then the herrings began to come in from the sea, first the larger and then the smaller ones." As during winter the small crustaceans are not found near the coast in such large quantities, the migration of the young herring toward the sea will, on the whole, be much less disturbed than during summer, and there are no instances of the spring-herring having returned to the coast to seek food after having spawned.

On the fishing banks of Cape Breton County, Nova Scotia, ten or twelve years ago fine halibut were extremely plentiful and then they mysteriously disappeared. As it did not appear that the fishery has been carried on to excess, local fishermen were in perplexity as to the cause. Recently, 1898, the halibut have reappeared, and the defunct fishery has been resumed with vigour. Some temporary change in the surface of the banks on which the halibut feed no doubt accounts for the disappearance, or the exhaustion of the food itself, which has had time to restore itself in the intervening period. The molluscs, annelids, &c., upon which the fish feed may have been covered over and smothered by sand, drifted by some unusually strong undercurrent, and this may now have resumed its normal level and condition, for the bottom of the sea in many places is thus alternately changed and restored. Now the area referred to is literally alive with fine halibut, 30 pounds to 150 or 200 pounds weight, and in the fall a remunerative fishery is carried on by the Canadian fishermen and by U. S. schooners. A reverse state of things is exhibited by the Cape Breton schools of mackerel which ten years ago, after a period of decline, appeared in all their former abundance. So abundant indeed in 1889 and 1890 that old fishermen declared they had seen nothing like it since their early days. Now the mackerel fishery has reached its lowest possible level and the schools have almost wholly disappeared.

The cases referred to in the foregoing pages include those more salient and probable, but the scarcity and total disappearance of fish may arise from other circumstances plain and apparent in some cases, but obscure and difficult to discover in other cases. The evils of obstructing schools of fish in their migration to their spawning grounds especially in rivers and lakes are apparent. Wharfs and mill-dams, walls of netting and accumulations of lumber and rubbish have destroyed salmon, alewives, striped bass and other fish, or caused them to seek wholly new resorts. The salmon nets off Charlotte County, New Brunswick, have, it is claimed, diverted whole schools of salmon from the New Brunswick shore and caused them to cross the Bay of Fundy and ascend the Nova Scotia rivers opening into the bay. This may or may not be so, though the increased catches of Nova Scotia salmon were coincident with their decrease in certain New Brunswick rivers and streams. The blocking of fine rivers by enterprising business firms is too prevalent an evil to demand special notice.

II

THE FOOD OF THE STURGEON

BY PROF. E. E. PRINCE, DOMINION COMMISSIONER OF FISHERIES, OTTAWA.

There are few phases of fish life so little known generally as the feeding habits and peculiarities of the food of different species. Yet it is of the highest importance for a judicious administration of great fisheries which provide a means of livelihood, and are a source of food for the people, that the facts regarding the means of nourishment and the peculiar methods of obtaining it should be ascertained. Otherwise, regulations might be devised to protect one species, which would have the effect of exterminating another, and fishes of inoffensive feeding habits suffer from lack of proper safeguards, resulting in the destruction of an important fish supply.

One of the most common arguments urged by parties interested in extending any particular fishery is the claim that the particular kinds of fish specially referred to are injurious to others. By eradicating these particular kinds, it is argued, the remaining species will be encouraged and increased. Many fishermen hold the view that any fish which is predaceous and feeds upon other fish should have no protection, either by close seasons, netting and mesh limitations, &c., but for the benefit of the fisheries generally should be decimated. As applied to the voracious cat-fishes, the wolf-like grass pikes and even the doré or pickerel the argument appears plausible enough, but it must be remembered that under undisturbed natural conditions, the predaceous and inoffensive kinds have always inhabited the same waters and that the balance of life was duly maintained until man's operations came in as an interfering force. These operations were in the great lakes and inland waters of the Dominion generally, most actively directed against the lake whitefishes, the lesser whitefishes or lake herrings, &c., and the capture of these in immense quantities, especially at the spawning time, has undoubtedly left them at a serious disadvantage in the maintenance of their existence. Physically, and in habits and modes of life, less able to hold their own against the strong, active and voracious species, their disadvantages have been increased by the decimation of the parent fish, so that the numbers of young brood each season are wholly unequal to compensate for the double loss thus brought about. It is a general law, especially amongst fishes, that those species which are in danger on account of feeble powers of defence or because they are not endowed with adequate means of escape or weapons of offence, rely upon the multitudes of the young fry produced each season to withstand the drain upon their numbers. Hence, a knowledge of the breeding habits and the quantity and character of the fry is essential; but as a preliminary step it is most necessary to have some accurate account of the food and methods of obtaining it in the case of every species of economic value. It is not sufficient merely to rely upon the statements of dealers and those engaged in fishing for a livelihood, for even in cases where the opinion may not be unduly biassed by self-interest, it is rarely based upon actual examination and observation. Hence, the charges almost universally made against the sturgeon that it is the most voracious of all fish-eating species, that it scours the spawning grounds of the great lake-trout, the whitefish, and every other kind of valuable market fish, sucking up the eggs with its tube-like mouth and scooping in whole schools of defenceless fry, demands serious attention. If the sturgeon be an arch offender of this character, and the most destructive of all our predacious fish, the question of adopting special protective regulations in order to increase its numbers requires grave deliberation. There are few fishes in our fluviatile and lake waters of greater market value. Its flesh is in great demand—

its ova, of which caviare is made, are eagerly sought after, and a number of other valuable products are obtained from the viscera and waste. Its protection on the ground of its high and increasing economic value appears desirable; but if its extremely predaceous and destructive habits be as so frequently alleged, the value of the other fisheries which the sturgeon (it is said) so seriously injures, the whitefish, lake-trout and other species, have a first claim to legislative attention. Dr. S. A. Forbes, in an interesting paper published some years ago (Illinois State Fish Commission Report, 1890) gave a general account of the food and feeding habits of fresh-water fishes, so far as his own researches had gone, and in his list of predaceous or fish-eating kinds, including the pike, pickerel or doré, the large-mouthed black bass, channel cat and cat-fishes generally, the sturgeon is not included.

