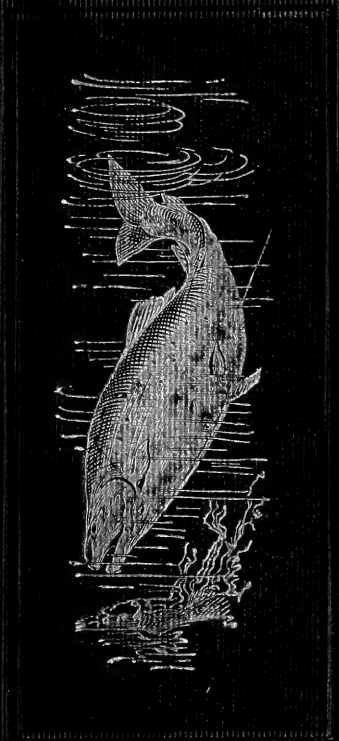
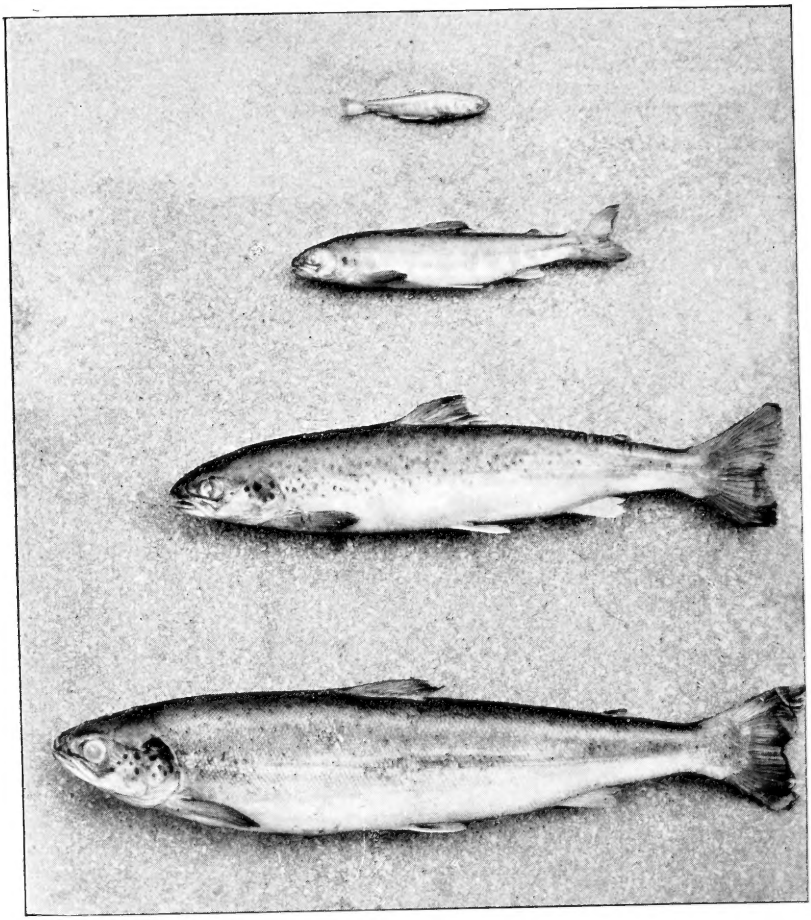


THE LIFE OF THE SALMON



Frontispiece

Young salmon artificially reared at the Duke of Richmond and Gordon's ponds near the mouth of the Spey. From above downwards the fish are one year, two years, and three years old. The fourth and largest fish is also three years old, but has spent its third year in a sea-water pond.

THE

LIFE OF THE SALMON

WITH REFERENCE MORE ESPECIALLY TO THE FISH IN SCOTLAND

BY

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INSPECTOR OF SALMON FISHERIES FOR SCOTLAND

LONDON
EDWARD ARNOLD
1907

TO

THE DISTRICT FISHERY BOARDS

OF SCOTLAND

I RESPECTFULLY DEDICATE

THIS BOOK

CONTENTS

CHAPTER III

Results of Salmon Marking

CHAPTER IV

The Scales of Salmon as Records of the Salmon's Life

CHAPTER V

The Feeding of Salmon and Growth of the Genitalia

CHAPTER VI

The Salmon and Water Temperature

APPENDIX

LIST OF ILLUSTRATIONS

PREFATORY NOTE

I AM indebted to the Royal Society of Edinburgh for permission to reproduce the Frontispiece and Plate I., which have already appeared in the Proceedings of the Society as Illustrations to papers of my own.

I desire, also, to thank Sir Herbert Maxwell for valued criticism with regard to certain views I have ventured to express in this little book, and Mr. H. W. Johnston for many kindnesses in facilitating the experimental work in which we have been much associated.

W. L. C.

CARR BRIDGE,
August 15, 1907.

INTRODUCTORY

To all who endeavour to understand the life of the salmon, two disadvantages are naturally present. The fish cannot at all stages of its life be brought under observation; it goes from us into the *ewigkeit* of the ocean, where on the whole it spends more time than in our rivers, and where its doings excite men's imaginations and their faculty for romance. Secondly, the fish belongs to a genus so susceptible to the influences of environment that it has to be studied in different localities and under varied conditions, if we would escape a too narrow vision of its habits and characteristics.

Even then we have to bear in mind that what we actually see may not always be believed, that exceptional appearances have to be suspected and strange occurrences investigated; while the whole history of salmon literature reminds us that to write on this subject is to open up argument and to court dispute. I have heard of a Cabinet Minister who, when asked to advance salmon fishery legislation, promptly declined, saying he wished to die in his bed. The heat and intolerance which have been exhibited, in Scotland at least, over disputes about the life of the salmon almost rival the spirit shown in recent

times over Church distinctions. Precisely similar lines of investigation have led contending observers to completely opposite deductions, the reason being that the observers were in reality striving for supremacy rather than for truth.

No wonder, then, that critics find safety in saying we know very little about the salmon. They are, even at the present day, perhaps not far wrong. But writers seem to have acquired the habit of safeguarding themselves by emphasising the "mystery" or "dire perplexity" in which the whole subject is shrouded. One of the most recent tells us that the result of the whole body of literature on the salmon is to give the Philistine "numerous erroneous ideas on the subject, along with a few 'proved facts.'" It is clear that he does not think much of the "proved facts"—regards them apparently as on the same level with the judge's famous characterisation of the evidence of the skilled witness.

With humility, however, we must plod on searching for our facts if we hope to gain that true conception of our subject which can alone give us a scientific basis from which to extend a sound regulative treatment of our salmon fisheries. Alexander Russel has truly said, concerning the importance of this matter, that "without some knowledge of how, when, and where the fish breeds, dwells, and feeds, it is useless to speak and unsafe to act."

The general principle lying at the root of all salmon fishery legislation has been to counteract the natural tendency of man to over-fish, to capture fish at a harmful time or in a harmful way, or to

erect engines which obstructed the ascent of salmon and facilitated their capture in undue numbers. The Scottish statutes of four hundred years ago commonly put down practices which "destroy the breed of fish, and hurt the commoun profite of the realme." From earliest times it has been considered necessary to protect spawning fish by close seasons, and to do this satisfactorily observation as to the breeding season has been inevitable. Like the crime of sheep-stealing, the crime of poaching salmon in close time was punishable by death. In an Act of the first Parliament of James I. (1424) we find "Quha sa ever be convict of slauchter of Salmonde in time forbidden be the law, he sall pay fourtie shillings for the unlaw, and at the third time, gif he be convict of sik trespasse, he sall tyne his life, or then bye it." The transference from forty shillings (Scots) to the death penalty seems rapid, nor is any indication given as to what may be regarded as the ultimate price of a poacher's life. One thing seems clear, however : those early Scottish legislators were determined to preserve the breed of salmon. God bless their memory! In more recent times we have had not a few examples of how easy it is to destroy the salmon of a district, and how difficult it is to restore the breed.

At once the most primitive and most deadly method of catching fish which inhabit rivers is by the erection of built barriers and enclosures. The Australian blacks make dams and pools of branches and stones, and drive the fish into them before floods subside. The North American Indian has for long

years erected his barriers of logs to stop the ascending salmon, so that he may scoop out his little supply, regardless of the consequences to the river stock. The officials who supervise the salmon fisheries of the American continent are still opening up those Indian dams. The fishing weirs of England and the cruive dykes of Scotland are the British pro totype of the aboriginal structures; indeed, the Gaelic word *cruive* seems to indicate that branches were originally used. They are now stone weirs with fishing boxes in the gaps—usually the only gaps—left for the descent of the water and ascent of the fish. The salmon yairs of the Solway Dee are analogous structures in which the leaders or walls are still made of wattle.

Cruive dykes were erected in most Scottish rivers in early days, but where owners of such structures held also interest in upper waters the dykes were for the most part voluntarily abolished on account of their extremely injurious influence on the breeding stock. In 1424 they were abolished by statute when set in fresh water "quhair the sea filles and ebbis," and now only some six remain in Scottish rivers, only three of which are fished.

In spite, however, of those ancient statutes providing for the preservation of breeding fish, and of the more modern regulations as to meshes of nets and annual and weekly close times, as well as recommendations for the reduction of legitimate netting, there are those who regard such restrictions, such interferences with the liberty of the subject, as superfluous and undesirable. In evidence before

Lord Elgin's Commission in 1901 I heard the assertion made that salmon spawn in the sea as well as in fresh waters, and I have met more than one tacksman of salmon fishings who insisted that a grilse was a different species of fish from a salmon. These views die hard, especially when there seems to be some commercial advantage in holding them.

Since the great development of rapid transit by which fish can be sent to market, the use of ice, and especially since the sharpening of competition amongst salmon fishers and the consequent great improvement in methods of fishing, a more exact knowledge of the life of the salmon has become more and more necessary. We not only require to know when the fish breeds, and that it can only reproduce its species in our rivers, but we want to know how often the fish breeds in its lifetime—or, perhaps one should say, how seldom it breeds; at what age it begins to breed and at what age it ceases to breed. We also want to know its habits of migration to and from fresh water, and how much time it spends in the sea; whether fish migrate from one river to another, and where salmon go in the sea, what the salmon's food is and when it is in best condition. More than this, for the better regulation of the fisheries we want to know the conditions which govern fish in ascending rivers and tributaries—a subject of value to netsmen and anglers alike.

These are definite points of practical importance nowadays, for on a thorough knowledge of the life history of the fish itself can sound regulative treatment alone rest.

In former days the legislator said in effect, "The salmon breeds in our rivers, and after breeding is not fit for human food: we must protect the fish while it breeds, and protect the lieges against unwholesome feeding." The system of having District Fishery Boards and the supervision of a central authority has now sprung up, however, and our legislation must necessarily take account of this and of the duties which naturally fall to be dealt with by one body or the other. In Scotland, our District Boards are composed entirely of the proprietors who own the rights of fishings. The Crown may be, and frequently is, a local proprietor of such rights, but none but proprietors have apparently any say in the matter of local management. With the natural trend of modern development it is perhaps fair to assume that in the future District Boards will have assigned to them wider discretionary powers: they will be expected to know what is for the best interest of the districts under their charge; while the central authority will be expected to concern itself in the general interests of the salmon fisheries as a whole and in the particular questions which, arising locally and of local importance, require settlement at the hands of a neutral authority.

Already in many districts private associations are springing up in order to deal more effectively with such points, for instance, as the amount of netting which safely may be allowed in particular districts, a point which, if they had power, District Fishery Boards might very well be expected to control. Each district has to be dealt with on its own

merits in a case of this kind. These associations are usually, it is true, concerned very largely in the preservation of good salmon angling. But it is to be borne in mind that this very preservation of good angling plays a most important part in maintaining an adequate breeding stock of fish. The number of fish captured by rod, although in some districts it is very considerable, does not seriously reduce a river's stock as indiscriminate netting does. The most exhaustive inquiry into the welfare of our salmon fisheries conducted by the Elgin Commission and reported upon in 1902 resulted in, *inter alia*, a most important recommendation in favour of reducing netting in narrow waters where fish congregate after leaving the sea. It was decided that there exists in every river a point above which it is advisable that no netting of any kind be carried on, and that the effort should be to allow a proportion of every run of fish entering a river to ascend to the unnetted waters.

The increased value of salmon angling makes it possible, moreover, to compensate most fully those who may be required to cease netting, and without any hesitation it may be said that the result of action of this kind has already proved most satisfactory to all concerned. The Aberdeenshire Dee is a conspicuous example. The annual value of the salmon fishing of the district has risen from £7000 to £19,000, and the Aberdeen Harbour Commissioners, a body possessed of valuable salmon fisheries on the coast and in the mouth of the river, and who fish for commercial purposes alone, voluntarily subscribe

to the funds of the Angling Improvement Association, because of the benefit which they find has resulted to their own fishings.

To the angler also who is sportsman in the best sense of the word belongs much of the credit of having noted the special features of the salmon's life in fresh water. By his experience he accumulates knowledge of particular runs of fish as the netsman at the mouth no doubt may also do, but he, as he quietly casts his fly or spins his bait, hour after hour and month after month, has the opportunity of coming into closer touch with the many interesting habits of ascent and distribution: he has his line in the water before the netsman has a chance, and he sees the season out after the nets are off; he is able to note the peculiarities of habit in spring, summer, and autumn. It is sometimes said that the charm of angling is its uncertainty, but this takes account only of the fish-killing results. The true disciple of Izaak is a contemplative man who has his mind occupied by many piscatorial reflections as he plies his art: he is quick to observe, yet many perplexities make him slow to draw his deductions. It is very often true of him that the more he has seen the more he realises how little he knows. Conversely, those who have not seen very much are usually able to talk a great deal about what they do not understand. Hence the not altogether unfounded belief that fishermen are cranks.

No doubt the primary object of the angler is to catch fish. He goes forth equipped for that purpose, eager for its fulfilment. But if there were no other

attractions than the hooking, playing, and landing of the salmon, some of us who do not catch many fish because we always fish on a bad day, when the river is too low or too high, or rising or falling, or, to put it shortly and with much more truth, those of us who are bad fishermen would find small pleasure in angling. "Wha's catchin' fush?" the small boy retorted when rebuked for catching fish on Sunday. He was fishing, and perhaps enjoying himself in spite of a guilty conscience, but he was not catching fish. In salmon angling there is the exercise and the pleasure which belongs to the skill required in the proper performance of the exercise, two elements which form perhaps the chief joy of athletics and outdoor games. But in addition there is the engrossing study which belongs to all forms of hunting, the study of the habits of the creature hunted, so that skill already acquired may be turned to greater advantage.

From this the step is a short one to a more intelligent knowledge of the life history of the creature apart from its mere sporting value. It is very natural, therefore, that sportsmen should be naturalists, and should render in the case of the salmon valuable help to the elucidation of the fish's life. Then the freshness and the leisure of life by the river-side gives the characteristic setting to the whole. How varied are the phases: the precious grey day with the favourable breeze, the bluster and battle of the day of squalls, when the whole concentration of the fisher and his every hope of success is in self-control and quiet determined effort; or the

peculiar joy of standing waist deep in a clear Highland river, the water lapping one's bare elbows as one casts, the nearness of the glitter on the surface, the sense of being part of this moving, life-giving force! These are joys, apart altogether from the success of the sport, which more than compensate for the strokes of ill fortune, the dire disasters when sun, moon, and stars seem to fall from their places, as well as for the petty exasperations which on certain days seem constantly to dog one's steps.

But the angler carries away with him when he leaves the river the results of his observations, and when he smokes his evening pipe those salmon problems rise again in his mind, and he goes to the river on the morrow with fresh suggestions and explanations, fresh points to follow out by renewed observation. Sir Joshua said that to get his fine results he mixed his paints with brains. So in sport, as in other things where perfected appliances mean a good deal, it is after all "the man behind the machine that counts." Yet what a long time it has taken us to gain anything like a satisfactory knowledge of the salmon.