Perhaps the best account of the food of the sturgeon is that of the late Professor J. A. Ryder (Bulletin United States Fish Commission, 1888), for it gives information upon the subject from the early larval stages up to the adult. After the embryo has exhausted all the yolk, hanging like a sack from the under part of its body, it takes very small food, and probably up to the third month, when it first exhibits small conical teeth, it subsists upon minute plant forms, infusoria and animalculæ, as well as worms, microscopic shrimps, and the larvæ of water insects, rhizopods, diatoms, &c., which abound on the slimy bottoms of sloughs, creeks and estuaries, and are swallowed by the little sturgeon in quantities. Later, when between one and two inches long, minute teeth being present in the throat as well as upon the jaws, the stomach has been found to be crammed with small water-fleas or crustacean mites, though worms, insects and possibly fish larvæ constitute much of its food. Larger crustaceans, the shrimp-like isopods and amphipods, in addition to the foregoing microscopic organisms, when the sturgeon reaches the mature condition. Ryder found that its food is composed of larger organisms, though in his examination of the digestive organs he was struck with the very meagre débris or remains in the stomach or intestine, and the difficulty on this account of deciding what forms the principal elements in its dietary. In specimens entering rivers from the sea, shells of the common black mussel *(Mytilus)* occur, and remains of the large, deep-water species *(Modiola)*, commonly called the horse-mussel. Ryder concluded that shell-fish are largely devoured by the sturgeon. At Tampa Bay, Florida, Mr. Elkington observed (according to Ryder) that the sturgeon dig up the soft bottom with their snouts. During my numerous official tours as General Inspector of Fisheries for the Dominion, extending over most of the waters of Canada, I have made frequent inquiries respecting the food of the sturgeon. Published observations are very fragmentary and, with the exception of the late Professor Ryder's account, no systematic attempt to deal with this important subject seems to have been attemped. Dr. Hugh M. Smith justly observed in his account of the "Fisheries of Lake Ontario" (Bulletin, United States Fish Commission, volume X, 1890), that "while it is known that the sturgeon is a bottom-feeder, and that the shape of the mouth and the general anatomy must determine the character of its food, much yet remains to be learned concerning the food and habits of the fish." Professor Browne Goode pointed out (Fisheries of the United States, Section I., 1884, page 660) that the stomach resembles the gizzard-like organ of the menhaden and mullet, and is perfectly adapted for grinding molluscs. Milner, as quoted by the authority just mentioned, holds that it does not feed very extensively on the spawn of fishes, but subsists almost entirely on shell-fish in the lakes, principally gastropods, the thinner-shelled kinds of the genus *Physa*, *Planorbis* and *Valvata*, as well as *Lymnæa* and *Melantho*. The European sturgeon, as Parnell stated, consumes marine worms: "In the stomach of one from the Tay was found an entire specimen of the so-called sea-mouse *(Aphrodite aculeata)*" and he also noted, somewhat vaguely, that small fish and worms seem to be its principal food. Yarrel informs us that "the débris of crustaceans and half-digested pieces of fish, mixed with decaying vegetable matters and mud, have been found in the stomachs of sturgeons and their food is probably any soft animal or vegetable organisms that they find at the bottom." There is no evidence that I can find supporting the view that sturgeon are predacious or pursue and devour other fish, and the construction of the sucking mouth and its habit of grubbing along the bottom would

be adverse to such a propensity. On the other hand, there are just as few observations in support of the theory that the sturgeon is addicted to consuming the spawn of other fishes, or decimating the young fry when hatched out. Perhaps the most prevalent opinion amongst fishermen and fish dealers is that the sturgeon is a spawn destroyer. A large Detroit fish merchant once assured me that he had seen several gallons of spawn which had been swallowed, taken from a sturgeon, and he considered that it was a fish entitled to no protection whatever on account of this evil habit. The view is very widespread that fishes' eggs and newly-hatched fry form a considerable part of its food. "Experience goes to prove," to quote from a published statement on the subject, "that sturgeon feed almost exclusively on the eggs of other fish." Were this very prevalent opinion supported by reliable observations, and therefore well founded, the wisdom of protecting this fish in waters abounding in non-predacious and valuable species would be open to question. As a matter of fact, excepting in Manitoba and the North-west Territories, where sturgeon are of such vital importance for the sustenance of the Indians—"It is to us Indians," a Blackfoot hunter is recorded to have said, "in the water, what the buffalo was on land," and excepting in British Columbia, no special code of protective regulations has been formulated in Canada. In New Brunswick, in connection with the depleted St. John River sturgeon fishery special rules have been enforced. But in view of the uncertainty as to the facts of the alleged destructiveness of the sturgeon, very strict protective legislation has not been carried out.

It is very evident from the structure of the sturgeon's mouth that the fish is powerless to capture very active prey. There are no movable jaws for seizing and, in the adult, no teeth for tearing it. The mouth is protrusible, in the form of a flexible telescopic tube, and, like a hog's snout, is suitable for turning up the soft mud at the bottom of the water. Just in front of the mouth are four slender feelers which assist in the grovelling operation. Fishermen are well aware that it is not necessary to use any bait in order to catch sturgeon, and in some rivers a "trawl" has been used, consisting of a series of strong sharp hooks fastened at intervals along a stout rope. The rope is stretched across the bed of the river, and so intent are the fish in the "grubbing operations, that they press upon the trawl with all their force and are pierced by the sharp hook. Many sturgeon also are netted; but when feeding, it seems to be demonstrated that the fish glide over the bottom, protruding the long mouth, like a trunk, and sucking up the mud and nutriment upon which they mainly subsist. The strongly muscular character of the stomach, and its large capacity, even when compared with the large size attained by the fish, all indicate that food so easily comminuted and digested as the fry of fishes or their spawn, does not form a large part, if any part of the food of this fish. There are, indeed, difficulties in crediting the common allegation, arising from the fact that the fish usually stated to suffer from the depredations of the sturgeon spawn in localities, not as a rule, frequented by that fish. Thus, in the great lakes the whitefish always spawn upon hard grounds. They especially prefer rocky reefs and shoals, much waterworn and full of crevices and jagged edges. In some waters, as in Lake Erie, there are areas of honey-combed rock, or plateaus of deeply eroded limestone, which are famous as the resort for great bodies of whitefish, and probably other species. The depth over these reefs varies from 4 feet to 20 feet, and neither the depth nor the character of the bottom is favourable to the movements of the sturgeon. Its slow, heavy, grovelling movements are such that on jagged, water-worn surfaces it would suffer serious injury; and a soft muddy bottom, such as is found in deep channels and in slow running estuaries and creeks forms the usual haunts of the sturgeon. I have had the opportunity of examining sturgeon from the extreme eastern and western waters of the Dominion, and in none of the specimens were found any evidences which bore out the common opinion that the sturgeon is a devourer of spawn. It is true that some sturgeon sent to Ottawa for my examination from British Columbia were found, to my surprise, to contain large quantities of a small, smelt-like fish the Oolâchan or candle-fish *(Thaleichthys richardsonii)*. One specimen, a male sturgeon, 71 inches long, contained thirty Oolachan, each 5 or 6 inches in length, and the other specimens were quite distended with these small fish. Possibly these fish were ascending from the sea in such numbers that they could not escape the suctorial jaws of the cumbersome sturgeon, or it may be that they were