It is only seventy years since Shaw,* at Drumlanrig, proved that the parr is the young of the salmon and not a small adult member of the salmon family. All the early writers, up to Parnell (1838), describe the parr under the name of *salmo salmulus*, and the author named states at considerable length

* Shaw, "An Account of Experimental Observations on the Development and Growth of Salmon Fry." Trans. Roy. Soc., Edin., vol. xiv. p. 547, 1840.

the differences between the parr and the young salmon. Those of us who have grown up since Shaw's time can scarcely understand how the parr could have been regarded as a distinct species, far less the extraordinary controversy which the discovery was the means of starting. Yet those early disputes gave the stimulus needed for investigation over a wider area. Since the earliest attempts at salmon marking, at artificial culture, and the rearing and crossing of different salmonids, as well as by the study of the different runs of fish in our rivers, and by the results of netting salmon on our coasts, a body of information has slowly been accumulating. Disjointed and very imperfect as this information has undoubtedly been, it has nevertheless served to indicate the lines along which more systematic information should be sought.

A signal endeavour to crystallise our views in this particular was the publication of Mr. Willis Bund's "Salmon Problems," a book which has undoubtedly done a great deal to advance the genuine search after radical facts in the life of the salmon. Since this book was penned the doings of the salmon have been followed with greater precision, and the fish has, as it were, been made to tell his own tale to a greater extent. The reliable identification of fish caught, set at liberty, and recaptured has been the means, through the instrumentality of the Fishery Board for Scotland and the Board of Agriculture and Fisheries in Ireland, of providing us with an amount of information as to migrations and increase of weight hitherto unapproached. Investigations as

to the feeding habits and nourishment of the salmon, as to the records of growth, migrations, and spawning to be read from the study of the scales, as well as inquiries into allied and auxiliary subjects, have greatly added to the data now ready to hand.

My endeavour in the present volume is to draw together results which we have received during those recent investigations, but which have been set forth in isolation, not set forth at all, or, what is perhaps much the same in result, printed between the blue covers which so successfully conceal a Government's information.

CHAPTER I

SMOLTS

Early ideas concerning smolts—Rearing of smolts in captivity—Marine *versus* fresh water origin of the salmon—Hatching fry from smolt eggs—British smolts descend when two years old—Marking of smolts—Habits in migrating to sea—Autumn migrations—Development of smolts in sea—Herr Dahl's capture of smolts in the sea off Norway

THE Stormontfield experiments on the Tay, although they at first gave new vigour to those who disbelieved Shaw, ultimately, after the long dispute described by Russel in his book on the salmon, became a vindication of the Drumlanrig results and a source of much additional information on the growth and migrations of parr and smolts. Many anglers of renown in the present day are puzzled to tell a parr from a young trout. Yet, curiously enough, the dispute never dragged the trout into its vortex. The parr was either a young salmon or a distinct species. Professor Grassi of Rome slew the *leptocephalus** idea without question. People did

* *Leptocephalus* was long known as an interesting semi-transparent little fish not uncommon in the Mediterranean. The investigations of Professor Grassi into the deep-water fauna of the Straits of Messina led to the discovery that this little fish was simply the larval or post-larval stage of the common eel.

not seem to mind so much when only an eel's reputation was at stake; to tamper with the salmon's genealogy was by comparison like disputing a title to the peerage. However, the results of the Stormontfield investigations were finally given to the world in two small books, one by William Brown in 1862, the other, since republished, by Robert Buist in 1866. Buist superintended the operations carried on by Peter Marshall, and both were familiar writers to the angling papers of the time, the latter under the title of "Peter of the Pools."

With regard to the descent of the parr and smolts from the ponds, the results were regarded as showing that 60 per cent. descended when two years old, 32 per cent. when three years old, and 8 per cent. when only one year old. This was indeed regarded as the proportions in which the young salmon migrated to the sea, but the ponds are several miles above Perth and many miles from the sea, and it is safer to say simply that in this proportion they descended from the ponds. I have even heard some curious hints as to the way certain fish were made to descend, and we know that the argument was as keenly contested as any land reform bill, but such hints probably do not matter much. An attempt was also made to rear smolts in salt water, and a pond on the coast was secured for this purpose. Unfortunately some local poacher put an effectual closure on the experiment by stealing the fish when, as was reported, they had attained the size of herrings. The poacher not only committed

an offence as serious as the time-honoured crime of sheep-stealing, but robbed the observers of information which might have saved them from much subsequent error.

Various batches of smolts before descending from Stormontfield were marked by removing or mutilating in some particular way the adipose fin. A limited number were also marked by the attachment of small rings. About the same time (1864) the Tweed Commissioners were conducting some valuable experiments of a similar kind. None of the Tay smolts marked by the attachment of the rings were recovered, but three at least of the Tweed smolts which had been marked by the attachment of wire were recovered as grilse in the Tweed after a year's absence, one in 1855 and two in 1856, the first weighing $3\frac{1}{2}$ lb., the second and third weighing each $6\frac{1}{2}$ lb. In spite of these, however, it was contended, with the publication of many particulars, that the Tay smolts marked by fin-cutting were freely recaptured as grilse of three pounds and upwards, after intervals varying from one and a half to three months, and as a result it became very generally believed, in Scotland at least, that the grilse of our rivers caught in May, June, and July, or later in the season, had only descended as smolts in the spring of the same year, and were therefore only $2\frac{1}{2}$ years old. Other and similar fin-cutting experiments were made elsewhere in Scotland, with apparently the same results ; and illustrations accompanied certain of the reports to show there could be no mistake about the conclusion. Curiously enough, in the last few years a similar series of observations

has been made in England, and the results deduced from them have been to show that the grilse had been a whole year away from fresh water. I refer to the experiments conducted in the Tavy in Devonshire by the direction of the Duke of Bedford. Here the method of marking was the same, but the deduction different. I am not aware what the appearance of the mutilated fin was in those Devonshire grilse, but in Ireland, where some adult fish marked with a label on the dorsal fin were also marked "by a wide notch cut far into the adipose or dead fin,"* it was ascertained that when one of those fish was recaptured "the fin had recovered its usual form, the outline of the notch being just visible as a faint scar." With smolts kept in confinement, after mutilating the fins it has also been found that the mark healed up, so that there was considerable ground for the belief held by not a few that this method of marking without the attachment of some foreign substance was not reliable.

A good deal of additional information as to the growth and migration of smolts has been obtained by the numerous hatching and rearing operations which have been carried on all over the country. It is undoubtedly the case that the artificial conditions materially affect the issue, and that in many respects artificially reared smolts behave differently from those in the wild state. The steady and abundant food supply increases the rate of growth, and apparently exaggerates the variation which may exist. For

* Holt, "Report of Sea and Inland Fisheries of Ireland for 1901," part ii. p. 181

instance, I have two smolts which were reared at the Duke of Richmond and Gordon's ponds near Fochabers at the mouth of the Spey, which are of precisely the same age, viz., twenty-one months. One is fully eight inches in length, while the other is only four inches. Under natural conditions experience shows that it is well-nigh impossible to find a salmon smolt of eight inches even at twenty-six months. The smolt of the sea trout may occasionally be found of this size, but not that of the salmon. The reason for the greater size of the sea trout is simply that this fish has a much more estuarial habit, and after descent of the fresh water continues to feed and live and apparently to move up and down in the tidal waters of estuaries. Many common brown trout are to be found under precisely similar conditions and feeding on a purely marine diet; in the estuary of the Tay near the Tay Bridge I have found large silvery common brown trout with freshly swallowed herring as well as much digested herring in their stomachs and intestines. Yet we must not too hastily believe that we see in such instances as these the cause of the seaward migration of the salmon. In spite of the fact that the eggs of the salmon can only live and develop in fresh water, there are many who consider that the salmon and indeed all salmonids are originally of marine origin. Mr. Boulenger, whose word on such matters is important, points out, in his chapter on the salmon family in the *Fishing* volume of the Country Life Library, that "the overwhelming majority of the members of the sub-order of which the salmonids

form part inhabit permanently the sea, the clupeids, or herring tribe, which are their nearest allies, being certainly of marine origin, as proved by their abundance in cretaceous seas, yet a few, like the shads, ascending rivers to spawn without this ever having been adduced as evidence in favour of a fresh water origin of the family to which they belong."

The more we learn about the salmon, the more we have to realise the very considerable amount of time which it apparently spends in the sea. Sea trout are chiefly estuarial in habit. Loch Leven trout may very possibly be sea trout, or at any rate migratory trout—which amounts to much the same thing—shut off from the sea. It is easy by a little judicious feeding to make them practically indistinguishable from ordinary sea trout. Brown trout taken from Dorsetshire to New Zealand quickly acquired a migratory habit and became large silvery fish, inhabiting the sea for the most part, and ascending rivers to spawn. The brown trout which I have referred to at the mouth of the Tay were clearly doing the same, while in localities such as Orkney and Shetland and the Outer Hebrides we have the established tidal variety which has been called *S. orcadensis*; and in the West of Ireland we have *S. estuarius*, the so-called slob trout. I do not agree that there is any specific distinction, any more than I agree that a ferox is not a brown trout. In all these examples we may say that to feed is in one sense the impulse which causes the change of habit and consequent modification; and in the same way, taking salmonids as we now find them, it is evident

that artificial feeding can still further induce very marked differences.

In all rearing ponds in Scotland, however, the smolt assumes the migratory dress at two years of age, although it commonly attains to the size of the natural or wild smolt before that period. This is strong presumptive evidence that the smolt naturally lives and feeds in our rivers for two years after hatching, and that it then is ready to go to the sea. Several attempts have been made to prevent the descent of smolts, so as to produce land-locked salmon. In most cases the attempts have failed, owing chiefly to the disappearance or death of the fish, as in the experiments of Messrs. Morgan and Pell in South Wales and of Dr. Murie in the ponds of the Zoological Gardens. At Howietoun greater success ultimately attended experiments made in this direction, for although many smolts jumped from the ponds and perished, so that the ponds had to be netted over to preserve the remainder, a fish was ultimately reared which was fertile and which spawned, and from which fry were reared.* The resulting specimen, however—the one fish which spawned—which was described as a grilse, was a very poor apology for a grilse as we properly understand this sprightly young salmon. The largest fish which is figured is ill-shaped, spotted, and with the parr marks still evident, and weighed only $1\frac{1}{4}$ lb. It may resemble in some measure the land-locked salmon of the American lakes or of Sweden, but it is a poor thing to call a grilse, and forms in my opinion

* Day, Trans. Linn. Soc., 2nd ser. "Zoology," vol. ii. part 15.

a strong argument in favour of allowing all smolts to get to the sea. It is much easier to accustom a young parr or a Loch Leven trout to salt water than to accustom a smolt to fresh water.

It has to be noted, however, that the eggs of the fertile females of the Howietoun experiments were not fertilised by milt from male salmon reared under the same conditions, but by milt from Loch Leven trout. This materially detracts from the value of the result. Within recent years a limited number of the smolts reared in the Duke of Richmond and Gordon's ponds at the mouth of the Spey were found to contain well-developed ova, and an experiment was made as to the possibility of rearing brood from smolt eggs. It has long been known that male parr or smolts are occasionally sexually mature. So far as I am aware, the occurrence of ripe female smolts amongst artificially reared and hand-fed salmon had not previously been noted. A ripe male smolt not being procurable when the ripe females were first found, fertilisation was satisfactorily accomplished by using milt from an adult salmon. The fry hatched out and grew quite normally, and, as I was able to note from specimens kindly sent me by Mr. Rae, the superintendent of the Duke's salmon fisheries, were at the age of one year quite indistinguishable from the salmon fry produced from the eggs of adult females.

The following year, however, when ripe female smolts were again discovered, care was taken to obtain ripe male smolts for purposes of fertilisation. On this occasion, although at first impregnation

seemed to have been successfully obtained, all the eggs died before hatching.

In the experiments above related the abundance of food was carefully seen to, and up to the smolt stage, as has been said, such artificial feeding will induce excessive growth. Yet in attempts to produce grilse in fresh water the best result is a stunted, flabby-looking fish. But a few attempts have also been made to produce grilse in confinement in salt water ponds. We have already seen what became of the Stormontfield fish. A fish from the Usk, kept in the salt water tanks of the Brighton Aquarium, is reported to have lived for five years, and to have then attained to a weight of 8 lb. Some similar experiments have, I understand, been made at Plymouth in the laboratory of the Marine Biological Association. Other experiments have been made at the mouth of the river Spey, in a pond specially excavated for the purpose by direction of the Duke of Richmond and Gordon. Those last-mentioned experiments I have in a measure been able to follow.

The pond was constructed of cement work sunk in the gravel of the sea beach, and was connected to the sea by means of a syphon. In the second week of September 1901 some twenty-five smolts nearly two and a half years old were first introduced. In the adjoining fresh water ponds they had been raised, and having been retained beyond their natural time of migration, had already assumed and then lost the silvery dress. They were put straight into pure sea water, where they ceased feeding at once, and where in a few days four died. On a certain admix-

ture of fresh water being allowed to enter the sea pond the fish recommenced feeding, and by regulating the density of the water so as to obtain a more gradual transference from fresh to salt, the fish became thoroughly acclimatised. Owing, however, to an unfortunate accumulation of disintegrated and decaying seaweed drawn in from the outer beach through the syphon, and which was suddenly stirred up so that a large quantity of gas was liberated, many of the fish suddenly died, and the remainder had to be transferred to the fresh water ponds.

After a second attempt had been made under healthier conditions, Mr. Muirhead, his Grace's commissioner, kindly sent me a specimen 13 inches long (33 cm.). It was a beautiful silvery little fish, and had been reared for two years in fresh water and one year in the sea pond. It was figured along with a specimen of a young fish from Galway river in the Proceedings of the Royal Society of Edinburgh (xxv. p. 395). I understand, however, that for some reason or other the pond has again become unsatisfactory; but it would appear that, given healthy conditions of sea life and suitable food, the artificial rearing of grilse is quite a possibility.

These experiments under artificially induced conditions do not, however, teach us a great deal about the real life history of the salmon. The descent of the smolt to the sea is prompted by a most powerful instinct. Give fish in confinement as much and as carefully selected food as they can eat, and the silvery smolts are in no way induced to forego their seaward migration. For the healthy growth and

development of the species salmon as we now know it the bracing qualities of the sea, with its rich feeding, are absolutely necessary. I am aware that some are inclined to insist on the importance of the amount of feeding in our streams, and to go the length of suggesting that the stock of a salmon river should not be allowed to increase beyond the point where the smolt food fails to go round. To this I would reply that I would not limit the supply of adult fish on the chance of the parr starving, first because parr are evidently able to do a good deal of starving, and secondly because no man can well estimate the amount of parr food in a river. I should start to kill off the trout first. Also it seems to me that the amount of variation in the times and seasons when parr can go into sea water is probably an excellent provision against any danger of overcrowding.

Herr Dahl, in Norway, considers that the parr there leave the rivers when one year old. I confess I am not satisfied that he is correct, and an examination of the scales of Norwegian parr which I have had an opportunity of seeing—thanks to Mr. H. W. Johnston—supports this view; yet we know that the severe winter conditions of Norway modify very materially the habits of the adult fish. The fry of other salmonids seem to have different habits from those observed in Britain. Mr. Rutter has investigated the matter in the Sacramento river of the Pacific coast of America, and finds that there the fry begin to descend whenever they can swim, and commonly reach brackish water in about three

months' time. The adult fish are no doubt in great numbers in those west coast American and British Columbian rivers, yet the rivers themselves are of vast size, and the amount of food for fry must be practically unlimited. In any case we have no evidence that smolts would starve in any of our rivers if they did not descend when they do. No doubt they get a greatly increased and varied amount of food when they do go into the sea, but the time when the migration takes place is the time when the best feeding season is commencing, and it seems to me necessary to take the natural instinct for a temporary marine sojourn into account as well as the need for increase of food.

The time at which spawning takes place naturally influences the condition of the fry, and possibly, within limits, the time at which the smolt enters the sea. We have in Scotland at the present time, when account is taken of the Border rivers, considerable variation in the limits of the spawning season. So far as reports show respecting the times at which fish are noticed spawning in the various Scottish districts—which reports are published annually in Part II. of the Fishery Board's Reports—there is a difference between the earliest and the latest mean periods of fully two months and a half. If, however, the Border rivers Tweed, Annan, and Nith are excluded—and they have been subject to special and peculiar conditions—the difference in mean time between Scottish districts is reduced to one month. In other words, the height of the spawning season in the earliest river, viz., November 7, is one month

earlier than the height of the spawning season in the latest river, viz., December 8. Of course, in all districts one may find the spawning season extending over a long period if the very latest pair of spawners are taken into account, and exceptionally early or exceptionally late fish spawners—caused, it may be, in great measure by the presence or absence of frost—may account for a great deal of the diversity seen in the sizes of parr at any one season, but the chief periods of spawning have to be reckoned with in estimating the period of the smolt's average stay in fresh water.