sickly or dying fish, perhaps captured fish thrown overboard dead by some fishermen who had more than they required, and thus they might fall an easy prey to the far from predacious sturgeon. Lying at the bottom in masses, the sturgeon would devour them greedily, sucking them up without difficulty. So vast are the quantities of this fish in early spring in some of the Pacific rivers that they often form solid masses, working their way slowly into the river. It appears in immense shoals, and is caught either with the scoop-net, or, like the herring on the sea-board, with the rake. This simple device is merely a long light pole, flattened in one direction so as to pass readily through the water and with the edge set towards the lower extremity with a row of sharply pointed teeth. The fisherman, entering the shoal, passes the implement repeatedly through the water with a rapid stroke, each time transfixing several fish. Thus a copious supply is soon secured. The Oolâchan is, in the estimation of most people, one of the most delicious products of the sea. Smaller than the herring, it is of a far more delicate flavour; and so rich that, when dried, it is inflammable. This fish is not confined to Fraser River, but frequents, likewise, the Nass, a large stream issuing in the extreme north of British Columbia; another stream debouching into Gardner's Canal; and probably other rivers along the coast. Those caught at the mouth of the Nass are of a quality even richer than those of Fraser River. The natives, who assemble there in great numbers in spring to prosecute the fishery, besides drying them in large quantities, extract from the surplus a fine oil, which is highly prized by them as a luxury, and forms a staple article of barter with the interior tribes. This oil, of a whitish colour, and approaching to the consistence of thin lard, is regarded by those who are acquainted with its properties, as equally efficacious with the cod-liver oil so commonly prescribed; and it is said to have the great advantage of being far more palatable. If the Indian, with his simple apparatus can make considerable catches, there is little difficulty in conceiving how the sturgeon could secure ample food supplies, where the water around him was simply a moving mass of these delicious fish. The sturgeon were examined about the middle of May, and it has been noticed that the Pacific sturgeon usually ascends the rivers at the time the Oolâchan run commences.

I have also had the opportunity of examining specimens of sturgeon from the River St. John, N.B., where, at one time, an extensive sturgeon fishery was carried on. Operations of too destructive and unlimited a character resulted in the almost total extermination of this important species in the river in question. In the specimens examined in the River St. John, there were no traces of fish remains whatever, although the shallows were crowded with newly-hatched, defenceless gaspereaux, shad, and other clupeoids. Most of the spawn of these last-named fish must have hatched out by the middle of June, yet, judging from the minute size of the fry, quantities of fish ova must still have been lying on the spawning beds of the Washademoak, and the shallows near Gagetown, Sunbury County. Apart, however, from a quantity of mud and masticated vegetable ooze, in which unicellular algæ were plentiful, the capacious stomach was loaded with fresh-water mollusca. The shells, in a large number of cases, were almost perfect, except that the periostracum was digested off, but the larger shells had undergone some trituration, and the lip was lacking. A vast number of opercula, showing the spiral structure in the semi-transparent horny matter, occurred in the mud, and consisted chiefly of vegetable matter, but no characteristic structure could be made out, so that its real nature was uncertain. Probably it consisted of leaves and stems of aquatic plants, much triturated, and here and there the silicious tests of diatoms, desmids and other lowly plants appeared. The specimens were captured and examined about the middle of June, and as I was much engaged at the time with other departmental duties I was assisted in the determination of the contents of the stomachs examined by Mr. Andrew Halkett, of the Department of Marine and Fisheries, a zealous and gifted observer who has devoted much attention to the study of mollusca and other branches of zoology. Some of the specimens being partly triturated, there was a little uncertainty in their determination; but this doubt exists only in the cases of *Amnicola limosa* and *Sphærium triatinum*. In all, there were no less than eleven species of shells amongst the contents of the sturgeon's stomachs from St. John River, viz :—

Planorbis parvus, Say.
Planorbis bicarinatus, Say.
Planorbis campanulatus, Say.
Limnaea catascopium, Say.
Amnicola limosa ?
Amnicola porata.
Campeloma decisum, Young.
Valvata tricarinata, Say.
Valvata sincera, Say.
Sphærium (Cyclas) striatinum ?, Lamk.
Pisidium abditum, Haldeman.

Taking into consideration the fact that the sturgeons examined had been feeding in the close neighbourhood of the spawning beds of the anadromous fishes (the shad, gaspereaux, &c.), which ascend to deposit their eggs in well-known regions near the Washademoak, Grand Lake, &c., it was anticipated that portions of the egg-capsules of the species referred to, would have occurred in the food or that portions of larval fishes, which crowded the shallows, would have been present. The food, which was abundant, consisted solely of shell-fish and vegetable matter, with a few scattered unicellular algæ. A more prolonged investigation and the examination of the food contents in the stomachs of a large series of sturgeons would show, there is much ground for thinking, that the rapacious character commonly attributed to the sturgeon is not justifiable. The present limited study, so far as it goes, is conclusive enough, for no trace of eggs or fry was perceptible under the most minute and patient examination. In view of the existing system of planting fry of salmonoids and other valuable fish, and of the precautions for protecting parent fish and their spawning beds, such a conclusion is of some value, and it indicates the probability that the sturgeon is not to be credited with the predacious propensity and evil character so commonly attributed to it. Fish merchants and fishermen desirous, at all costs, of extensively pursuing the sturgeon fishery, and using the argument that in exterminating this valuable fish benefit must result to other fisheries, have no reliable evidence so far to support their contention. Their view may have some ground in fact, but the depletion of sturgeon in many well-known waters haa not sensibly resulted in a great increase in other fishes to which the sturgeon was specially thought to be inimical. Wherever the sturgeon fishery has been actively prosecuted, the supply has been rapidly depleted, and extensive destructive operations inevitably end in this result, as the fish are specially sought after when loaded with the ripe spawn, from which caviare is made, and the immature sturgeon are caught ruthlessly on account of the value of their flesh, and the waste products from which isinglass is made. As has been already pointed out, the famous St. John River sturgeon fishery rapidly succumbed, the abundant schools which were found in the great lakes, and especially the numbers found in the Detroit River and St. Clair waters have seriously declined. In Georgian Bay, sturgeon were so plentiful that they were a nuisance in the nets, and in Lake Superior the fishery forms now a wholly inconspicuous element in the western fisheries. In Lake of the Woods the sturgeon fishery has been carried on vigorously for not more than four or five years, and it is generally admitted that the manner and extent of the fishing operations are such that it cannot long withstand the heavy strain now put upon it. In British Columbia, the sturgeon of the Fraser River have grown to importance, but overfishing, especially in the Pitt Lake waters has resulted in a sudden and serious sturgeon is of prime importance in deciding what legislative steps are necessary, in view of these serious results.

III.

NOTES ON THE HABITS AND LIFE HISTORY OF CANADIAN SALMON

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Of all the finny dwellers in our waters the true salmon *(Salmo salar, L..)* is perhaps the best known and most highly esteemed. In symmetry of form, in brilliance of silvery armour, in dash and vigour of movement, in strength and quality of "fight," and above all in the supreme esculent qualities of his richly tinted flesh, the true salmon has no peer. According to old English law the salmon along with the whale and sturgeon ranked as "Royal fish," and by common consent the salmon's title to that pre-eminence remains undisputed. The indomitable perseverance exhibited in his arduous migrations, the choice, which the salmon unfailingly makes of the purest and noblest rivers, and, again, the value from an economic point of view of the salmon as a food product add to his claim to be regarded as the "King of fishes." The Dominion, traversed as it is by some of the coldest, clearest and most majestic rivers in the world, is *par excellence* the chosen home of the salmon. It may be doubted whether there are any salmon rivers in the world to compare in most respects with the Restigouche, the Miramichi, the St. John and a score of others, famous in the annals of sport. So much has been written about the salmon and allied salmonidæ that the treatises if collected together would form an extensive library. Yet a condensed and accurate account of the true salmon, and of valuable allied forms is not generally available, and the following notes aim to supply the want and to embody all the most recent knowledge respecting the salmon and the salmonidæ generally.