The temperature of the water materially controls the length of time between impregnation and hatching, and various experiments have been tried to ascertain on the one hand how soon hatching may be brought about—and too early hatching is naturally accompanied by a constitutional weakness of the alevins—and on the other hand how long hatching may be retarded, so that eggs may be safely sent to the Antipodes. Such points are of practical importance to the fish culturist, but under natural conditions in this country hatching may be expected to take place in from ninety to 100 days, in temperatures varying from 40° to 45° F. If the water temperature is constantly kept on the verge of freezing point (32° F.) hatching is retarded for about 148 days. If the eggs are frozen, or encased in ice in a closed vessel, they die : oxygen must be taken in and carbonic acid given off; the young salmon even inside the egg must have the power to respire. In like manner, if the eggs become coated with any

deposit, be it natural sediment or polluting matter of a more toxic sort, this transmission of gases through the egg envelope is hindered or prevented, with more or less serious results.

The salmon's redd or spawning bed is therefore selected in clean and not too fine gravel, where a current of water brings a constant supply of the necessary oxygen and prevents deposit. By successive quick movements of the salmon's tail the gravel of the selected spot is displaced—and with the aid of the current it is surprising how large the stones overturned in this way frequently are. A shallow trough is thus formed, and in this the eggs are deposited. In nature all the eggs are not extruded at once, because all the eggs in the ovaries do not become ripe simultaneously. The eggs at the posterior extremity of the ovary become ripe first, and becoming free for extrusion are first deposited. On extrusion they are at once fertilised by the attendant male fish, and are then covered by gravel moved as before. The female then leaves the redd. As the remaining eggs ripen she returns and repeats the process, till after the expiry of several days all the eggs are shed.

It has repeatedly been noticed that the advent of frosty weather induces the females to frequent the spawning fords, and conversely a spell of mild weather seems to prolong the period during which spawning is carried on. Weather conditions therefore materially affect the length of time taken, but I am inclined to estimate that on an average the female salmon completes her reproductive functions

in a week or ten days. In small streams the time may be shorter.

When a salmon is stripped for hatchery purposes as many eggs as possible are pressed from the abdomen, and the fish is left in a collapsed and wrinkled state quite foreign to the naturally spawned-out kelt. At the hatcheries of the Pacific coast rivers in America each female is first killed and then slit open. A considerable proportion of the eggs so taken are not naturally ready for extrusion, and yet the percentage of loss through unfertilisation or subsequent death is small. In the natural process all extruded eggs are perfectly ripe, and it is extremely unlikely that the percentage of unfertilised eggs is greater. Over against this, however, we have to reckon with the attendance of the hungry trout as the redd is being covered, and the subsequent attacks of creatures capable of penetrating amongst the gravel. With the conditions which obtain in the great majority of our Scottish rivers there is abundant evidence to show that the natural spawning of the salmon produces a return in smolts sufficient to provide for a full stock.

The egg, then, lodged in a dark crevice between stones of the river bottom, develops till the time of hatching arrives. The little fish, with its attached yolk-sac, its food supply, then wriggles out, and for a period of about fifty days continues to grow in those dark recesses. Towards the end of this period, as the yolk-sac has become much reduced, feeding through the mouth is commenced, and efforts for

exit to the upper water are begun. When the yolk-sac has entirely disappeared the little fish is practically an inch long, and is ready to roam over the quiet shallows and to explore the sanctuaries where such small fry congregate. Great numbers of such tiny creatures may sometimes be discovered in unexpected places. On one occasion I found an undermined slope of a weir which I was examining crowded with them ; on another occasion an isolated pool round the pier of a viaduct was similarly peopled.

At the commencement of their lives more than at any other time the salmon move in shoals. They are, of course, unable to withstand strong currents, and are on emerging from the redds no doubt washed down stream to the first quiet localities where they can assemble, their instinct apparently being to take up positions where they are not easily reached by trout and other predatory fishes. In such places it is to be feared, however, that certain birds are most apt to find them, in spite of their strong protective colouration. The black-headed gull, which nests inland, and does not disperse its young to the coast for several months, is a pretty bird, which salmon fishers may freely regard with pleasure in a lady's hat. He is an expert fisher of shallow streams, and far outnumbers all other birds which in my opinion must be regarded as enemies of the salmon. He might well be excepted from the protective list of many a County Council.

The inch-long salmon takes up its free-swimming life towards the end of April, and has two years of

river existence in front of it. Feeding is not apparently carried on as steadily in winter as in summer, if we may judge from the habits of parr reared in ponds, and growth is not therefore steady, but in a year the little fish is $3\frac{1}{2}$ to 4 inches long. At two years the fish becomes a smolt, the characteristics of which will be referred to presently. All the rearing experiments show that in this country the normal age for the silvery scales to appear and for the instinct of seaward migration to show itself is when the fish are about twenty-five to twenty-six months old. Every one knows also that the chief season for descent is the spring. The old rhyme that the "first floods of May take all the smolts away" is not far wrong. Climatic conditions determine the amount of variation from the normal, and we may state that mild springs, in inducing an abundance of feeding early in the season, seem to produce an early descent instead of a late descent, as would be the case if the fish went down solely for the purpose of procuring food. From the end of April to the beginning of June is the season of chief descent to the sea.

With regard to the late spawning times in the Border rivers, to which reference has been made, I would here venture to express the belief that we have a condition brought about, not by any natural cause, but by the action of man in regulating the fisheries so as to allow an undue amount of netting to continue too long each season. If the amount of netting in confined waters was reduced and the remaining nets wisely regulated, the earlier running

fish would be allowed to remain in better proportion, and the spawning season would in time harmonise with the normal. A long belt of netting in a river renders the weekly close time inoperative: all early fish are captured, and only late-running fish remain to keep up the stock. The statement is by no means speculative. As will be shown at greater length in a subsequent chapter, physiological investigations of the most exhaustive kind have shown that in widely different rivers geographically the ovaries of the salmon reach maturity with remarkable seasonal uniformity.

Reference has been made to the great variation in the rate of growth of artificially reared smolts. This does not seem to exist in the natural state. In a series of smolt-netting experiments recently made in the waters of the Tay below Perth it has been found that, while various sizes of parr are present, the silvery or migratory smolt is wonderfully uniform in dimensions. Great numbers of smolts were passed under observation, and batches were measured at intervals. They were found to be from 5 to 6 inches in length (measuring to the centre of the forked tail), and to weigh from 1 to 2 ounces. The netting and marking of Tay smolts was commenced in the spring of 1903.* The part of the tidal water where the fish were found in greatest numbers was about four miles below Perth. The river above this point is affected by the tide for several miles, but the fresh water is

* Twenty-third Report, Fishery Board for Scotland, Part II. Appendix III.

merely dammed back by the inflow of the denser water of the lower estuary. At Kinfauns, the part of the river indicated, the smolts accumulated in great numbers, so that with a small-meshed sweep net it was possible without any difficulty to catch them in hundreds at a time. We attempted to follow the smolts in their further descent, and proceeded down the river, drawing the net on one side or other as we went. From the time we left the neighbourhood of Kinfauns the smolts became fewer, and when we had descended about two miles and a half, and had reached a point a short distance below the mouth of the river Earn, where sea-weed begins to make its appearance upon the shore, smolts could not be found at all. We proceeded down the estuary, however, and, thanks to the courtesy of the Tay Fisheries Company, who granted the use of their steam yacht, completed a survey of all available fishing places, both on the shores of the lower estuary and on the shallow banks in mid stream near the Tay Bridge, till eventually we reached Budden Ness and the open sea, some twenty miles below our starting point. Not another salmon smolt did we catch, however, although sea trout smolts were everywhere in evidence, as well as brown trout, herrings, flounders, a young turbot, sand eels, pipe fish, and various marine shore forms. In this we repeated the experience of Herr Dahl in his attempts to follow salmon smolts from the rivers of Norway down the fjords.*

In June of the following year (1904) I was able

* K. Dahl, "Œrret og Unglaks." Christiania, 1902.

to make arrangements for a series of observations by means of a boom-net used in fishing for sparlings or smolts (*osmerus*). This net is worked from a smack anchored in the channel; the mouth when extended by its booms and the pressure of the current is 24′ × 18′. Operations were commenced a short distance below the mouth of the Earn, where we had on the previous season lost trace of the smolts, and were continued down the estuary at intervals till a point was reached below the Tay Bridge and opposite the city of Dundee, the essential feature being the working of the net in the channel or fairway. This fishing yielded most interesting results. The net was set forty-six times, and salmon smolts were now captured freely. Some 1085 young salmonids were taken, and the great majority of these were salmon smolts, the others being sea trout.

Two points were specially noticeable :—

1. As the descent of the estuary was made, the size of the salmon smolts did not increase.

2. All salmon smolts captured were taken when the net was set so as to fish the ebbing tide. When the net was set so as to fish the flood tide or incoming current sea trout were alone taken, and many of these were nearly twice the size of the salmon smolts. Sea trout were also taken during ebb tide.

The natural inference from those observations seems to be that, after congregating in great numbers at the extreme upper limit of the brackish water, the salmon smolts make a steady and comparatively rapid descent to the open sea, without hanging about

and growing in the estuary, as sea trout appear to do, and that in making their descent they forsake the shallows for the main current. In rivers which flow directly into the sea with little or no natural estuary, such as the Spey, Dee, or Helmsdale, the transference of the smolts must be comparatively rapid, but in such localities a considerable body of fresh water no doubt spreads itself out delta-wise over the denser sea water in such a manner that the necessary conditions are supplied to the smolts. It seems certain that just off or at the mouths of such rivers the smolts are in great numbers in May and June, and at times fall an easy prey to coal-fish and other members of the cod family. The mouth of the Spey has been occasionally netted when smolts were seen to be descending, and great quantities of coal-fish captured and destroyed or given away. The stomachs of those fish were found to be full of freshly swallowed smolts. It appears, however, that the coal-fish do not always time their visit correctly, since on more than one season of smolt descent a very large draft net failed to capture any of them.

It has been said that in netting the upper tidal waters of the Tay at Kinfauns parr of very varying sizes are found. Some of those little fish are not more than an inch and a half to two inches in length. Without doubt many gravid adult fish entering the river during the actual spawning season—and it may be stated here that ripe male fish come in from the sea in full red spawning livery, as netting in close time for experimental purposes fully shows—that these gravid fish make their redds and spawn almost

within reach of sea water. The small fry found in such localities may therefore be naturally regarded as in part at least the offspring of salmon which have spawned in the neighbourhood. It has to be recollected, however, that two parts of sea water to one of fresh kills salmon eggs. It seems probable, however, that other young fry, following the instinct to form into shoals which we know parr possess, have joined themselves to companies of larger parr, or it may be have been to some extent washed down by floods. In any case these small fry and all stages of parr are to be found in the upper tidal waters at all seasons of the year.

In order to ascertain whether or not smolts migrated in any numbers in the autumn, and at other seasons than spring, netting at Kinfauns was continued through an autumn and winter. This work was taken up by the Tay Fisheries Company, with the permission of the Tay District Fishery Board, the catches being noted and the little fish returned unharmed to the water. Murie, Day, Traherne, and Willis Bund have all mentioned or described an autumn migration as occurring in England or Ireland, but evidence on this head was wanting from Scotland. In the Tay the smolts were found in a somewhat less brilliant dress during the months of September and November 1905, but they were in small numbers. On November 7, for instance, only twenty-nine were taken after fourteen hauls with a small-meshed net. The particulars and a detailed description of some of the specimens are given in the twenty-fourth Report of the Fishery Board for Scotland, Part II.,

Appendix III. In December those silvery fish were not found, nor was there evidence from the netting during January and February that any migratory smolts were present. On March 27, 1906, however, fifty parr and smolts were taken, many of which were about $5\frac{1}{2}$ inches long (the extremes were 4·6 cm. to 14 cm.), and in appearance approximating to the ordinary spring smolts. We have no positive evidence, however, that those March smolts were entering the sea, and it may be that they were representatives of parr which, like the 8 per cent. of the Stormontfield fish which were reported to have descended after only one year in fresh water (the ponds), have reached and have remained in those upper tidal waters for some time, and which would probably be amongst the earliest to leave for the sea after a second year. This view is strengthened by an examination of their scales made by Mr. H. W. Johnston, which showed that the fish were "rising two years." Throughout this smolt netting I could find no evidence that one-year-old fish left the river for the sea or assumed an appearance suggestive of their descent before they were two years old.

With the departure of the smolts for the sea we may regard the first stage of the salmon's life as completed. Up to this time the life has been in fresh water, where observation on man's part is less difficult than in the sea. The earliest reappearance of the fish in fresh water is as a grilse, and the study of the intervening period of marine life has till recently proved too difficult for most who have attempted it.

A certain number of stray specimens have from time to time been captured, which have given us glimpses of the salmon's development in this stage. When trawling with a shrimp net for experimental purposes in May 1901, two miles off Blackpool, *i.e.*, about twenty miles from the mouth of the Ribble, Mr. Archer was fortunate enough to catch a young salmonid 7 inches in length, which Professor Herdman and Dr. Noël Paton considered to be a salmon smolt. Professor Herdman found the stomach and intestines fully charged with nourishment. The remains of two young sprats were in the stomach, and the scales of other sprats or of young herring could be distinguished in the contents of the intestines, together with the remains of small crustaceans (copepods), which, however, may have been ingested from the swallowed fish, since sprats and herring feed largely on copepods. This smolt had apparently got clear away from the mouth of any river, and had commenced to absorb the particular kind of nourishment which we know the adult salmon fattens upon. Herr Dahl reports * receiving from mackerel fishers who had been working off the coast of Norway three young salmon measuring respectively 17·5, 39·0, and 43·0 cm. ($6\frac{7}{8}$, $15\frac{3}{8}$, and 17 inches); and by fishing with fixed engines of small mesh he himself secured at the island of Garten, in the Trondhjem Fjord, a few small salmon measuring from 45 to 70 cm. ($17\frac{5}{8}$ to $27\frac{1}{2}$ inches). The same writer, who has made a most exhaustive search in European museums for specimens of young salmon, reports that in Bergen

* "Œrret og Unglaks." Christiania, 1902.

University are two examples, 23·5 and 28·0 cm., which Professor Collete informed him had been found in Christiania fish market amongst some young mackerel.

In 1904 there came into my hands a young salmonid, 14 inches long and $15\frac{1}{2}$ ounces in weight, which had been captured by Mr. Milne, salmon tacksman, at the mouth of the Galway river, in Ireland, and who was kind enough to send the specimen for my inspection. I submitted the fish to Mr. Boulenger, of the British Museum, who, along with his colleague, Mr. Regan, agreed that it was a specimen of *salmo salar*. I described and figured the fish as such,* but pointed out the rather noticeable depth of the caudal peduncle, and that in this particular the fish resembled the condition commonly found in sea trout. In the total length the small of the tail (caudal peduncle) was contained $11\frac{2}{5}$ times, instead of from 15 to 15·9 times as in the smallest grilse I have been able to collect in recent years. In other respects the characteristics of the fish are clearly those of salmon. In the way of hearsay evidence one might mention a few similar occurrences of apparently stray specimens linking the smolt and grilse. I may mention only one, which the late Mr. Anderson, salmon tacksman in the Firth of Forth and fishmonger in Edinburgh, communicated to me. In his father's time, he informed me, a fixed net used to be worked at Queensferry, and while he was present, in June 1863, two small grilse were caught each weighing $\frac{3}{4}$ lb. Instances like

* Proc. Roy. Soc., Edin., xxv. p. 395.

these are no doubt exceptional, not only in that they are rare, but also because such specimens taken occasionally at or near the mouths of rivers at this stage are apparently examples of young salmon which have not followed the usual habits of their fellows.

To Herr Dahl we are indebted for the information respecting the apparently normal habits of the salmon at the stage we are now considering. As we have already seen, certain specimens were obtained by him in the sea at considerable distances from rivers, and also taken by mackerel fishers. It has been by following up this hint of the young salmon's habit that he is now able to answer the often put query, "Where do the smolts go after they leave our rivers?" Without doubt the satisfactory solving of this problem is a most valuable piece of work, for which the greatest possible credit is due to the Norwegian investigator.

In the summer of 1905,* Herr Dahl renewed his endeavours to obtain young salmon by offering rewards through the instrumentality of a Christiania gentleman. He obtained twenty fish in this way, captured between Sogne and Ulvasund. Eight of these proved on examination to be young salmon, the remainder being sea trout. The stomachs of these young salmon contained remains of herring, sand-eels, and sparlings. Permission to use a net of small mesh was obtained, and an agreement was come to by which a Mr. Waage of Brandasund should employ it in mackerel fishing. Between January

* Knut Dahl. "Uyere Oplysninger om Unglaks og dens Opholdsfteder." *Norsk Fiskeritidende*, 12, 1906.

19 and August 26 there were captured, between Storholm and Brandasund, off the south coast of Norway, forty-three salmon and 124 grilse. After August 26 to the end of September, twenty-two salmon and two grilse were obtained, giving a total of 191 salmon and grilse. Three of the grilse were small, viz., 46 cm., 46 cm., and 45 cm. (18 inches).

In 1906 two fine-meshed mackerel nets were used by Mr. Waage's men. One caught, between April 19 and August 26, twenty-three salmon and forty-seven grilse, and five of the grilse were under 55 cm. ($21\frac{3}{4}$ in.), viz., 37, 42, 42, 46, and 47 cm. After August 26, twenty-seven salmon and four grilse were got, but none of the latter were now under 55 cm. The other net caught between July 3 and September 29 forty-two salmon and grilse, but only one of the grilse was under 55 cm.

In contradistinction to these results in the open sea, Herr Dahl points to the results of his fishing in the southern fjords in 1903, 1904, and 1905. He made 930 attempts with a fine-meshed net, and in this time only caught one specimen of *salmo salar* under 55 cm.

His conclusion is that the young of the salmon, after leaving the rivers and fjords, pass to the open sea, and he declares that they occur constantly, and can be freely caught if suitable nets are employed in the natural habitats of young mackerel and herring.

We have already seen that our Tay sparling net experiments showed that the salmon smolts seemed to make a bolt for the open sea after leaving the upper tidal water. We already know from the

examination of sea caught salmon that herring and sand-eels seem to be their favourite foods. Now Herr Dahl has caught the growing smolts out at sea as they follow the shoals of their marine "supporters."

Next we have to deal with the time spent by the smolt in becoming a grilse before fresh water is revisited.

From the seasons at which young fish in the transition stage have been taken, as compared to their size and weight, as also from the early Tweed returns, which must be regarded as reliable although so few in number, it seemed certain that the view very commonly held in Scotland on this point was erroneous, and that a full year in the sea elapses between the time when the smolt leaves the river and the time when as a grilse it returns.

To obtain direct and reliable evidence on this point it was desirable to mark a large number of smolts by the attachment of some foreign substance. The presence of small spring fish in many of our rivers at the same time raised a problem which seemed likely to be solved at the same time and by the same means. In 1903 I had experimented at Fochabers Rearing Ponds as to a suitable mark for attachment. A small silver disc was attached by a split silver pin to the gill cover so that it lay flat upon the outside and yet gave room for the necessary expansion. The delicate bones of the smolt's operculum could not, however, stand the strain of this mark, and in a few weeks very many of the marked fish had dropped both disc and pin by the rupture of the gill cover.

In 1904 in the lower Tay I tried a simple piece of silver wire passed through the skin of the back close to the adipose fin, but the wire chosen was rather heavy. In the following year, however, Mr. Malloch, Perth, tried a finer silver wire, inserting it through the front of the dorsal fin and twisting it into a simple loop, and this was found to answer very well. From the commencement at Fochabers very great advantage had been experienced in not handling the smolts, but in using small vulcanite tubes for holding the fish when inserting the marks. By using these holders complete freedom from injury to the delicate little fish through handling was secured. Under Mr. Malloch's supervision, therefore, in 1905, the Tay Salmon Fisheries Company undertook the marking, and Mr. McNicol, who carried through the actual operation, succeeded in inserting the wire loops in 6500 smolts. The admirable results which have followed will be related in next chapter.

CHAPTER II

GRILSE

Return of marked smolts as grilse the following season—Habits of grilse in the sea—Ascent of grilse from sea—Habit of many to remain in sea beyond grilse stage—Small spring fish—The spawning of grilse—Ascent of grilse when in poor condition—Argument in support of the marine origin of the salmon—Entrance of salmon to fresh water not entirely explained by condition of satiety—Reproduction in fresh water—Possible transference of small fish from one river to another—Movements of marked grilse along coast of Scotland

THE smolts were all marked in the neighbourhood of Kinfauns, where, as already explained, the little fish can be most easily procured in spring. The operations were carried on from the end of April till early in June.

No recaptures of those wired smolts after attaining the grilse condition were made during the summer or autumn of the year of marking (1905), although the tidal waters were netted day and night as usual through the fishing season, and rod-fishing continued till October 15.

On June 1, 1906, the first recapture was made, the grilse having the unmistakable silver wire attachment. Soon afterwards others turned up in the nets. The first recapture was appropriately

PLATE I.—Dorsal fin of grilse, caught in 1906, with silver wire mark inserted when the fish was a smolt in 1905. Photo by Mr. P. D. Malloch.

presented by Mr. Malloch to the Perth Museum, a grilse of 2 lb. 15 oz. The second specimen was kindly sent to the writer, and was exhibited, with the mark *in situ*, to the Royal Society of Edinburgh.* It is a male grilse with genitalia in an undeveloped condition; length 24 inches, weight 4 lb. 8 oz. The interval of time between marking and recapture is thirteen months. Between the date of the first recapture and the end of the fishing season, 1906, those wired grilse occurred not infrequently in the Tay nets. No recapture was reported from any other locality. The weights varied from $2\frac{1}{2}$ to 9 lb. The following details of date and weight respecting the recaptures during June and July will sufficiently show the results of this experiment as regards grilse:—

	Date.	Weight.	
		lb.	oz.
1.	June 1	2	15
2.	„ 26	4	8
3.	„ 28	4	12
4.	July 3	3	4
5.	„ 4	5	8
6.	„ 10	4	4
7.	„ 14	5	12
8.	„ 14	7	0
9.	„ 16	6	8
10.	„ 16	6	12
11.	„ 16	4	8
12.	„ 24	5	8
13.	„ 26	7	0
14.	„ 28	6	8
15.	„ 28	7	2
16.	Aug. 4	5	0

* "Note on the Smolt to Grilse Stage of the Salmon," Proc. Roy. Soc., Edin., xxvi.

This is pretty good evidence that the first reappearance in fresh water of the fish which descended to the sea as smolts about twenty-six months old is not less than a year later when, as grilse, the fish are three to three and a half years old. The average weight of the Tay grilse mentioned is $5\frac{1}{4}$ lb., which gives an average increase, taking fourteen months as the interval, of 6 oz. a month. The increase in length may be taken as fully fourfold. This rate of increase is surely more in harmony with what we know of the growth of other creatures having a duration of life similar to that of the salmon than with the sensational increase demanded by the view previously held, and stated as a proved fact by several writers, that grilse come into our rivers after an absence of only a month or two.

Reference has been made to the food of the Blackpool smolt. In a little book, now out of print, on the natural history of the salmon, written by a salmon curer and tacksman of fishings at Inverness, named Alexander Fraser, and published in 1830 at the *Inverness Courier* office, I find this shrewd observation: "I have found seven small fish in a grilse of $3\frac{1}{2}$ lb., and several, particularly herrings, in the body of salmon." The writer then goes on to speak of the sea as the feeding place of the fish: "Salmon in lakes and rivers can, like other fish, subsist for some time on little or no food. In the river Ness they have been known to continue for about eighteen months, the interval between their entry and their departure for the sea, and during this time their food must be very limited indeed.

It is in salt water that salmon obtain the chief part of their food, and hence they fall off in condition in proportion to the time of their abode in rivers."

We need not enter for the present on the vexed question of the non-feeding of salmon in fresh water ; suffice it to say that grilse, like salmon, as a rule enter our rivers in a highly nourished state. They follow shoals of herring to a considerable distance from the mouth of their native river, and they show remarkable cleverness, whether they swim in company or individually, in finding their way back again. The fact that grilse are taken in bag-nets set at considerable distances from the mouths of rivers is sufficient to show that the wandering must be fairly wide. Of course in the early stages of their growth the fixed nets set on our coasts would not retain them, since the mesh is a wide one adapted specially for their safety. On the east coast of Scotland the annual close time terminates in most districts on February 10, and fixed nets are again put in the water. Although during the first of the season it is possible that the small growing grilse would still pass through the mesh, we are, I think, quite justified in believing that, were the fish on the coast, grilse would be got in fair numbers before May. The fact that grilse do not occur, or practically do not appear, in the coast nets till May leads one to infer that until about that time they are not within the netted zone. As a rule in Scotland the earliest grilse seem to appear on the coasts of Banff and Aberdeen, where a few begin to appear about the middle of April. The record for earliness

is, I believe, March 6, 1905, when a $2\frac{1}{4}$ lb. grilse was caught at the mouth of the Dee. Willis Bund mentions ("Salmon Problems," p. 87) that on rare occasions grilse appear in the Severn in February. Such occurrences are, however, altogether exceptional, and fishermen do not look for a regular run of grilse till May, while the greatest run is usually considerably later. The special point of interest seems to me to be that the grilse appear, as it were, all at once on the coast, so that within, it may be, two or three days such a market as Aberdeen may be flooded with them, where only very few were before to be found.

The year 1902 was a remarkably good one for grilse, and having been favoured with a return of the numbers of salmon, grilse, and sea trout caught during the season by the Aberdeen Harbour Commissioners, I constructed charts showing graphically the relative captures.* From the fixed net fishery on the coast north of the mouth of the river Dee the first records of grilse were on April 15, but comparatively few were taken between this and the end of May and beginning of June. Signs of a great run of grilse appear in the chart in the second week of June, and on the 23rd of the month there is an enormous catch. Good takes last well through July, and at the end of July and again from August 10 to 13 there are two other marked rises in the curve representing grilse. These last rises are also noticeable because simultaneously occur rises in the salmon

* Twenty-first Annual Report, Fishery Board for Scotland, Part II. Appendix II.

curve, as if the particular influences which brought grilse in shore to the netted area of the coast also affected the salmon in the same way. A separate chart of curves was given for the sweep-net fisheries in the mouth of the river Dee. In this the first grilse are shown as caught on April 18, or three days later than on the coast, while the date of the greatest catch is June 27, or four days later than the maximum in the coast nets to the north of the river mouth. The fixed nets, which are situated to the south of the river mouth, do not share in the marked influx of grilse. From these considerations it would appear that the grilse approach the shore from the north of the Dee, that they travel together in large numbers, and, working along the coast in a southerly direction towards the mouth of the river Dee, very slowly and no doubt in an off and on manner (else the first nets encountered would absorb the great bulk of the run) enter fresh water three to four days after having struck the coast "from the bosom of the deep," as a fisherman picturesquely put it to me on one occasion. Everything we know about the salmon in this stage seems therefore to indicate that after leaving the river as a smolt, which it does completely and with some rapidity, the young fish does not as a rule again visit the shore, much less the river, until a year has passed, when in company with its fellows it swims into shallow water and when some re-enter the rivers of their nativity.

In the Baltic around the island of Bornholm a line-fishery exists for salmon. The bait used is herring, and the lines are set so as not to go to the

bottom. Isolated cases have occurred of salmon being captured on cod lines off Scotland, and of steam trawlers capturing salmon ten to forty miles from land,* and I have heard of the capture of a salmon in the Pacific, some 400 miles off the American coast. This was, of course, not *salmo salar*, but none the less the occurrence is interesting, as showing that salmonids do go far from land. Yet no marked salmon has been caught after crossing the North Sea or even St. George's Channel. One or two Norwegian marked fish did, I understand, turn up in England, but on investigation it was found that they had come across the North Sea in a steamer, just as one or two Scottish marked fish which were discovered in a fish shop in Cornwall went from Aberdeen by rail. In pursuit of their natural food, however, both grilse and salmon clearly leave the coast, and the fact above referred to that grilse make their appearance in the coast nets somewhat abruptly, and that a good "head of salmon" sometimes occurs simultaneously with this run of grilse, leads to the inference that they have forsaken the feeding grounds when they draw in to the land and move along the coast. On the east and south coasts of Skye and the east side of the island of Raasay the bag nets catch such a large proportion of grilse that the fishery may be spoken of as a grilse fishery. On this account the nets are not put in the water at the commencement of the season, but only brought up to full strength before the main runs of

* Twenty-fourth Annual Report, Fishery Board for Scotland, Part II. p. 76.

grilse may be expected. When the grilse appear on the coast of Skye it is certain they are not on their way to any rivers in Skye, because the Skye streams are in summer so small that even a grilse would run aground amongst the stones. When the autumn rains have swollen those streams, fish ascend to spawn. In the same way the Raasay grilse must be on a passage elsewhere, since there are absolutely no salmon streams in the island. The manager of the fisheries says he has no idea whence the fish come or whither they go.

But many of the grilse which travel along the coast do not go into fresh water. When the chart of curves illustrating the 1902 grilse fishing at Aberdeen was constructed the net and coble fishing was also recorded from the river mouth. The results of this fishing in the river are far below the result of the bag-net fishing on the coast to the north of the river. It may be said in reply to this that the coast nets met the first of the run and caught the great majority of the fish. There is no means of proving that they did not, but equally it may be said there is no reason for believing that they did. The fish were on the coast in great numbers.

The following statement shows the number of grilse and salmon, and their weights, taken at the fishings of the Aberdeen Harbour Commission from 1872 to 1897, the great majority of the grilse being captured in coast nets. The table is from the sixteenth Report of the Fishery Board for Scotland :—

Season.	Salmon.				Grilse.			
	No.	Weight in lb.	Total Wght. for each period of 7 years.	Percentage.*	No.	Weight in lb.	Total Wght. for each period of 7 years.	Percentage.*
1872	3,981	59,303	—	—	5,923	27,338	—	—
1873	4,200	48,895	—	—	7,239	34,598	—	—
1874	8,100	88,398	—	—	6,187	27,219	—	—
1875	5,961	63,987	—	—	4,714	20,501	—	—
1876	2,873	33,788	—	—	9,184	39,297	—	—
1877	4,811	55,086	—	—	7,737	37,556	—	—
1878	8,918	116,308	465,765	—	3,350	14,446	200,955	—
1879	1,897	22,964	—	—	7,284	31,141	—	—
1880	4,178	43,587	—	—	5,410	23,720	—	—
1881	4,873	47,191	—	—	11,400	49,349	—	—
1882	6,530	62,717	—	—	7,415	32,413	—	—
1883	6,886	70,384	—	—	13,852	70,555	—	—
1884	5,424	64,866	—	—	6,129	27,817	—	—
1885	4,597	53,989	365,698	78·5	15,129	73,958	308,953	153·7
1886	6,370	68,536	—	—	9,583	39,502	—	—
1887	5,052	55,535	—	—	14,847	60,644	—	—
1888	7,843	83,292	—	—	12,905	58,653	—	—
1889	5,623	60,573	—	—	9,336	38,379	—	—
1890	7,085	66,114	—	—	9,220	43,140	—	—
1891	9,477	107,566	—	—	11,775	58,318	—	—
1892	8,594	88,932	530,548	113·9	11,329	48,620	347,256	172·8
1893	6,795	71,185	—	—	5,068	18,131	—	—
1894	4,581	45,932	—	—	6,277	28,020	—	—
1895	7,002	75,603	—	—	14,938	76,836	—	—
1896	10,790	122,746	—	—	9,766	41,426	—	—
1897	4,834	50,218	—	—	4,060	16,948	—	—

* The weight for the first septennial period is taken at 100, and for the later periods as proportional parts of the first.

There are 229,957 grilse as against 157,275 salmon.

I have also figures for 1904, showing in like manner the grilse and salmon caught on the coast of Caithness in the Thurso district. In July of that year there were 2032 grilse as compared with only 290 salmon. The Thurso is not conspicuous as a grilse river.