The family salmonidæ embraces fresh water and salt water species some occurring at great depths of the sea like *Bathylagus* and brought up from 2,000 fathoms depth by H. M. S. "Challenger," others confined to comparatively shallow fresh water areas like the whitefish *(Coregonus clupeiformis)* of the great lakes, or seeking some depth in inland waters like the great lake trout *(Salvelinus namaycush)*. The grayling, at any rate one species, Back's grayling *(Thymallus signifer)* prefers the rippling streams of the Arctic and peri-Arctic regions, while others are equally at home in fresh or salt water like the true salmon, the smelt, the candle fish or Oolachan of the Pacific and the sea-run brook trouts. The smelt-like capelin prefers to linger within the limits of brackish water and of pure sea-water.

The old disputes as to the nature of the twelve-barred parr, the view that grilse or salmon peal are really a small but distinct species of salmon and the like, are settled for ever; but authorities still wage hot controversy upon vital points in the salmon's life history and indisputably show that the interest attached to the habits of this fish from the early infant stage onward is perennial. The questions still discussed include such as the following:—"Do salmon feed in fresh water? Are salmon indifferent as to which rivers they ascend for spawning, or are they true to their own streams? Do salmon resort to the depths of the sea or do they merely remain in inshore waters?" Many of these questions, though still debated by anglers and sportsmen generally, have been decided definitely by scientific authorities, and in the succeeding pages the main facts in the wonderful life-history of the salmon and of allied forms, often confounded with the true salmon, will be briefly set forth so far as they have been established by exact investigation.

Notwithstanding the exalted position commonly accorded to the salmon principally on account of its fine qualities as a game fish and a food fish, there are some points in its structure and anatomy which are of a marked primitive and lowly character. In the lowest fishes the skull and much of the skeleton consists of gristle or cartilage, but as we rise in the scale of fish life we find that by deposits of lime in the soft cartilaginous material the skeleton becomes changed into dense white bone. Thus the skull and shoulder bones of a cod become changed into hard bone; but in the salmon this change is only partially accomplished and much of the skull, the shoulder elements, &c., remain as soft cartilage. The position of the paired fins is primitive and while in many fishes the hind pair or ventral fins are placed far forward, as is the case with the haddock, the mackerel and the bass, in the salmon they retain their early position half way along the body. Other lowly features might be instanced, but the most remarkable and, to the naturalist, the most perplexing is the absence of oviducts in the female salmon. In the more highly organized fishes the eggs after being formed in the egg-glands or ovaries pass backwar along a pair of tubes called oviducts and so find an outlet. In the lowest fishes there are no such tubes, but the eggs drop from the ovaries when ripe and roll along the abdominal chamber till they find exit. The salmon is exactly like the lamprey in this primitive, or as some think, this degraded feature.

Regarding the distribution of the salmon it may be said that of the rivers pouring directly into the waters of the Atlantic every one in Canada is a true salmon river. In a few cases it might be appropriate to speak of them as salmon rivers in the past tense, yet some waters like the tributaries of Lake Ontario, which are no longer resorted to by salmon in numbers or with regularity are still found to yield an occasional salmon. The Superintendent of Fisheries for Upper Canada described in his report for 1859 the capture of an extraordinary number of salmon at certain points along the lake. At Port Credit he said there were taken 470,000 fish in 1856, two-thirds of them being salmon. It is difficult to understand such a haul of salmon, for the mention of salmon trout (the great lake trout) in the same report shows that the two were not confused as they frequently are in some parts of Ontario. Indeed even at that date salmon had seriously declined. Many of the streams running into Lake Ontario (he says) were once the resort of myriads of salmon (the salmon proper from the ocean). "I have seen them from 1812 to 1815, swarming the rivers so thickly, that they were thrown out with a shovel, and even with the hand. Now it is rare to see one in those same waters, and the question occurs, is it not possible to entice them back to their favourite haunts? One cannot but feel deeply at the loss—the calamity I may say,—which we have sustained in the destruction of these noble fish. After all the reckless and destructive agencies which have been used, the great numbers which are still found in some parts of the lakes show their vitality, and gives us the best guarantee that no very expensive means need be used for their preservation."

Just as the lobster has its northern limit so the salmon appear to cease as the rivers of the Arctic circle are approached. There is a common opinion even amongst fur-hunters and traders that salmon inhabit some of the rivers pouring into Hudson Bay, but long conversations with residents from Fort Churchill, Chesterfield Inlet, &c., who have lived upon the various rivers in question, have shown rather that the large salmon-like fish captured for food have been enormous sea-trout, or species of Salvelinus allied to the great lake trout. I have had the opportunity of examining specimens of these large salmonoids from the northern Labrador coast, and any examples of so-called salmon submitted to me proved to be recognized species of northern trout and not the true salmon. The true salmon appears to cease north of Hamilton Inlet, and is probably not found in the rivers of the district of Ungava.

The Atlantic salmon of Canada are identical with the salmon of the British Islands and northern European rivers, though minor local peculiarities are noticeable. The head is smaller and more acuminate and the body is more gracefully attenuated both in the shoulder and tail region in the British form. The Ouananiche, a land-locked salmon of Lake St. John and certain lakes bordering on the international line in the basin of

the St. John River and the St. Croix River, is regarded by most authorities as a salmon which, as a rule, remains permanently in fresh water. It has ceased to descend to the sea, though anglers on the Saguenay River report occasional captures of these fish. The tail portion of the trunk of the fish is much lengthened and narrowed and the tail far more expanded proportionately than in the salmon, and it is forked. Some experts doubt the correctness of the common opinion that it is a land-locked variety at all, but the fact that smelt, sea-bass and the salmonoids readily become acclimatized to fresh water, and the example of the small speckled trout, which becomes so remarkably modified under changed conditions supports the common view regarding the ouananiche. The brook trout or speckled trout which migrate up the Nepigon River to and from Lake Superior, are notable for their large size and massive build, and still more the sea-run brook trout which become utterly transformed in shape, size and coloration show how vastly surroundings change the form and external features of familiar fish. The well known instance of the introduction of English river-trout into New Zealand is even more striking. Prior to 1867 there were no salmon or trout in New Zealand. There was but one insignificant salmonoid, an inferior kind of smelt. In 1864 the first batch of eggs reached New Zealand, but in October, 1868, a series of trout eggs sent from England in 1867 were hatched out at Otago and planted. In 1869 another shipment was taken to New Zealand, and many other shipments from the British Isles took place. Now, the trout of British streams rarely averages more than 1½ pounds to 2½ pounds—a 3-pound or 4-pound trout would be a rarity, though specimens have been reported of 15 pounds weight. As a rule 1-pound or 2-pound trout are considered by British anglers as mature well-grown fish. In New Zealand, however, most of the trout have gone down to the sea and have become sea-trout ranging from 10 pounds up to 25 pounds weight. In the small streams the trout still keep their normal coloration and show the usual deep-red spots, but as they grow larger the spots become fewer and finally disappear altogether. In snow rivers this takes place when the trout are one-half pound weight. The vast changes in size, shape and coloration seen in the English trout introduced into the waters of the Antipodes demonstrates the potency of environment.