The seine nets worked in the narrow waters of a river are more deadly engines than the fixed nets on the coast—a statement which, I suppose, very many

will call in question. If the grilse had entered the river Dee in any great numbers, the seine nets would have found them. With regard further to the question whether or not all the grilse come into our rivers, I beg leave, with the recognised privilege of a Scotsman, to answer this question by asking another, viz., What is a small spring fish? If all grilse enter our rivers, how is it possible that small spring salmon of 4, 6, or 9 lb. weight can be found in our rivers just when grilse have finished spawning and are descending again to the sea? These small spring fish cannot have spawned at an earlier stage. If they had been up rivers on a previous occasion they would have been very small grilse, and as kelts would have been lighter than any kelts to be found. But if I may anticipate a little here, I would say that a study of their scales shows that they have not spawned. Only two hypotheses are possible—

(1) That they have previously ascended fresh water, but have returned to the sea without spawning.

(2) That they have never been into fresh water since they left it as smolts, but have passed their grilse stage in the sea.

With regard to the first, I would say that while it is certainly true that some fish ascend rivers and again drop back, there is no evidence to show that in so dropping back any fish enter the sea for a renewed period of feeding, but only through force of floods, intense cold, injury or disease, or some more or less temporary cause. Further, we have for several winters carried on systematic netting operations for

the purpose of marking fish, and at such times we find grilse of both sexes continuing to ascend, and *invariably* spawning or about to spawn. We have never found any grilse which having entered the river are to be regarded as non-spawners. The second hypothesis, on the other hand, seems borne out by all evidence of direct observation. The scale of the small spring salmon is very like a grilse scale in this, that a continuous sojourn in the sea is stamped upon it, yet the fish seems to be the same age as the grilse kelt. The scale of a 7 lb. fish of this class is figured in Plate III. of Mr. Johnston's paper on "The Scales of Tay Salmon." * When reference is made to the tables showing the lines of growth after smolt descent (pp. 70 and 71), we notice that whereas in the second year grilse scales show—in May 7, in June 10–15, in July 14–21, and in August 17–25, *i.e.*, an extreme range of 7–25 lines; the small spring fish does not show less than 20, and in February, March, and April has from 26 to 31 lines. In other words, the small spring fish does not exhibit a paucity of lines, which is readily explained in the case of the grilse owing to the cessation of feeding and the ascent of fresh water. This evidence is in my opinion a strong corroboration of the view that the small spring fish has not been in the river as a grilse, but has passed the usual grilse stage in the sea.

In the spring of this year, however (1907), evidence has been obtained which may be said to settle finally the problem of the small spring fish. This valuable

* Twenty-third Annual Report, Fishery Board for Scotland, Part II. Appendix II.

evidence is the recapture of small Tay "springers" bearing in their dorsal fins the silver wire loops distinctive of the smolts marked in the Tay in 1905. The first of these fish was taken on February 18, a 9 lb. small salmon ; the second on the following day, 8 lb. ; the third on February 21, a 9 lb. fish. Others followed through spring and summer until, in August, after a stay in the sea of some twenty-seven months, fish of 18 and 27 lb. were captured. The ascent of fresh water is for the first time. The total number of those wired spring and summer fish was considerably less than the number of the grilse.

Some of the light weights amongst these clean fish are extremely like grilse, and this is to be expected, since they are only just passing into the more advanced appearance, or the "gilling" appearance, as it would be termed by Mr. Willis Bund. The grilse, therefore, which we find spawning in our rivers are only a proportion of the fish of their own age which left the rivers as smolts (and which survived the dangers of the deep). It may be this proportion varies considerably in different years owing to the greater or less inducement to remain in the sea, and that this may be a factor in determining good and bad grilse years, as much as the actual number of smolts which descended—the factor usually regarded.

The state of nourishment, the condition of grilse entering rivers, certainly varies in different years. I have already noted that 1902 was a good grilse year ; it was good both in the matter of numbers and the actual condition of the fish. Conversely, 1903 was a poor grilse year, the run not only being

short, but the condition of the fish exceptionally poor. I noticed some grilse in Dundee market which were, without exception, the worst-conditioned grilse I have seen. On inquiry I found they had been sent to Dundee from elsewhere—for very shame, I imagined. In the same year some salmon on the north and east coasts, more especially about Caithness, were remarkably tasteless and dry in the flesh, and at the same time I noticed that the local herring tasted apparently of nothing so much as sawdust. Now the presence of those poorly nourished grilse and salmon is noteworthy in two respects: first, simply because fish were entering rivers in a poorly nourished state (although some poor fish I had evidence of were caught in sea nets); and second, because the actual numbers of grilse were deficient. As a rule grilse on entering the mouths of rivers are found to be charged with nutriment, pyloric appendages loaded with fat, and stomach empty. At the mouth of the Tweed, Tosh and Grey * found 4 per cent. out of 231 male grilse and only 1 per cent. out of 188 female grilse with signs of recent feeding. Hoek at the mouth of the Rhine, examined 2000 fish, and found food in only seven. The highly nourished condition has been regarded as in itself sufficient reason for the ascent of fresh water. Dr. Noël Paton puts it thus: † "When on the rich marine feeding grounds as great a store of nourishment as the body can carry has been accumulated, the fish returns to

* Thirteenth Annual Report, Fishery Board for Scotland, Part II. Note 2.

† "Investigations on the Life History of the Salmon," 1898, Special Report, Fishery Board for Scotland.

its native element." The exhaustive and most important investigations of Dr. Noël Paton and his colleagues demonstrated most clearly the manner, *inter alia*, in which the great store of nourishment is used up in the development of the genitalia, and showed the corresponding loss in muscular tissue as this development proceeds. With the condition of satiety comes naturally the disposition to cease feeding, and with the cessation of feeding the ascent of fresh water commonly follows.

So far we seem to be on perfectly safe ground, but I am inclined to think that the condition of satiety has been somewhat forced in the argument as to the result which it produces, viz., the ascent of fresh water. I admit that the normal condition of fish on entering fresh water is that of high nutrition, but let us inquire a little further into the argument that this high state of nutrition causes the salmon to leave the sea for the fresh water, or at any rate that this is the primary and dominating factor in the migration. Being in this highly fed up state, fish are able to fast for long periods; and be it noted this is not peculiar to the salmon, but has been ascertained to be true, for instance, in the allied herring, whilst amongst higher animals the same peculiarity is reported as being true of seals. Why do they fast, and why does the salmon so fast only in fresh water? It has been said by way of explanation that, having attained an overplus of nutriment in its tissues, the salmon enters fresh water to rest, and that this may be regarded as natural, since in entering fresh water the salmon is in reality, as it

were, returning home. It is essential for this argument that the salmon be regarded as a fresh water fish which has gone to the sea to feed. This forms, I admit, a plausible explanation of the presence of early running fish in our rivers. That they do not nourish themselves in fresh water has been proved. Whether they can be said to feed in fresh water must not be discussed here. This point, about which so much has been written, is really not very important. It is in essence a dispute about terms. Let us be thankful we can catch them with flies and other baits.

But can the salmon be properly regarded as a fresh water fish? Dr. Noël Paton realises the importance of this for his argument when he says, in dealing with the factors determining migration, in the general summary (p. 169): "In considering the question it must be remembered that the Salmonidæ are originally fresh water fish, and that the majority of the family spend their whole life in fresh water." To my mind it is not clear that the majority of the family do so spend their lives, but further, it is not sufficient to regard the British Salmonidæ in this matter; we must take into consideration the group of fishes, or at least the sub-order, to which the Salmonidæ belong, and judge the salmon as it appears in relation to its near allies. If in this way we take the seventeen genera of Boulenger's classification, we find that the majority are more marine than fresh water, including *Bathylagus* (Gthr), the deep sea form recently added to the British fauna *;

* Holt and Byrne, "Fisheries Sci. Invest. Ireland, 1905," II. (1906.)

that one or two, such as *Thymallus* (the graylings), are purely fresh water, and that the genera *Salmo* and *Coregonus* include species which are both marine and fresh water in habit. It may fairly be noted, however, that the species of the two last named genera, usually considered as inhabitants of fresh water alone, can somewhat readily be accustomed to the sea—that indeed any salmonid may apparently be accustomed to salt water—whereas a pure fresh water fish, such as a carp, at once succumbs to the effects of salt water. Also we have *Osmerus* (the smelt or sparling), which is classed along with four other genera, three of which are marine, coming into our estuaries to spawn. In the allied group of fishes, including the herrings, we also see the herring itself, the sprat, and the shads coming freely into estuaries, and the shads spawning in fresh water.

If, further, we consider the salmonids, let us say the British salmonids, which are commonly found in fresh water, and note their characteristics in relation to the common developmental characteristics of the genus *Salmo*, we may observe that certain features common to salmon parr, the so-called parr marks and the complete dentition, very usually survive throughout the life of the fresh water form. If salmon smolts are retained in fresh water beyond their natural time of descent to the sea, they assume again the trout-like appearance of the juvenile. We have already seen in the previous chapter that the Howietoun specimens which spawned, and which were figured by Day in the Transactions of the Linnæan Society, retained the parr marks. The land-

locked "salmon" of Lake Wenern, which seem in reality to be trout, are reported to have not uncommonly the same appearance. As the salmon grows after visiting the sea, the teeth on the shaft of the vomer bone disappear, and eventually the teeth on the head of the bone go also. Trout retain those teeth throughout life. In other words, the trout commonly retains the juvenile characteristics of the salmon, which develops fully only by visiting the sea. This retention by fresh water trout of the juvenile characteristics of the salmon does to some extent suggest that the salmon has developed from a trout-like origin, after acquiring the habit of migrating to the sea. If this is so, *Salmo trutta* and its varieties occupies an intermediate place between the fresh water trout and the salmon. New Zealand trout rapidly acquire the migratory habit. But, on the other hand, and in view of the fact that the majority of the salmon family are purely marine, may we not have some cause for the view that our fresh water trout itself represents a species in which evolution has been arrested to a greater degree than is seen in the case of the salmon. The salmon fall off in condition after entering fresh water. It is easy to say that they do so because they do not feed, but if fresh water is their original element, why should they not feed, and why should they fall off in condition?

I firmly believe that many of us have got into the way of regarding the salmon as a fresh water fish simply because we observe him almost exclusively in fresh water, where he spawns, and further get into the way of regarding the silvery

scales of the fish as secondary and more or less accidental results of his visiting the sea and feeding there. We admit that he thrives surprisingly in the sea for a fresh water fish, but we know he can spawn only in fresh water, and ask how can he be a marine fish if he cannot propagate his species in the sea. Do we call the common eel a sea fish because it spawns in the sea? We call it the fresh water eel. Is the shad a fresh water fish because it spawns in rivers? In my view, the prevailing characteristics of the group of fishes to which the salmon belongs are those of marine fish of plastic nature, capable of much local variation both of appearance and habit, many of which enter fresh water freely. The fry exhibit a strong impulse to descend the rivers of their birth and to enter the sea; they do not develop into normal or healthy adults if they are retained forcibly, nor under usual conditions do they come to sexual maturity unless they have visited the sea. In some localities where great lakes occur a degenerate race becomes possible, but these land-locked salmon cannot be regarded as representatives of what the salmon used to be; they are not the fish through which evolution could proceed. It is quite possible that *Brachymystax*, the large salmonid of the Siberian rivers and Lake Baikal, which viewed systematically comes between *Salmo* and *Coregonus*, may be a migratory fish which remains in fresh water for longer periods than our salmon, and which in its great size and full development differs in this respect from the so-called land-locked salmon, but the life history of the

fish seems still uncertain. It is significant, moreover, that in these Siberian rivers the local species of *Coregonus*, which with us are purely fresh water fish (the vendace and powan), are fully migratory, as reported by Günther. It is quite possible to imagine that in early times salmon were so numerous in our rivers that a suitable supply of food was impossible, and that therefore the habit of migrating to the sea developed, but this is a mere supposition. As a matter of natural history it is, on the other hand, I think, more in harmony with what is known of the habits of the other members of the group to suppose that the habit which has developed is that of migrating to fresh water primarily for the purpose of spawning, and that in large continental rivers and in rivers of land now disconnected from continents the habit of remaining for long periods, and by some species of living more or less permanently, has been acquired.

If, however, as I have shown, it happens that in some seasons in our islands salmon ascend our rivers in comparatively poor condition, a serious blow is struck at the view that the primary cause of ascent from the sea is the state of satiety. Along with the procuring of food, the other great instinct is that of reproducing the species, and a fish not up to the normal standard of high nutrition may still be impelled by this instinct, even if the reproductive elements are, it may be, unable to produce eight or nine hundred eggs per pound weight of fish.

I have dealt with this point of the marine as opposed to the fresh water origin of Salmonidæ,

because if the view in favour of the marine origin is correct, our conception of the migratory habit must be influenced accordingly. We must not regard the descent to the sea, although it is the first migration in the life of the individual fish, as the real direction of migration, but rather that the parr is in fresh water because the parent migrated from the sea to spawn, and that the grilse and the adult fish alike migrate primarily for the same reason, although the condition of satiety plays an important part in the case of early fish. When in a later chapter we deal more particularly with the migrations of early and late running fish the application of this conception of the salmon's origin will again be taken up.

More inquiry is still needed as to whether or not grilse and small salmon enter certain rivers, and in later life as large salmon enter other rivers. In Alaska it is reported, for instance, that small fish of very uniform size are found in some of the smaller rivers, while in large rivers of that coast, such as the Fraser in British Columbia and the Columbia river in California, only a much larger fish, but again of uniform size, is seen. In a report for the year 1905 * Mr. Archer suggests that further inquiry may show that this obtains more often than is supposed, and instances a case of "a fish marked in the Figgen river in Norway—a river in which the fish are said seldom to attain to a weight of more than 11 or 12 lb., and are usually considerably smaller. This fish weighed 5 lb. when first taken and marked, and was recaught rather more than two and a

* Board of Agriculture and Fisheries, Annual Report of Proceedings under the Salmon and Fresh Water Fisheries Acts, p. xviii.

half years later off an island on the coast more than 90 miles distant from the river where it was marked. It then weighed 18 lb. The unusual size it had attained, coupled with the fact that it was taken much nearer to rivers frequented by large fish than the Figgen river, is at least suggestive of the idea that the explanation of some rivers holding fish of a much smaller average size than others may be due to the fish seeking new rivers after they have attained a certain size."

In a chart showing migrations of salmon along the coast of Scotland * are five lines indicating movements of marked fish from the river Deveron, which debouches on the southern shores of the Moray Firth, to the east coast nets near Aberdeen. Three of the five fish referred to were grilse, and in each case this rather marked migration had been made in four months or less. We have of course no proof that those fish would not have travelled back again, but I certainly consider such a return unlikely.

The great majority of marked fish, grilse as well as salmon, are found again in the rivers in which they were marked, but such cases are suggestive of the possibility referred to above. Yet after the considerable amount of salmon marking which has now been carried out in Scotland, it is natural to suppose that if such a transference occurred frequently in our rivers, more direct evidence of it would by this time have been obtained.

I have made reference to the large proportion of

* Twenty-fourth Annual Report, Fishery Board for Scotland, Part II. p. 69.

grilse as compared with salmon which are caught in many localities on our coasts, and to the fact that grilse appear to affect some localities more than others. Major Traherne tells us* that in the Hampshire Avon and the Ogmore in Glamorganshire grilse are absent, although adult salmon are to be found. I believe, as a matter of fact, this statement is open to question. It seems undoubtedly true that grilse, although abundant on the coast, may not enter certain rivers as salmon do. That, in other words, the proportion of grilse to salmon on the coast is a very different thing from the proportion of grilse to salmon in any particular river. When we come to deal with rivers, however, it has to be remembered that we introduce not infrequently the complications due to the action of man in, it may be, overfishing or in polluting the fresh water, and that changes may be going on which prevent our regarding the results found as normal. In the Tweed, for instance, the early reports show, according to Willis Bund, that from 1808 to 1853 there were never less than three grilse to one salmon, and that from 1853 to 1876 there were two grilse to one salmon. In later years the grilse have continued to diminish. In the Severn they have apparently become rather conspicuous by their absence.

Hoek at the mouth of the Rhine found that grilse formed only 24·1 per cent. of the fish ascending that river. Observations such as these are necessarily made only during the fishing season, while, as I have already said, winter netting in

* "The Habits of the Salmon," p. 88.

certain localities shows that grilse continue to run with the latest of the spawning salmon. In the Tay in 1902 and 1903 we carried on winter netting at Almondmouth, a short distance above Perth, where a very fair sample is to be obtained of the stock of fish in the lower river. In November we netted for three days in each year, and found a pretty even balance :—

	Grilse.	Salmon.
November, 1902	107	64
November, 1903	100	132
	207	196

The fish enumerated are unspawned, spawning, and spent. We caught in addition several clean run salmon. At a higher part of the river, less suitable for the finding of spawning fish, we had only eleven grilse (all unspawned) and fifty-one unspawned and spent salmon. I am unable to give figures worthy of mention respecting the stock of fish in the upper Tay, but in all probability the salmon considerably outnumber the grilse, on account of the large number of spring fish which ascend this well-stocked river. Of no river of any size can it be said that it practically holds nothing but grilse, nor are the grilse in any river with which I am acquainted in this country in the proportion of seven grilse to one salmon, as was the case on the Caithness coast in 1904. Willis Bund refers to the small proportion of grilse in our rivers, and adds that "the number of grilse, so far as one can see, that spawn are below the proper proportion." The same writer shows ("Salmon Problems") that it is impossible to show any clear

connection between good smolt years and good grilse years. The explanation of this I have already tried to suggest. Since all grilse do not enter fresh water as such, one would not expect to find any clear connection between good smolt years and good grilse years; the state of nutrition and development of grilse in the sea being more likely to influence the run of grilse to fresh water than the great or small number of smolts which descended. The summer grilse usually make a quick ascent, and seem to show a preference for tributaries with rather rapid water. The late running grilse, like the late salmon, distribute themselves over the lower reaches of rivers. After spawning it is remarkable how quickly the great majority of them leave the river, this being noticeable in grilse of both sexes, and in large as well as small rivers. In our winter netting in the Tay, grilse were found ripe amongst the last of the late running salmon, and amongst descending kelts they were amongst the first. During marking operations it is common to retake salmon kelts which have been marked and which are still hanging about the same water, but we have hardly ever taken a recently marked grilse kelt. Some grilse, however, which have ascended a considerable distance appear occasionally to remain longer than the average.

From the observations of Grey and Tosh * respecting Tweed fish, as well as from the observations of Hoek and Meischer in the Rhine, it appears that in July and August the weight of the genitalia of

* Thirteenth and Fourteenth Reports, Fishery Board for Scotland, Part II.

female grilse bears a much smaller proportion to the weight of the body of the fish than is the case in female salmon. In this respect grilse differ from salmon, both large and small, where the proportion is practically constant at 3·02. In grilse it is only 1·95 during the months named. In terms of 100 this percentage in grilse and salmon respectively is as 64 to 100. As the season advances, the degree of development of the genitalia steadily increases, but the proportional development is later in the grilse than in the salmon, or commences later, although both grilse and salmon become fully ripe at about the same time. These particulars were clearly deduced by Archer* from the observations referred to.

After leaving the river, it is clear that the grilse can and does travel to fairly distant points on the coast at considerable speed. A Deveron grilse kelt marked at the mouth of the river (Duff House) was found in a coast net 50 miles distant (Port Errol) in 88 days. A similar recapture was made in 109 days. Another Deveron grilse which had travelled 70 miles to Cove, south of Aberdeen, in 122 days was found on recapture to have gill maggots (*Lerneopoda salmonea*, Linn.) still attached. The fish was sent to me in Edinburgh with the mark *in situ*, and I had the maggots carefully diagnosed by Mr. Scott, a specialist in the lesser crustacea and a naturalist on the staff of the Fishery Board. It is as yet uncertain how long those fresh water parasites can remain attached to the gills in sea

* Fourteenth Annual Report Fishery Board for Scotland Part II. p. 9 *et seq.*

water, but presumably the fish's sojourn in the sea had been comparatively short. A more striking instance is to be found in a Brora marked grilse—the river Brora enters the sea on the east coast of Sutherland—which was recaptured in the Pentland Firth, exactly 100 miles away by the coast line, after an interval of only three and a half months (109 days). There is some reason to suppose that this fish had forsaken the river Brora, since a Helmsdale fish marked within a few miles of the other has also been taken in the same locality, but instead of in a bag-net near the mouth of the river Halladale, as was the case with the Brora fish, it was taken by rod up the river Halladale. We must not, however, overlook the fact that such wanderers are in all probability exceptions to the general rule, but, as has been said, there seems to be a possibility that fish leaving small rivers, or rivers only frequented by small fish, are more likely to wander elsewhere than fish belonging to large rivers such as the Tay.

The information as to hitherto unexplained points in the life of the salmon, obtained by the systematic marking of recent years, must now, however, be followed out in a separate chapter.

CHAPTER III

RESULTS OF SALMON MARKING

Early marking operations—Modern method of marking—Divided migration—Scottish and Irish records showing short and long periods in the sea—Increase of weight in kelts recaptured as clean fish—Significance of divided migration in regulating fisheries—Salmon returning to their own river—Recaptures in other rivers—Recaptures on the coast—Direction of movements on coast—Kelts recaptured as kelts—Spring fish marked and recaptured

The immortal Izaak tells us in his "Compleat Angler" (1653) of observations made on the homing instinct of the salmon by tying ribbons or tapes to the tails of young fish, and how the fish were found to return from the sea to the same part of the same river. More recent observers also sought to identify fish so as to study their movements, but the methods employed were not, as a rule, so harmless as those of the lover of the gentle art. Mackenzie of Ardross in 1823 attached brass wires to the tails of salmon and grilse kelts. The late Duke of Atholl used copper wire and a copper label the size of a halfpenny in marking Tay fish, and between 1850 and 1863 obtained interesting recaptures, although the copper, pressing tightly upon the

growing fish, is reported to have caused considerable laceration.

From those returns we learned something of the great increase of weight attained in salmon after the sea has been visited, and of the length of time certain individual fish had been absent from the river; but the investigations were not sufficiently sustained to enable any one to understand the variations which occur in any district or in different districts and to make a sound deduction as to the general habit and life history of the salmon in its migrations, feeding, and reproduction. Still less could proper deductions be made from other observations made by Young of Invershin, Fraser, Buist, and others, whose method of marking was almost invariably that of cutting the adipose fin of the fish.

The one outstanding series of observations in those earlier days was carried through by the Tweed Commissioners, who from 1851 to 1864, and again from 1870 to 1873, conducted a valuable set of operations to elucidate the life history of the salmon and bull-trout of the Tweed—investigations which were scientifically conducted as well as sustained with regularity. These investigations have already been referred to as yielding us the three early examples of marked (wired) smolts recaptured as grilse.

The more recent marking operations carried on by the Fishery Board for Scotland were commenced by Mr. Archer during his term of office as Inspector of Salmon Fisheries. They were instituted on the lines of experiments already made by him in Norway

for the purpose of discovering primarily the range of influence of the Sands river. The treatment of the fisheries of this his own river had resulted in a very distinct improvement,* and the marking of salmon kelts was commenced, so that the movements of Sands fish could be followed.

The mark now used in Scotland is only slightly modified from the pattern originally used by Mr. Archer. It consists of a small silver plate, which bears upon it a distinguishing number, and a silver wire soldered to the long axis of the back of the plate, and also passed through the plate so that the two ends of the short wire project at right angles to the plate. The mark is commonly attached to the fish by pushing the two wire points through the base of the dorsal fin, so that the surface of the plate bearing the number rests upon one side of the fin and the points of wire project at the other. The points are then twisted together—without pressure upon the fin rays, if possible—and bent flat to the side of the fin. At time of marking a note is taken of the weight, length, sex, condition, date, and place; and at recapture the same particulars are, if possible, secured, and the records compared.

The same system is now also adopted in Ireland, where, however, a double plate is used, so that, if necessary, the distinguishing number may be read without the removal of the mark from the fish. Both in Ireland and England the silver marks are

* Eleventh and Twelfth Annual Reports, Fishery Board for Scotland, Part II.

PLATE II.—Measuring length of salmon on marking board and piercing dorsal fin for insertion of mark.

PLATE III.—Weighing fish suspended by worsted tail band after insertion of mark.

now oxidised, so as to render them less conspicuous to other fish.

Four reports on the Scottish results have now been published (20th, 22nd, 24th, and 25th Reports, Part II.), and the records of over three hundred recaptures discussed. In Ireland two reports have appeared (Report for 1901, Part II., and Fisheries, Ireland, Sci. Invest., 1904, VII. [1906]), and in England one short report has been published (Agric. and Fisheries for 1905, Salmon Acts, &c.). We have now, therefore, got a considerable number of records with which we can deal respecting the movements and increase of weight and length of the salmon of our country, and when we combine the results from the separate countries we are in a position to view the salmon's life with some breadth of horizon.

The most outstanding feature is the demonstration of what has been called the divided migration of the salmon—the habit of the fish to remain short periods and long periods in the sea. A shrewd forecast of this dual habit as seen amongst Tay fish was made by Mr. John Dickson, for many years agent for the Tay Fishery Proprietors, and who wrote on divided migration of the salmon as early as 1860 in the *Perthshire Courier*, and who has ever since continued to assert that this habit when properly understood will be found to completely explain the presence of early and of late fish in Scottish rivers. It has always been sufficiently clear to the observant that all salmon are not annual spawners. The mere fact that when fish are spawning, and when spent

kelts are returning to the sea, we have clean, well-fed fish with quite undeveloped reproductive organs entering and ascending our rivers, is sufficient to show that there are, at all events, a number of salmon each year which disregard the reproduction of their species. Such fish have sometimes been described as barren, but this is simply because at the time of capture they show no very evident sign of sex or of the active function of their genitalia. This missing of a spawning season has led other observers to suppose that the salmon is a biennial breeder.* The Scottish and Irish salmon marking results show that the salmon is both an annual and a biennial spawner, and from the study of the scales there seems evidence for the belief that some fish may spawn less frequently than even every other year.

The salmon lives and grows in the sea, but has to enter fresh water to spawn. It frequently enters fresh water long before the spawning season. Fish doing so in spring are fish which have spent what is called the long period in the sea; they have missed a spawning season. Summer fish may also be fish of long absence from fresh water, but very many of them may be regarded as annual spawners, or at any rate as fish which are reproducing their species on two consecutive years. The understanding of this feature—this divided migration—in the life of the salmon is in great measure the key to "salmon problems." Both this spawning habit and its results,

* Atkins, "The Biennial Spawning of the Salmon." Trans. Amer. Fisheries Soc., 1885.

and the growth of the fish with its many surprises, must be viewed in strict relation to this divided or dual habit of marine sojourn. It would be out of place to compare at a given time a fish which had returned to fresh water after a short sojourn in the sea with a fish which had been feeding and growing for twelve or eighteen months. When a classification according to short and long periods is adopted, there is still much that is difficult to understand and great variation in results, but the life of the salmon seems to be cleared of that obscurity which has for so long defied the penetration of many and varied search-lights. Moreover, it is also necessary to give attention to the localities from which fish come, since what is considered a large fish in one place may be a comparatively small one in another, so that fish of similar weight are not necessarily of similar class or age. Further, it seems necessary to have regard to the particular years in which records are acquired, and to compare different periods, when treating the subject broadly. Classification by weight, length, or other particular is only useful in questions of migration when fish of one locality are being dealt with. I was never so much impressed with the necessity for comparing only similar periods till a combined analysis of Scottish and Irish results was attempted. It has been my intention in writing these chapters to avoid tables of statistics, because of their rather formidable and uninteresting appearance, but in the present instance I must ask the indulgence of the reader in giving the data—in as condensed a form as possible —from which deductions are made.

In dealing with the question of the short and the long periods of sojourn in the sea, only one class of particulars are reliable, the returns of fish marked when kelts after spawning and recaptured as clean fish in fresh waters or the mouths of rivers after the termination of their sojourn in the sea. It happens that in a combination of the Scottish and Irish returns there are 117 recaptures of this class which can be dealt with. In the following tables these are separated into groups according to the years of marking and recapture; the records of fish marked in certain rivers are placed together, and all fish of short period are separated from fish of long period. The details extracted are the numbers of the marks, the intervals of time given in months, the increase in weight, and the weights of the kelt marked. Scottish and Irish results are given in parallel double columns.

SCOTTISH RETURNS.

SHORT PERIOD. Years 1896-1902.

No. of Mk.	Mths. of Intvl.	Kelt Wght.	Incr. of Wght.	River.
		lb.	lb.	
769	5	6	10	Helmsdale
924	6	5	5	Helmsdale
1027	6	8	6	Brora
1058	5	9	4	Brora
1092	6	13	11	Brora
2636	4	6	2	Brora
2649	5	8	4¾	Brora
6000	6	7	5	Brora
7303	4	5½	3½	Brora
1167	2	6	3	Spey
Total . . . 10				

LONG PERIOD. Years 1896-1902.

No. of Mk	Mths. of Intvl.	Kelt. Wght.	Incr. of Wght.	River.
		lb.	lb.	
863	13	10	8¾	Helmsdale
941	15	4½	4	Helmsdale
3472	16	5	9	Helmsdale
717	14	6	8	Brora
2647	11	6	8	Brora
6040	14	6	10	Brora
2459	13	12	13	Spey
2472	17	7	12	Spey
5852	13	8	11	Tay
Total . . . 9				

IRISH RETURNS.

SHORT PERIOD. Years 1898-1902.

No. of Mk.	Mths. of Intvl.	Kelt. Wght.	Incr. of Wght.	River.
		lb.	lb.	
164	6	9	4	Owenea
169	6	6	6	Owenea
537	8	11	—	Owenea
24	7	6	5	Foyle
1250	6	5	6	Foyle
636	7	4	3½	Bann
1223	5	4	3¼	Bann
6988	5	4	2	Moy
4926	5	6	2	Erne
4788	3	5	1½	Bush
4234	4	6	—	Laune
1252	6	6	2¾	Laune
1266	7	6	5½	Laune
4039	6	5	4½	Blackwater
1407	5	4	4½	Caragh
1422	4	6	9	Caragh
4602	5	2½	2½	Corrib
5302	4	4¾	4	Barrishoole
Total . . . 18				

LONG PERIOD. Years 1898-1902.

No. of Mk.	Mths. of Intvl.	Kelt. Wght.	Incr. of Wght.	River.
		lb.	lb.	
6998	16	4	17	Moy
6999	15	4	12	Moy
Total . . . 2				

SCOTTISH RETURNS.										IRISH RETURNS.	
SHORT PERIOD.					LONG PERIOD.					SHORT PERIOD.	LONG PERIOD.
Years 1902-1903.					Years 1902-1903.					Years 1902-1903.	Years 1902-1903.
No of Mk.	Mths. of Int.	Kelt. Wght.	Incr. of Wght.	River.	No. of Mk.	Mths. of Int.	Kelt. Wght.	Incr. of Wght.	River.	None.	None.
		lb.	lb.				lb.	lb.			
3077	5½	6	4½	Tay	8044	14	6¼	12¾	Tay		
7707	6	6	6¼	Tay	8108	18	8	12	Tay		
8171	7	11	6	Tay	8161	18	14	19	Tay		
9062	9	13	8	Tay	8241	15	13	11	Tay		
9402	5	4	6	Tay	8306	14	6	12	Tay		
8343	6	6	8¾	Tay	8311	15	13	4	Tay		
					8329	11	10	9	Tay		
9639	3	4	4½	Deveron							
9622	5	10	9	Deveron							
Total . . . 8					Total . . . 7						

SCOTTISH RETURNS.

SHORT PERIOD.

Years 1903-1905-6.

None.

LONG PERIOD.

Years 1903-1905-6.

No. of Mk.	Mths. of Intvl.	Kelt. Wght.	Incr. of Wght.	River.
		lb.	lb.	
8347	17	12	13¼	Tay
9410	14	6	13	Tay
4B	17	11	9 est.	Tay
16B	20	16	18	Tay
732	24	12	8	Helmsdale
807	16	7	9	Helmsdale
1158	16	8	10	Helmsdale
1180	16	5	9	Helmsdale
749	18	7	12	Helmsdale
1186	17	4½	7	Helmsdale
1167	17	3	8	Helmsdale
1203	13	5	7½	Brora
1204	13	5	9	Brora
1223	13	5	5	Brora
1232	13	6	8	Brora
1266	13	4½	10½	Brora
Total . . .				16

IRISH RETURNS.

SHORT PERIOD.

Years 1903-1905.