Passing to the Pacific waters of the Dominion we find a wholly new group of salmonoids abounding there. With the exception of the steelhead and the black-spotted trout *(Salmo purpuratus)* which are close allies of the true salmon and the English river-trout, the so-called salmon of British Columbia are distinguished by many important features some of which especially the length of the anal fin, and the comparatively small scales are apparent at once to the ordinary observer, while the more abundant species are notable for their small size, though it is as a rule canned, one spring salmon being counted an equivalent for three sockeye salmon. The dog-salmon *(O. keta)* 10 or 12 to 20 pounds, is not an abundant fish, but its range is extensive as it occurs in all the rivers of the Pacific from the Sacramento to the waters of Alaska. It is the last to come in and appears at the end of September and runs to the middle of November. It is often marked by dark though indistinct transverse bars, and shows pale green patches about the gill covers and shoulders. Its flesh is stated by Dr. Bean to be of a beautiful red colour when it comes in, but it deteriorates rapidly. All the specimens which I examined in British Columbia were large, 15 pounds to 20 pounds, and the flesh was of a dirty white colour. The teeth were enormous curved instruments, white as ivory and very formidable. It is of no market value though used by certain tribes of Pacific Indians.

The other species worthy of reference in this brief sketch are the blue-back or sockeye salmon *(Oncorhynchus nerka)* which like all of the genus to which it belongs has 14 or 15 rays instead of the 9 or 10 rays of the true *Salmones*. Its weight ranges from 4 pounds to 10 pounds, though the latter weight is somewhat unusual. Its flesh is dry but firm and of a rich red colour, hence its value for canning purposes. A deep coloured salmon is more in demand in the canned-goods market than pale pink, or white flesh, for which indeed there is little or no demand. The sockeyes ascend the British Columbia rivers in countless myriads during July and August or even later and they are followed

by another small species the Humpback salmon. The two kinds often overlap so that nets fished for sockeyes take numbers of humpbacks towards the close of the season. The humpback *(O. gorbuscha)* is a shapely fish on entering the estuaries. Its weight is 2 pounds to 5 pounds, and like other species the male becomes curiously malformed. The ridge along the back rises to a remarkable height while the jaws lengthen enormously. It ascends a comparatively short distance as a rule, and the change is more rapid and observable than it is in the case of the sockeye, the male of which also becomes grotesquely humpbacked. The flesh is white and the species has hitherto been little valued. The coho or silver salmon *(O. kisutch)* is an elegantly formed and from an economic point of view a superior fish, though the pink tint of its flesh is somewhat pale. Ten pounds to 15 pounds is the usual weight, though they grow to be 20 pounds or 30 pounds. They run very late, the early schools following close upon the last sockeye run, but the main run does not come in until October. The largest of all the Pacific salmon in the Quinnat, or spring salmon, ranging from 20 pounds up to 70 pounds or 80 pounds. They are also called Chinook salmon, and are characterized by a comparatively small head, deep body and large expanse of tail. Its flesh is pale pink, though white, and red and white-fleshed specimens are common, and its edible qualities could hardly be surpassed. On account of its unwieldy size and the pale colour as well as the uncertainty of the colour of the flesh, the quinnat is not especially prized by British Columbia canners, though it is nevertheless used. They haunt the inshore waters all through the winter and enter the rivers in March and April, continuing to come in in small schools all through the summer. The spring salmon is stated to ascend the Yukon for 1,500 miles, but it also resorts to spawning grounds much nearer the mouths of the rivers, as I have seen it spawning on a tributary of the Fraser not more than 120 or 130 miles from the sea. It has long been known that ordinary sea water has a very injurious effect upon the yolk which is so abundant in the eggs of all the salmon tribe. Professor McIntosh showed 30 years ago that in the young fry of Tay Salmon, the yolk becomes dense, and of the consistency of cartilage or Indian rubber when placed in sea water, hence the deposition of the salmon's eggs in the sea would involve their total loss. A recent Norse observer, Mr. O. Sagaard, has found by experiment that salmon can be hatched successfully if the salinity is 9 per cent strength ; but if stronger, or if weaker, say 2 per cent or 3 per cent, the results are as fatal as ordinary sea water. It is possible that some of the so-called salmon of the Pacific coast may spawn in brackish waters or so short a distance up river channels, or in coves and inlets where abundant fresh water pours down from the precipitous mountains adjacent, as to ensure a suitable admixture. In this connection the published observations of Messrs. A. B. Alexander and Scofield are of extreme interest. They show that the dispersive and the schooling habits of the young salmon fry vary with the conditions surrounding them. The observations further demonstrated that some run into salt water and that they probably go out at intervals in small schools. The movements of the fish in the streams are regulated primarily by the food supply, which in its turn may be affected by temperature or rains. When the food supply grows short, the young fish instinctively move down stream. In the fresh water they show no tendency to congregate in schools. Their numbers in any given locality are determined by how many the place will accommodate and give each an equal chance to secure its food. They prefer to scatter and shift for themselves. Young salmon in tide water, especially those in brackish water, seem to move in schools.

Certainly schools of small salmon fry 2 inches to 3 inches in length have been noticed in the Straits of Georgia in the month of June which had evidently just passed through the "parr" stage and had assumed a bright uniform silvery appearance and showed no indication of the transverse bars or "parr" marks. Now the true Atlantic salmon attains the size mentioned in about two months after hatching, say in June, but the "parr" marks may be retained for a year at least when the silvery exterior of the smolt is assumed. Hence the British Columbia species must much more rapidly pass through the various changes characteristic of the fry, and probably reach the mature

stages in the half the time of the Atlantic species. If the recently published statement be reliable that a marked salmon, 24 pounds weight and 36 inches in length, had been taken in the fall of 1898, which there was evidence to show was one of a batch of small fry planted in the spring of 1897, then our ideas as to the growth of these fish must be entirely changed. It is *prima facie* improbable that a larval fish a fraction of an ounce in weight (the newly hatched salmon weighs the one-hundredth of an ounce) should reach in sixteen or eighteen months a weight of 24 pounds. Indeed I have a number of sockeye salmon fry in my possession which show twelve or thirteen "parr" stripes, though less distinctly than at an earlier stage and they are seven months old. They are from 2 inches to 3½ inches long and weigh barely 50 grains each (about ⅛ oz). At the same rate of growth they would reach 5 or 6 ozs. a year later, and that is the weight of a smolt 7 inches long at the time that it descends to the sea. Until the evidence is clearer and more convincing it is advisable therefore to adhere to the usual scientific opinion that a Pacific salmon as a rule does not reach a weight of 8 to 15 pounds in less than three years, but as it is in every sense full grown at that weight in the sockeye and other species, its development is far more rapid than that of the eastern species.