No. of Mk.	Mths. of Intvl.	Kelt. Wght.	Incr. of Wght.	River.
		lb.	lb.	
2435	7	6	3	Bann
2439	7	5	3½	Bann
2450	6	5	5	Bann
2760	7	5½	5	Bann
2123	5	4	3	Erne
3007	6	4	1¾	Erne
3487	6	8	1½	Erne
1976	8	4½	5½	Foyle
2522	7	9	5½	Owenea
2820	7	5	5	Owenea
4296	7	5	6	Owenea
4300	7	3½	3½	Owenea
5052	6	7½	4½	Owenea
5058	7	9	3½	Owenea
2142	4	6	8	Caragh
1754	4	4	5½	Laune
Total . . .				16

LONG PERIOD.

Years 1903-1905.

No. of Mk.	Mths. of Intvl.	Kelt. Wght.	Incr. of Wght	River.
		lb.	lb.	
1258	16	9½	6½	Killarney
804	13	4	7	Killarney
808	13	3½	9½	Flesk
5138	17	5	13	Bush
6741	17	4	9	Erne
42	16	5	9	Erne
44	17	5	7	Erne
1248	17	5	13	Foyle
3094	14	11	16	Slaney
1650	11	6½	10½	Suir
2149	14	4½	13½	Caragh
3057	11	5	7 est.	Laune
Total . . .				12

SCOTTISH RETURNS									
SHORT PERIOD.					LONG PERIOD.				
Years 1906–1907.					Years 1906–1907.				
No. of Mk.	Mths. of Intvl.	Kelt. Wght.	Inc. of Wght.	River.	No. of Mk.	Mths. of Intvl.	Kelt. Wght.	Inc. of Wght.	River.
		lb.	lb.				lb.	lb.	
1194	4	9	7½	Naver	1155	17	5¾	7¼	Helmsdale
2041	4	8	1	Naver	821	18	9	7	Helmsdale
2013	4	7	7	Naver	1395	15	7	15	Helmsdale
					1396	18	6	7½	Helmsdale
					1121	17	7½	9½	Helmsdale
					1149	15	13½	6½	Helmsdale
					1626	18	4	7	Helmsdale
					1146	18	7	7½	Helmsdale
					9567	16	13	14	Tay
					8279	17	9	16	Tay
7780	6	12½	11¾	Tay	9569	17	11	19	Tay
9194	4	5½	6	Tay	9341	15	3	8	Tay
1466	6	12	8½	Tay	9342	15	4	8	Tay
Total number . . 6					Total number . . 13				
Combined totals . 24					Combined totals . 45				

IRISH RETURNS.	
SHORT PERIOD.	LONG PERIOD.
Years 1906–1907.	Years 1906–1907.
Combined totals . 34	Combined totals . 14

In sixty-nine Scottish and forty-eight Irish returns of kelts recaptured as clean fish in fresh water we have therefore in Scotland practically twice as many long period fish as short period fish, while in Ireland we have fully twice as many short period fish as long period fish—two somewhat opposite conditions at first sight. The Irish kelt weights are on an average considerably less than the weights of the Scottish fish, this being largely owing to the heavy Tay kelts in Scotland, but any idea as to there being a difference in habit amongst light and presumably younger fish seems dissipated by the middle group of Scottish returns, where in 1902 and 1903 we have out of a total of fourteen recaptures seven short and seven long period fish. This only exemplifies what has already been said as to weight of fish in particular localities being no guide for comparison. The interesting point to notice, however, is that while in the first group of Scottish and Irish fish there is an insignificant appearance of long period fish in Ireland, there is in the 1903–1905 group a marked increase in the proportion of these fish, and that similarly the proportion of long period fish in Scotland greatly increases at the same time, there being in fact an entire absence of short period fish in this group. In other words, it would appear that in the years 1903, 1904, and 1905 there has been some influence at work which has apparently induced a larger proportion of fish, both in Scotland and Ireland, to remain in the sea till the end of the season's netting. The short absence is still the most common in Ireland, but the proportion of long

period fish is considerably greater than appeared in the earlier years of the Irish marking. In Scotland, comparing the first and third groups (the second group is practically a one river group, and therefore in this connection of less value), we have first an almost even balance of long and short absence, and then the long absence becomes completely ascendent.

It is of little avail to speculate as to the nature of the influence which has apparently been at work. The salmon has latterly remained at home in the sea, be it because he required longer time to feed up through a scarcity of food, or a greater delight in an abundance of food, or lack of inducement to ascend the rivers, we cannot say, but it is right to notice that in the Helmsdale and Brora, from which the majority of returns in the 1903–1905 group come, the chief fishing takes place in spring, the season when long period fish are for the most part captured. The condition displayed by these records can scarcely be the result of accident. The Scottish records cover a period of eleven years, and the Irish records a period of seven years. With regard to the average intervals of time in the two countries, there is little difference. The short period in Scotland averages almost exactly five months, in Ireland not quite six months. The long period in Scotland is fully fifteen and three-quarter months, in Ireland a little under fifteen months.

When the average weights of kelts are regarded, it is apparent that in Scotland or Ireland no difference is noticeable either in the fish which

have adopted the short period or those which have adopted the long period. The average kelt in Scotland is, however, about 2 lb. heavier than the average kelt of the Irish records, the weights being respectively $7\frac{3}{4}$ lb. and practically $5\frac{1}{2}$ lb. If individual districts in Scotland were compared, it could be shown that the same variation exists between kelts of say the Helmsdale and the Tay, the former being, so far as these records show, $6\frac{3}{4}$ lb. and the latter 9 lb.; but the purpose of the above tables being to elucidate the divided migration, the fact that such differences exist in the one country only serves to bring out more forcibly the fact that this divided migration is independent of the weight of the fish. The subject of the increase of weight in kelt to clean condition will have to be dealt with more fully later, but to complete the statement as to the tables the increase may be briefly given here. The Scottish returns show an average increase in the short period of 6 lb., in the long period of 10 lb.; the Irish records, in the short period $4\frac{1}{4}$ lb., in the long period $10\frac{5}{7}$ lb.

In the previous chapters the life of the smolt and grilse has been traced, and evidence has been educed to show that the smolts which descend in May at the age of fully two years make their first reappearance in fresh water at two separate seasons and in two stages of life, viz., in a year as grilse, and in a year and a half, having spent two winters in the sea, as small spring fish. This in the life of the salmon is the commencement of the divided migration. The tables just given prove the continuance

of the habit, and show that fish of all weights adopt at one time or other this varied period of marine sojourn. It will be instructive now, however, to refer to a few concrete cases by way of illustration, showing by the actual data collected respecting individual fish the nature of the evidence, for tables such as these often conceal truth as language conceals thought. And first we may conveniently take the case of grilse, and see what becomes of them after spawning and descending to the sea.

Amongst the Tay records we have two marked grilse kelts which may be selected. They were numbered 9402 and 8044. The former adopted the short period in the sea, and the latter the long period. No. 9402 was recaptured after five and a half months (the average period) as a summer fish weighing 10½ lb. The record of marking and recapture is as follows :—

9402	4 lb.	25″	Kelt grilse	Fem.	Feb. 5, 1903	Tay	Upper water
	10½ „	30″	Clean salmon	Fem.	July 31, 1903	Tay	Estuary nets

The other grilse kelt (although we may observe that the length is remarkable for a grilse), after spending fourteen months in the sea, or an autumn and winter longer than the first-mentioned fish, returned as a clean spring fish of the large class, a class, be it observed, which is more pronounced and definitely constant in the Tay than in any other river in Scotland. This record is as follows : —

8044	6¼ lb.	29″	Kelt grilse	Fem.	Jan. 9, 1902	Tay	Stanley
	19 „	36¾″	Clean salmon	—	Mar. 14, 1903	Tay	Benchill

Other records exactly analogous to these have been obtained from the Tay marking.

The next stage which has to be referred to is that of the small spring fish, the fish of the same age as the grilse kelt, but which has not entered fresh water as a grilse. This class of fish is well marked in the Helmsdale and Brora, from which a number of records are seen. It is also well marked in the Dee. As a kelt it is usually 5 or 6 lb. in weight. A Brora fish marked 7303 is an example of short period migration, and another Brora fish, 6040, may be taken as showing the long period. The former returns in three and a half months as a clean fish of 9 lb., the latter returns in fourteen months as a clean fish of 16 lb.

The records are:—

Short Period.

7303	5½ lb.	31½″	Kelt	Fem.	Apr. 16, 1901	Loch Brora
	9 „	(?)	Clean	Fem.	Aug. 2, 1901	River Brora

Long Period.

6040	6 lb.	27″	Kelt	Fem.	Mar. 15, 1901	Loch Brora
	16 „	33″	Clean	Fem.	May 15, 1902	Loch Brora

This completes in a manner the grilse and its prototype the small spring fish, but it may be asked whether grilse kelts which are subsequently found as summer salmon continue to be annual spawners, or whether one fish may be at one time an annual breeder and at another a fish of long absence in the sea—a long period feeder. Two other Brora records which show remarkably small increase of weight in a two years' interval seem to indicate that in both cases the greater part of the time between

marking and recapture must have been spent in fresh water, and that annual spawning had prevented any very substantial increase.

In both records the fish were recaptured as well as marked when in the kelt condition.

The records are :—

7225	5½ lb.	28″	Kelt	Fem.	Mar. 15, 1902	Loch Brora
	8 „	34″	Kelt	Fem.	Mar. 28, 1904	Loch Brora
7298	4 „	25″	Kelt	Fem.	Apr. 20, 1901	Loch Brora, a grilse
	6¼ „	30½″	Kelt	Fem.	Mar. 18, 1903	Loch Brora

Only a study of the fish's scales could yield definite evidence, but, arguing by analogy, the presumption is that both fish had before the date of their recapture spawned three times. The weights offer strong contrast to the case of the clean spring fish of the Tay which has only reproduced its species once, but has, although apparently a year younger than the 4 lb. Brora fish, already reached the weight of 19 lb. This is an example of extreme difference between fish continuing in the short period habit and a fish, from a river remarkable for its large fish, after spending the long period in the sea. No such difference could be found if the more natural comparison be made of short period with short period fish and long period with long period fish.

In continuing the progressive examination we have now to deal with the kelts of the summer fish, which, after having spawned as grilse, appear on their second annual ascent as fish of 10–14 or 15 lb. in a river such as the Tay. In spawning a female salmon loses approximately one-fifth of its weight.

We therefore select Tay kelts weighing 8–12 lb. In doing so we are still, I consider, fairly free from the possibility of including fish of another class, so long as we restrict ourselves to returns from one river; and in making such restriction preference must be given to the Tay, not only because the classes of fish are there well defined, but also because the numbers of returns are considerable. We are still, of course, dealing exclusively with kelt to clean fish increases. A fish showing the short period in this class is No. 8171. It was seven months between marking and recapture, and from a kelt of 11 lb. had become a summer fish of 17 lb. The record is :—

8171	11 lb.	38″	Kelt	Fem.	Jan. 18, 1902	Tay	Battleby
	17 „	—	Clean	Fem.	Aug. 20, 1902	Tay	Estuary nets

As an example of very rapid growth in the Tay we have No. 7780, a kelt of 12½ lb., which doubled its weight in six months. With regard to the fish showing the long period, it may be said that, if they are of the same class as the fish just referred to, and have spawned in two successive years, their future record shows that a salmon may at one time of its life adopt the short absence in the sea and afterwards stay for the long period. Five fish could be so cited which from being kelts of 8–12 lb. have become fish of from 19 to 25 lb. in from a year to a year and a half. One record may suffice :—

8108	8 lb.	38″	Kelt	Fem.	Feb. 6, 1902	Tay	Battleby
	20·3 „	38½″	Clean	Fem.	Aug. 18, 1903	Tay	Estuary nets

In all these stages we see this same divided

migration, and without any doubt the same habit subsists throughout the life of the salmon. When, however, we reach the stage in advance of that just presented, it becomes impossible without the assistance of scale examination in each case to identify with certainty the particular class of fish marked. The weights of the summer fish last referred to are from 19 to 25 lb., but the weights of the large Tay spring fish are, we have already seen, very similar. Therefore the arbitrary selection of kelts is almost certain to include both classes of fish. To carry out the same system of selection is, moreover, to deal with really heavy fish, which, as every one who has long looked forward to the landing of a thirty-pounder knows, are not to be met with every day. Fish much heavier than 30 lb. are of course taken from time to time, but we are approaching the normal limits of the salmon's growth in Scotland or Ireland, and heavy kelts which are marked do not for the most part reappear. I can, however, instance two Tay fish and one Deveron fish which take us beyond 30 lb. The Tay fish show the long period in the sea, and the Deveron fish shows the short period, so that we may fairly assume that the twofold habit obtains till a late period in the salmon's life. The records are :—

8161	14 lb.	36″	Kelt	Fem.	Jan. 17, 1902	Tay
	33 „	43″	Clean	Fem.	July 27, 1903	Tay
16 B	16 lb.	36½″	Kelt	Fem.	Feb. 11, 1904	Tay
	34 „	43″	Clean	Fem.	July 17, 1905	Tay
6541	19 lb.	38″	Kelt	Fem.	Mar. 4, 1902	Deveron
	34 „	41½″	Unspawned	Fem.	Oct. 22, 1902	Deveron

The Deveron kelt was reported as very well mended when marked at Muiresk. Its condition when recaptured at Ardmiddle, which is just above Muiresk, and in the upper waters, clearly showed that the fish would soon have spawned, *i.e.*, within about eight months of the date of marking.

The data dealing with the kelt to clean fish condition form only one section of the salmon marking returns, but introduce the particular migratory movements, which are perhaps of greatest practical importance to our salmon fisheries. The dual habit of migration shows us that a large number of salmon remain in the sea even when their fellows are reproducing their species in the rivers. So far as the returns show, the proportion of what may be termed the feeding fish is subject to variation in different localities and in different seasons, and is much greater in Scotland than in Ireland. Moreover, we do not at any time either in our rivers or in our sea salmon nets recover a large proportion of the fish marked. The marking experiments conducted in connection with the North Sea Fishery Investigations, in which large numbers of flat-fish have been marked, have yielded a much higher percentage of returns than have ever been obtained in marking of salmon. This is rather striking when it is recollected that the salmon congregate in the confined waters of rivers, and are caught in such localities in large numbers. Some do no doubt lose their marks, but we have no evidence to show that this happens often. Marked fish may be recaptured and not reported, but with the interest now taken in the

matter and the wide circulation of notices respecting marking, and the offer of rewards, I do not think it likely that many records are lost in this way. Further, the examination of salmon scales seems to indicate that some fish may pass over two or it may be three consecutive spawning seasons.

So far as the Scottish returns go, it is clear that the majority of fish spend much more time in the sea than in fresh water; and the Irish returns, although fish showing the short period are in the majority, and their average absence about six months, nevertheless yield a proportion of long period fish, so that here also most time is spent in the sea. It is quite conceivable, therefore, that with our netting in the mouths of rivers and close in shore only on the coast at a definite season we fail to trace a proportion of our marked fish. Yet in contradistinction from this it has happened that from some 36 kelts caught by rod and marked in the Upper Tay alone, as many as 22 per cent. have been recaptured.

The stock of salmon is, however, entirely dependent upon the fish which enter the rivers, since salmon do not spawn in the sea and the ova are incapable of development if shed in the sea water. Hence the importance of moderation in our netting of rivers and estuaries of rivers. It is, of course, clear that amongst netted rivers those of large volume with wide estuaries are more capable of maintaining a suitable stock of breeding fish than small rivers with narrow mouths, since in the former a proportion of each run of fish is more likely to pass the nets, provided the gauntlet of netting is not too long to

render the weekly close time inoperative. But it should be borne in mind that a proportion of each run of fish is essential to the proper maintenance of a suitable breeding stock in any river. In operating upon the stock of salmon in the sea, however, we are drawing upon a larger supply; we are not catching definite runs of fish which are going to breed in the near future, but are catching fish which are moving off and on, or along, the coast. Some of them may be on their way to a river, many of them are not, but are fish living in the sea. The influence of such fishing upon the breeding stock is small as compared with the influence of the river net, and the fish so caught and marketed are in the finest condition possible. From statistics showing the results of different methods of regulating salmon fishing, as practised in the past not only in Scotland but also in Norway, there is, moreover, ample proof that the sea rather than the river is the place for the net.