All the salmonidæ of whatever genus or species pass through recognized stages. All commence with the egg, which is deposited in clear rippling portions of rivers and streams where gravel and small stones abound and where the water is sufficiently shallow to ensure abundant aeration. The second stage is the "alevin," or newly hatched larva, a delicate worm-like condition, in which the large elongated bag of yolk on the under side, the prominent tinted eyes, the slender tail, and the continuous fin-membrane along the bag, are seen in all the species. Whatever differences there may be in minor details the life history of the eastern or Atlantic salmon is typical of the allied species in our eastern and western waters and it may be divided into eight separate stages.

(1.) The egg stage, in which the fish is as yet unformed. The egg is a spherical object not unlike a translucent pea about ¼ inch in diameter. It is of a marked reddish hue on account of globules of oily matter of a salmon tint which is scattered through the ball of fluid yolk. After fertilization the ball of fluid yolk, somewhat yellowish in appearance, separates into two parts, one the lower, shaped like a flattened disk is germinal protoplasm and is the real germ mass out of which the fish is built up, the other more bulky portion is the food-yolk, finely granular, and containing as already noted the reddish coloured globules of oleaginous matter. Each egg possesses a transparent shell or egg-capsule like a thin skin or envelope, which is very strong and resistent. The egg of a salmon will resist great pressure, some experiments showing that a weight of 5 pounds 6 oz. may be placed upon a salmon's egg before it can be crushed. The eggs are produced in quantity, about 900 eggs to the pound-weight of the parent fish. A 36-pound female salmon will deposit 30,000 eggs, and they grow so rapidly in the ovaries that whereas in early spring the eggs are only about 1 per cent of the total weight of the parent, yet in November when the eggs are nearly ripe and ready to be deposited, they exceed one-quarter the total weight of the female. The ripe eggs are deposited in batches. In 150 days under a temperature 34° to 36° the young embryo has been fully developed and is ready to emerge. One-quarter the time is occupied if the temperature is kept very high, say 97° Fahr. and in 90 days when it is 45°, while the period is 101 days at 43° Fahr. Towards the end of March and during the month of April the embryo salmon have so developed in the eggs that they are ready to burst out. The thin shell ruptures and there emerges a tiny and almost transparent creature, difficult to recognize as a fish at all, and too feeble to employ its mouth in obtaining subsistence. As a rule the young salmon lies upon its side and does not wander far, lying hidden amongst the yellow gravel and remarkable chiefly for the large somewhat lengthened bag of yolk hanging from its under side and directed backward. The reddish orange globules which are so conspicuous a feature in the egg, are still prominent in the yolk-sac of the newly hatched embryo, and they become grouped in masses at the upper side—next to the body of the fish. Red streaks passing across the yolk-sac indicate the blood vessels which pour their contents by the great vitelline vein in front into

heart-chamber under the head of the fish. They are the vitelline veins, and they no doubt convey nutritious particles from the yolk into the body of the larval salmon and thus build up its frame. Frank Buckland noted that the heart beats at the rate of sixty pulsations a minute. Upon this bag of nutriment the little fish solely subsists for some weeks. At first it is ¾ inches long and about two grains in weight, but it grows rapidly at the expense of the yolk, which becomes more and more pointed behind, and may, as the late Sir J. G. Maitland observed, lose portions by pinching off. As Professor McIntosh noted the yolk if squeezed out into the water is transparent, viscous and tenacious, but soon acquires density like tallow, and the orange coloured globules usually sink to the bottom. The yolk-sac gradually shrinks, until it is seen only as a slight protuberance in front. The vitelline vein and other minor vessels begin to collapse and at the third week after hatching it is more than half gone, while during the fifth and sixth week, about the middle of May or later, it is seen only as a slight swelling. As the yolk-sac becomes less, the young fish acquires greater freedom of movement, and instead of lying amongst the pebbles upon its side, or by intruding the pendulous bag between two pebbles acquires an erect position, it can now shoot hither and thither through the water near the bottom. A couple of months after hatching the transparent feeble embryo has been changed into a silvery little fish, which by ordinary observers would be called a minnow with minute red spots and eight or ten dark patches upon each side. These bars or transverse patches are the "parr" marks and they persist until the salmon is ready to descend to the sea. This descent may take place about a year after hatching or it may be postponed until two or even three years, generally in the month of May or June. The mottled dress is lost and a uniform covering of bright silvery scales is acquired characteristic of the smolt. The silvery scalesh are very slightly attached and easily rubbed off, and the "parr" marks can generally be discerned underneath. The "parr" marks become indistinct and hidden under the newly developing silvery scales when the fish is 6 or 8 inches long. The smolt is 8 or 10 ounces in weigh

In the sea, the smolt becomes a grilse or adolescent salmon, weighing from three to eight pounds, with rounder spots, thinner scales, more forked tail and more slender, graceful shape than even the adult fish.

"There is nothing in the water," says Norris, "that surpasses a grilse in its symmetrical beauty, its brilliancy, its agility, and its pluck. I have had one of four pounds to leap from the water ten times, and higher and further than a salmon. Woe to the angler who attempts, without giving line, to hold one of three pounds; he does it at the risk of his casting line, or his agile opponent tears a piece from its jaw or snout in its desperate effort to escape."

Some grilse return within a few months (probably those that have remained the longer time in the "parr" stage in the upper waters), others do not come back for a year. It is extraordinary that the grilse should, in a few months, increase its weight eight or ten times, though a salmon liberated on January 16th, 1889, in Scotland was caught on the 3rd July following, having gained 10¼ pounds. Norris pointed out that smolts and grilse have been marked, and have gone to sea, and returned in six or eight weeks, while other grilse marked at Ballisodare, Ireland, did not return until 16 or 17 months had elapsed. During the summer months these ascending grilse are frequently found to show every signs of ripeness, both of milt and ova in European salmon, but, so far as ascertained on this continent, the male grilse alone is sexually mature. It is a curious fact that, while grilse appear to be rarely or never observed in some Canadian salmon rivers, yet in other rivers in the Dominion they abound. In certain seasons the Nepissiquit in New Brunswick has yielded to the rod far more grilse than adult salmon, anglers frequently taking over three hundred in the course of a week or ten days, when scarcely an adult salmon could be captured. Mr. C. G. Atkins, the well-known United States authority, has stated that grilse appear to be almost entirely absent from the United States salmon rivers, but this is certainly not usual with the rivers of Canada, and careful observers have noticed, even in British Columbia rivers, grilse ascending, although it has been denied that the Pacific species pass through a grilse stage. Mr. Ashdown Green has recorded his capture of a quinnat grilse, six pounds weight, in the Cowichan River, Vancouver Island, about 14 miles from the sea.

Professor Jordan also has recorded the presence of grilse in British Columbia rivers, and noted that they attain a mature reproductive condition at a very early stage. In Fraser River, in the fall, quinnat male grilse of every size, from eight inches upwards, pass up, the milt fully developed, but usually not showing the hooked jaws and dark colours of the older males. Females, less than 18 inches in length, are rare. All of either sex, large and small, then in the river, have the ovaries or milt developed. Little blue-backs or sockeyes of every size, down to six inches, are also found in the upper Columbia in the fall, with their organs of generation fully developed. Nineteen-twentieths of these young fish are males, and some of them have the hooked jaws and red colour of the old males.

The grilse which ascend in the late summer and in the fall, descend as grilse-kelts in the following spring. Some marked grilse-kelts were liberated by the Stormonthfield authorities and were recaptured on the ascent as mature salmon. When a weight of over eight pounds is attained, the fish is usually recognized as a salmon, a stage generally reached in the second ascent to the original spawning grounds. The cycloid scales in the adult salmon are found to be worn smooth over half of their surface, thus differing from the scales in the younger stages, when the whole scale is marked with a series of perfect concentric rings.

When the schools of salmon reach the estuary of a river they may remain only a few days, or it may be several weeks, playing about, before entering the channel of the river. This is commonly held to be for the purpose of acclimatizing the fish to their new fresh-water conditions. To quote from a well-known authority: "It first proceeds at its leisure to the head of tide-water. Here it stops awhile and seems to play about between the fresh and salt water. Whether it shrinks from encountering the sudden change from salt water to fresh, which is probably the cause of its dallying, or for other causes, it usually spends two weeks or more hovering about the border line between sea water and river water. When it has overcome its apparent repugnance to making the change to fresh water, it makes a rapid charge up the river for the clear gravelly streams which its instinct or sixth sense tells it to seek." It is also probable that the fish delay until a suitable temperature is reached. Curiously enough, when the schools have migrated some distance up the rivers, they will linger for long periods in pools, especially below falls and obstructions, during the time of the early runs of fish. Having attained the shallow areas suited for the "redds," in the upper waters, where proper conditions for depositing the spawn are provided, the pairing begins rarely earlier than the third or fourth week in October, and rarely later than the last week in November. The male salmon in all the various species undergoes remarkable bodily changes, while the female retains her normal appearance, except a deepening of the body, or enlargement, due to the growth of the ovaries and increased size of the eggs. The male Atlantic salmon, as Frank Buckland characteristically said, "wears a Joseph's coat of many colours, and the purple ground, variegated with sealing-wax red coloured spots on the side and cheek are very beautiful. * * * The hen salmon, on the contrary, wears a plain russet suit," though red spots are occasionally noticeable, and in both a golden orange tint appears on the sides. The lower jaw in the male becomes grotesquely lengthened. In the Pacific salmon, especialy the sockeye and the hump-back species, the back of the male enlarges and rises into a sharp, blade-like ridge, while the jaws are enormously lengthened, and the teeth are greatly increased in size and prominence. The male sockeye assumes a brilliant red colour on the sides and towards the dorsum, while patches of black and olive green also occur, and the elongated jaws are of a chalk-white colour. The Atlantic salmon energetically scoop out, in the gravel, deep hollows, in which the female places the eggs, afterwards covering them over, a process occupying a week or two and the parent fish then leave the buried eggs to take care of themselves and they hatch out in due course. The males fight a good deal, and the spawning grounds are the scene of much excitement and turmoil. This is as nothing compared with the commotion on the spawning grounds of the Pacific rivers, where the numbers of parent fish are incredibly vast. Thousands of male fish, with open jaws, rush about, carrying on the wildest warfare. In the chosen spawning grounds, as a rule a shallow tributary of some distant lake, the high-ridged backs of the males protrude above the surface of the

stream, and the fish can be seen dashing in all directions at each other, inflicting severe and deadly wounds. Often two male fish become inextricably interlocked, like the red deer and moose in the forest and die miserably from wounds and starvation. The tails and fins become greatly worn, and scars and fungus disfigure their bodies. Some of the male fish become so soft and degenerate as to be almost putrid in odour and appearance. It does not appear that any real nest is made by the sockeye, hump-back and smaller Pacific salmon. When depositing her eggs, the female fish twists her body like an inverted letter U, in sidewise fashion, and the ripe eggs are extruded rapidly in batches. They fall promiscuously amongst the gravel, the rushing waters carrying them into interstices and secure hiding places. The fish, in the act of depositing the eggs, often is quite exposed above the surface of the water, while the male fish, close by, fertilizes them by actively scattering the milt over the eggs as they fall. Frequently, at the moment the eggs are thrown into the water, the male fish rushes away with open mouth and gleaming teeth to attack a rival. There must, in consequence, be enormous waste of ova. After the spawning is done, the emaciated fish drop gradually down from pool to pool on their return to the sea. These lean, black, degenerate fish are called "kelts," and, as Buckland says, they are "in a wretched and miserable condition, many dying on the road." In Scottish rivers, quite a large number of fish are found dead annually, the majority being male fish, the dead females being very much rarer; the record on one Scottish river showing that 71,000 dead salmon were found in 12 years. On account of the vastly greater number of individuals in the Pacific rivers, the dead fish observed, subsequent to the spawning period, is enormous and has given rise to the popular notion that none of them ever return to the sea alive. "Probably none of them ever return to the ocean, and a large proportion fail to spawn," said Professor Jordan. In this view many authorities agree, though the grounds for the opinion are not fully conclusive. Thus, an authority says of the Pacific salmon:

"They grow less comely in appearance, more slimy to the touch, more unsymmetrical in form; parasites collect by thousands in their gills and under their fins; their tails and fins fray off; a white and loathsome fungus gathers over all parts of them, frequently destroying their eyesight; and swarms of suckers—the carrion-birds among fishes—wait about them to feed upon their lifeless bodies when they die. For some unknown and strange reason, the salmon in the higher tributaries do not hasten back to the salt water, which would clean their bodies of the parasites and fungus and restore their appetite, and with it their health and vigour; but they linger, with a strange indifference to their fate, around the spots where they have deposited their eggs, waiting patiently for the only possible relief from their wretchedness, which is death. Some uninformed persons, who have never seen these fish in their natural habits, have expressed some incredulity in regard to their all dying after they have spawned.

The same authority goes on to say that it is probably true that those that spawn near the ocean return to the ocean and recover their vitality, but others never do. In order to make sure whether I was mistaken in my views about it, I took the testimony, a year ago, of all the white men who have lived or worked on the river, and of all the Indians I could reach. It was the unanimous testimony of all that 'the salmon which pass the McCloud station in the summer, on their way up the river to spawn, die in the river and never return to the ocean.'"

The fish, especially the female fish, in multitudes of cases, are full of vigour after spawning and quite capable of accomplishing the migration to the sea. Indeed, one of the ablest authorities in British Columbia, Mr. Ashdowne Green, of Victoria, B.C., says, "I have every reason to believe that some individuals do survive and even recuperate in the fresh water before returning to the sea. I have taken spent fish in the North Thompson that were strong enough to make a good fight, and I could see nothing to prevent these from returning. At one time it was supposed that no salmon ever did so, but of late this opinion seems to be much modified," especially, Mr. Green adds, with regard to the spring salmon, or quinnat. My own experience with regard to sockeyes and humpbacks would indicate that they do not by any means all die, they are, in a large number of cases, very vigorous, and when secured by hook and line, by being hooked in the ridge of the back, they exhibit extraordinary strength and gameness, though, of course, such

fish will not take a hook in the ordinary way. It is difficult to imagine that even the smaller Pacific species make but one return journey to their native rivers, after making their first descent to the sea.

In ascending there are no obstacles which will deter the salmon, and their extraordinary leaps, 10 to 12 feet being a usual limit, are known to every one. Dr. A. Landmarks thinks that a 16-foot jump is possible if there be a deep pool immediately under the fall to be ascended. A recent observer, Dr. R. T. Morris, asserts that salmon can leap falls 18 feet high, and supports his declaration by published photographs. Salmon will certainly attempt to mount the most precipitous and forbidding falls and cascades. In ascending, the schools have been known to accomplish a distance of 40 miles in a day. Livingstone Stone estimates the rate in the Sacramento at two miles, and in the Columbia at three miles a day; but salmon, above tide-head, have been found with sea-fish undigested in their stomachs, and their rate of ascent must be vastly greater. The earlier runs appear to be most leisurely, and the fish appear, indeed, to regulate their rate of progress by the condition of the eggs in the ovaries. In their ascent, they practicaly eat nothing. Dr. Noel Paton's researches on Scottish salmon have shown that a peculiar degeneration of the walls of the stomach takes place, a "catarrh" it may be called, filling its chamber with a dense mucous mass, in which degenerate cells largely occur, and rendering the organ incapable of digestive functions. The same feature has been noticed in some of the fresh-water salmonoids *(Coregonus)*, the rigid condition of the stomach precluding the possibility of normal digestion. In the Pacific rivers it would, of course, be impossible for the migrating schools, on account of the vast numbers of fish composing them, to obtain any food in the ordinary sense, and the same physiological law applies to the schools of salmon in all rivers.

Some doubt has been thrown upon the generally accepted theory that salmon return to their own rivers. Certainly, on the two famous Canadian rivers, the Restigouche and the Miramichi, anglers and practical fishermen have always held that, though the rivers are practically adjacent, the schools belonging to one river never enter the other; indeed, the difference in size and general appearance is such that the men on the river distinguish them at once. This may be said to apply to rivers generally, the salmon of St. John River are unlike those of the Saguenay or Godbout, and none of them are identical in general appearance and build with those native to the rivers around the Bay of Chaleurs. Some accurate experiments in Scotland proved that salmon do, for the most part, return to their own rivers, and of 56 marked fish set free, 34 were afterwards caught ascending the same river, and the other 22 were taken in fixed tidal nets at distances of from half a mile to 500 miles from their native river. The Pacific salmon may not be so strictly true to this supposed instinct, and Professor Jordan lays little stress on it, but regards as somewhat accidental this supposed fidelity to its native stream. 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 movements 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 blue-back, 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."

Of the respective numbers of male and female fish which pass up during the season, some interesting facts have been observed. Thus, in the Penobscot River, Maine, U.S., out of 100 salmon examined, 34 were male and 66 were female, a proportion of the sexes which showed even greater disparity in the land-locked variety or Schoodic salmon, in which over 1,000 out of 1,604 specimens proved to be female, and the balance of 604

were males. In the Dominion hatcheries, the female salmon caught often exceed the male; but, on the other hand, in some years, as in 1893, there was a large surplus of male fish. As a rule, the ova of three female fish may be fertilized by one ripe male. No doubt the proportions of the sexes vary according to the portion of the year in which the captures are made, as there are grounds for thinking that in the earliest runs the female fish predominate and the parent salmon taken for the Dominion Government hatcheries are usually what are termed "late" runs. In most rivers, salmon run almost the whole year through, yet the main runs are confined to definite months of the year, an unusual drought or some special condition in the season retarding or accelerating the ascent of these main runs. "In America," said Dr. Browne Goode," the southern streams seem to yield the earliest fish. In Connecticut they appear in April and May, in the Merrimac in May and June, in the Penobscot most abundantly in June and July, though some come as early as April." Rivers are known as early or late, not in allusion to the period of spawning, but to the early or late appearance in general of the main runs of salmon. The Tamar, between Devon and Cornwall, is, as might be expected, an early river, and the Tweed is a late river; but the rivers of the east coast of Britain are all early, while those pouring into the Atlantic are late.

The time at which spawning salmon approach their rivers is really a somewhat complicated one, and appears to depend very much upon local features in the respective rivers; but the periods, annual or otherwise, at which salmon return, or rather the interval elapsing between their descent and their next ascent, has been a matter for much discussion. Experiments in Norway clearly proved that some salmon spawn annually, but while the proof was not conclusive that all do not do so, the fact that in a series of marked fish 20 were caught in the first year following, whereas 30 were taken in the second year following, supports the experiments on the Penobscot River within certain limits.

Of the growth of salmon, there is much accurate information, though the records are somewhat scattered. As I have, in a previous report (Departmental Report, 1895, page xx.) pointed out, "it takes nearly 250 alevins to make up an ounce, yet in sixteen months a weight of two ounces is reached, and twenty months later, when, as a smolt, the fish seeks the sea and becomes, after twelve or fifteen weeks more, a grilse of seven pounds or eight pounds weight *i.e.*, achieved. an increase of 68 times his own weight in three or four months." A salmon, 2½ feet long usually weighs 9 pounds or 10 pounds; when 3 feet long, 16 or 17 pounds, and when of the length of 4 feet, the weight is usually 50 pounds. Fish, 60, 70 and 80 pounds in weight are taken in some rivers, but the increase to these enormous weights is accompanied mainly by an increase in vertical depth and lateral thickness, rather than length. The well-known experiments of the late Duke of Atholl demonstrated the increase in weight in the short space of six months of salmon 10, 11½ and 12½ pounds weight to a weight of no less than 17, 18 and 19 pounds respectively.

For facility of reference, the following salient points are summarized in conclusion:—

(I.)—Eight stages may be distinguished in the life of the salmon: *(a)* the egg, *(b)* the larva, *(c)* the parr which descends after one or two years, *(d)* the silvery smolt stage assumed by the parr in its descent, *(e)* the grilse returning in a few months, or in a year or more, which may be sexually mature, *(f)* the grilse kelt descending to the sea, *(g)* the adult salmon, eight pounds weight, or more, depositing and fertilizing spawn annually or biennially, *(h)* the salmon kelt descending in the spring subsequent to spawning.

(II.)—The male salmon at the spawning season greatly changes in form and appearance, especially in Pacific species.

(III.)—A considerable proportion of parent salmon die on all salmon rivers, and this is especially noticeable on Pacific rivers.

(IV.)—Salmon cease to feed, and their digestive organs become non-efficient after entering fresh water.

(V.)—Each river has its own race of salmon, which show local peculiarities; and these, in the main, return to their own rivers.

(VI.)—Female salmon frequently predominate.

(VII.)—Salmon spawn annually, though some may spawn biennially, or in alternate years.

(VIII.)—Adult salmon grow rapidly in the sea, and may double their weight in six months.

(IX.)—There are runs of salmon which return without spawning, apparently omitting spawning for a year.