I am aware that in England this view is regarded by many as the rankest heresy. The English Act of 1861 practically abolished coast netting in that country, but permitted the pernicious policy of fishing rivers not only by nets but by various forms of fixed engine. A complete reversal of this policy has been found efficacious in restoring depleted salmon fisheries elsewhere (when other contributing agencies have not also to be dealt with) and is, by all arguments in the case, the sound course to follow. To capture 15,000 to 18,000 salmon on the coast of a single Scottish district, where the breeding stock is maintained by a well-stocked river now all but

cleared of nets and famous for salmon angling, should be sufficient to show that such a policy results in the creation of a valuable sea fishery. In the river in question, moreover, between 5000 and 6000 fish can be taken by sweep-net at the river mouth without interfering with the full supply of fish for angling and breeding.

A question most commonly asked when salmon marking is mentioned is, Do salmon return to their own rivers? The widespread belief that they do is in ninety-nine cases out of a hundred based on mere hearsay evidence, but it is none the less satisfactory to know that the salmon marking experiments verify the belief. As may almost already have been gathered from the cases cited, the great majority of fish do so return. From time to time, however, fish turn up in other rivers as exceptions to the general rule. In Scotland a Helmsdale fish was caught in the Halladale, 90 miles distant by the coast line. Similarly a Spey fish was caught in the Dee, 90 miles distant. The first fish went north, the other south. Other transferences are less distant. Helmsdale to Brora, a distance of only 12 miles—Deveron to Spey, and Spey to Deveron. In Ireland a remarkable case is reported by Mr. Holt in the first report of the Irish marking. The fish was marked D 95, on January 1, 1901, after having been caught, conveyed to Kilrea, on the Bann, and impounded there for hatchery purposes, stripped, and then allowed to rest for three days. The recapture was made 200 miles distant in the tidal waters of the Bundrowes, on April 9, 1901. The

fish appeared still to be a slat or kelt, and showed no increase in weight (7 lb.). In view of the rather peculiar nature of the estuary in which the fish was found, Mr. Holt suggests that possibly the fish had no intention of leaving the sea for fresh water, but having found its way into the basin of the river mouth during spring tides, had found its retreat cut off. In view of this explanation, the record is similar to a privately marked Scottish fish which travelled from the Grimersta on the west side of the island of Lewis to Castletown, which is on the coast east of Thurso, 145 miles distant. The fish was marked by Mr. Byres-Leek, "J. B.-L. 10," in March 1902, when a kelt. Five months afterwards, *i.e.*, in August, when recaptured at Castletown, it was still a kelt. I have the specimen preserved, as an August kelt is in my experience unique, and this fish showed not only the lank condition, but the abrasions below the jaws and on the ventral surface of the body, so commonly associated with the recently spent fish. Like D 95, the fish was a male, and it seems probable that the kelt condition may have subsisted through the fish having been originally perhaps only half spent, and having afterwards entered some river on the north coast of Scotland, such as the Naver, Polla, Halladale, or Thurso, in its journey along the Pentland Firth, and then only at a later date completed the shedding of its milt. There is, I think, a fair amount of evidence to suggest that under the most ordinary conditions the male fish which we see paired with females at spawning time do not complete the shedding of their milt, or do not always do

so (unless the female is a large one) in fertilising the ova of one female, but, like blackcock among birds, are somewhat catholic in their temporary attachments. That a partially spent or completely spent kelt may on occasion descend to the sea and ascend another river has been evidenced on more than one occasion. The Spey to Dee fish already referred to is an instance; another Spey fish—a male of 30½ lb.—after being handled at the Fochabers hatchery, turned up again in the Deveron in three months as a kelt, believed to be not yet completely spent, weighing 28 lb.

It is rather striking that the fish which show those pecular reascents are male fish which have been a good deal handled and stripped at hatcheries, and in all probability the descent and reascent would not have taken place in this apparently unnatural manner had the fish paired and spawned and possibly again paired without interference. A marked example of this peculiarity is seen in a fish which, like D 95, was conveyed to a pond and retained for hatchery purposes at Sandside. It was caught in the sea during the fishing season of 1905, and held up in fresh water till spawning time. It was stripped (a male), marked on January 15, 1906, and turned loose in a small stream not far from the hatchery. As is well known, no kelt seems to care to remain in a small stream for any length of time, and we are therefore not surprised to learn that the fish went to the sea without delay; but this fish was captured up the river Thurso, fourteen miles up, in sixteen days. A frightened creature commonly and

by instinct turns quickly in the direction in which it has last come—where it was not frightened; a frightened ascending fish goes down, and a frightened descending kelt goes up. In a small stream, however, escape by ascent is scarcely possible, and a forced departure from the course prompted as natural must only heighten and complete the alarm and demoralisation of the creature. In the small streams of the West Highlands the kelts which quickly and naturally descend recover condition in the brackish water at the mouths of the streams. If driven from such a haven of refuge by fear or any other compelling cause, recovery may be sought in fresh water elsewhere.

It does not always follow that fish caught in the sea at a considerable distance from their breeding river will not return thither. Yet in the search for food and the following of herring shoals it is not surprising that some fish may lose their bearings. In the drift-net fishing for salmon which is conducted off the coast of Ireland, nets appear to be shot at times as far as eighteen miles from shore, and if fish wander, say double or treble this distance, as salmon marking shows us they sometimes do, they may naturally resort to other rivers than were formerly visited; or, as has been suggested, some fish may systematically wander to rivers commonly frequented by larger fish, rather than return, after growth in the sea, to the rivers of their youth. In the salmon marking results we do not, however, find much evidence of this. The numbers caught in bag-nets on the open coast at a considerable distance from the

rivers in which they were marked represent only $8\frac{3}{4}$ per cent. It is remarkable in this connection that although a great number of fish have been marked in the Tay (of which eighty-six have been recaptured), no Tay fish has been recaptured either in another river or in coast nets. The great volume of water—reputed the largest in the British Islands—may make itself felt for a very considerable distance seawards, and so give a guide to Tay fish in the sea. Certainly to any one who has sailed much off the coasts of Fife and Forfar the influence of the Tay when swollen and discoloured by flood is very clearly seen, stretching as it often does in a great belt of discoloured brackish water in a southerly and easterly direction beyond the limits of St. Andrews Bay out into the open sea.

It is of some interest to notice the direction in which the Scottish fish caught in sea nets at some distance from the rivers in which they were marked chiefly travel. The Grimersta-Castletown fish, crossing the Minch and travelling the whole length of the Pentland Firth in an easterly direction, has already been referred to. Six Helmsdale fish travelled south and have been caught at Portmahomack, on the coast south of Tarbat Ness. Three Helmsdale fish went into the Brora, and one north to Dunbeath; another north to the river Halladale. A Brora fish also went north 100 miles, and was caught in a bag-net near the mouth of the Halladale. The contrast in the increase of weight in these two otherwise similar records is very remarkable. The Brora fish increased $5\frac{1}{2}$ lb. in eighty-eight days, while the

Helmsdale fish took 506 days to increase 10 lb., nearly double the increase, but in almost six times as many days. Probably, however, the second fish had spawned in the interval. The majority of the coast recaptures show movement in the opposite direction from those two similar records. Five fish have followed a very similar course in going from the Deveron right round out of the Moray Firth in an easterly and southerly direction to the neighbourhood of Aberdeen. The intervals between marking and recapture are 88, 109, 122, 126, and 187 days, and the increases in weight respectively $4\frac{1}{2}$, $3\frac{3}{4}$, $2\frac{3}{4}$, 9, and $4\frac{1}{2}$ lb. In the last-mentioned fish the estimate of weight could alone be obtained, as the mark was not noticed till the fish was displayed in a fish shop in Newquay, Cornwall. The increase of 9 lb. in the kelt weight in four months is considerable, more especially since the fish was a 16 lb. male kelt when marked.

Twenty coast recaptures are charted in the twenty-fourth Annual Report of the Fishery Board for Scotland, and of these, fifteen show a southerly and easterly and only five a movement in the opposite direction. It is unwise to lay too much stress upon a result which after all is deduced from a limited number of recaptures, but the trend of the currents corresponds with the direction in which the majority have travelled.

Before completing the records which are obtained from kelt marking, we have to deal with the fish which are afterwards recaptured as kelts. These fall into two classes: first the fish which have been

to sea in the interval and have again ascended and spawned, and second the kelts which have never left the fresh water.

In comparing the first class we have the possibility of noticing, better than at any other time in the fish's history, the actual net increase of weight, since at both times of observation the fish is reduced to the same condition. Clean fish vary in weight according to the time they have been in fresh water, and the state of their nutrition or genitalia. In the sea they are still possibly increasing in weight, and their record is in this respect incomplete ; in fresh water they are losing weight. Unfortunately it happens that recaptures of this kind are scarce, and at the best rather conflicting. Of course, the catching of kelts is not pursued in any sense as is the catching of salmon. Nothing is to be made out of a kelt when he is caught. I might first mention two Brora fish which have evidently spawned annually for three consecutive years :—

7225	5½ lb.	28″	Kelt	Fem.	Mar. 15, 1902	Loch Brora
	8 „	34″	Kelt	Fem.	Mar. 28, 1904	Loch Brora
7298	4 lb.	25″	Kelt	Fem.	Apr. 20, 1901	Loch Brora, a grilse
	6¼ „	30½″	Kelt	Fem.	Mar. 18, 1903	Loch Brora, a salmon

In the former the increase is $2\frac{1}{2}$, in the latter $2\frac{1}{4}$ lb. ; the interval is practically two years in each case. Two examples of Deveron fish show better increment :—

6504	12 lb.	36″	Kelt	Fem.	Feb. 22, 1901	Deveron
	16 „	38½″	Kelt	Fem.	Mar. 14, 1902	Deveron
6560	16 lb.	37″	Kelt	Fem.	Feb. 13, 1903	Deveron, Muiresk
	22½ „	42″	Kelt	Fem.	March 1904	Deveron, found dead 1½ mile above mouth

In the former the increase is 4, in the latter $6\frac{1}{2}$ lb., and in each case the interval is thirteen months.

Another record is from the Tay, but as the fish was found dead, and the weight merely estimated, the result—an increase of 3 lb. in exactly two years—is not so valuable as otherwise would have been the case. So far as it goes, however, the record corresponds with the slight increase seen in the Brora fish mentioned. The last record which I can mention from Scotland is rather remarkable, since in a year all but ten days the fish is reported as having gained only $\frac{1}{2}$ lb. in weight and nothing in length :—

7355	13 lb.	38″	Kelt	Fem.	Mar. 15, 1902	Loch Brora
	$13\frac{1}{2}$,,	38″	Kelt	Fem.	Mar. 5, 1903	Loch Brora

All these fish are clearly annual spawners, and since long period migrants are, in Scotland, in the majority and remain in the sea, their recapture in the kelt condition is less likely to occur. The small increase even in annual spawners is sufficiently remarkable. There are no available records from Ireland or England.

With regard to the manner in which kelts descend to the sea, and more especially the time they occupy in such descent, it may be useful first to recall the experiences of a former superintendent of Tweed bailiffs, as stated at p. 66 of the Tweed Reports, 1866. Mitchell relates that in 1854 he marked in the Whitadder 206 bull-trout kelts and took them down to the tideway at or near Berwick Bridge. "Few, if any, of these went down to the sea, as for many weeks after they were

occasionally caught in the Whitadder, and a number of them were got up the river as high as Norham." In the Tweed Report for 1875 it is stated: "The Committee met at Melrose to ascertain if it is practicable, when a great number of salmon kelts were collected in the cauld pool there on account of dry weather, to catch them with a net and put them over the cauld. A few shots were rowed and eight fish caught; but the experiment was not successful, as the fish put below the cauld did not go down the river, but remained in shallow water within reach of poachers." In the Norwegian Fisheries Report for 1895–96 Herr Landmark tells of a similar experience on the Aensira river, where two waterfalls exist. At both waterfalls fish-passes have been erected, and the lower pass was used as a convenient place to capture fish for hatchery purposes. The pass was therefore blocked by means of a grating inserted in its upper end. Fish, having been stripped, were placed above the fall, yet many of these fish were afterwards found in the fish-pass, having apparently descended by the fall and re-ascended in the pass. One such fish was recognised as doing so five times, although on each occasion after recapture it was put into the river farther and farther up stream. The seaward migration of kelts in Scotland is of course not influenced by the complete freezing up of parts of rivers, as is the case in Norway, where it is often, I understand, physically impossible for kelts to descend till released by the thawing of the ice.

With us, however, the descent in large rivers appears to be much slower than in small rivers. Kelts

can scarcely be caught in the small streams of the West Highlands, so quickly do they get away to the sea. In a large river, on the other hand, or in any river which broadens out into a large lake or into deep pools, the descent of female kelts at least is very slow indeed. A large number of recaptures of such descending kelts have been made in the Spey and Tay, and it would appear that so long a time as three months may be occupied in descending forty miles of river. Grilse kelts, as already stated, descend to the sea with some promptitude, but as salmon grow older their descent after spawning becomes slower, although this appears to be less true of males than of females. Large female kelts linger longest. The discovery of this habit makes a considerable difference in our interpretation of the increments put on in the sea. One fish may relatively be so much longer in reaching the sea than another even if both be, say, short period fish. In judging of increase from kelt weight this uncertainty of knowing when the sea was entered is always present. We may have in long period fish considerable uniformity of increase, since an actual delay at starting may in the longer period be made up. For instance, in Helmsdale long period fish of 480, 498, 504, and 506 days we find increments respectively of 9, 9, 9, and 10 lb. Yet clearly there may also be great variation. In short period fish we have similar results. Two Brora fish were taken, the one in 162 and the other in 163 days: the one had added 4 lb., and the other 11 lb. Many Tay fish recaptured are described as "bull-trout." In the Tay a bull-trout is in reality a

salmon (*S. salar*) which is more or less spotted about the operculum and shoulder, has maggots in its gills, and which when cut up is found to be pale in the flesh. It is not the bull-trout of the Tweed and Coguet, otherwise called the round-tail. These Tay bull-trout are not at all uncommon as fish of over 40 lb., and the natural presumption seems to be that they have their peculiar appearance through having adopted a more estuarial habit and different feeding than is common with normal *S. salar*. From Tay salmon which have been described as bull-trout on recapture eight examples may be selected. Four of them show the short period, and four the long period; two were described as unspawned grilse on marking. The particulars are of some interest, and are as follow: *—

Short Period.

A 6	lb.	Kelt	after	196	days	increased	6½ lb.
„ 4	„	„	„	176	„	„	6½ „
„ 7¾	„	Unspawned Grilse	„	265	„	„	4½ „
„ 5½	„	„ „	„	283	„	„	2 „

Long Period.

A 14	lb.	Kelt	after	556	days	increased	19 lb.
„ 13	„	„	„	447	„	„	4 „
6	„	„	„	556	„	„	8¾ „
„ 12	„	„	„	525	„	„	13¼ „

Here the uniformity is seen to be in the short period fish and a very marked extreme in the long period fish, but we must recollect that possibly the

* "Arretor," Proc. Roy. Soc., Edin., XXV. Part I. p. 27.

second fish may have spawned in the interval of 447 days, which is, of course, the interval between marking and recapture, not necessarily an indication of the length of time spent in the sea. Yet even without the second fish we have the first and third each with a precisely similar interval, yet one with twice the increase of the other. That these bull-trout do go to the sea may be inferred from the fact that sea lice are commonly found upon them, as well as gill maggots, when they come into the river. They are by no means confined to the Tay, but occur sparingly in other parts of the country. Personally I have noticed them also in the Ness, Helmsdale, and Dee. Günther has described them from the Beauly, and Parnell from the Forth.

The last series of observations on the habits of the salmon to which reference may here be made has been obtained by the marking and recapture of clean run fish. Now the habits of clean run salmon, otherwise spring fish, have given rise to much discussion, very largely because some rivers contain spring fish, while others, for no apparent reason, do not. It is proposed in another chapter to deal with early and late rivers, and in this rather to deal with the habits of the spring fish after it has entered its "spring river." At the outset, however, it seems necessary to recollect that the habits of spring fish seem to be subject to considerable variation under the conditions which obtain in different countries. In Norway, Iceland, Lapland, and possibly elsewhere clean summer fish ascend freely in snow water. In Scotland "snaw bree" prevents fish running; by

waiting they can, I presume, secure passage in a much more agreeable fluid. But in the normal early river the early fish have already advanced well up stream before winter descends upon the hills. If they encounter floods of cold, snowy water they may drop back to the warmer estuary if they have not ascended to upper waters, but in Scotland we have not evidence that clean fish are in any sense temporary visitors to fresh water or habitually drop back into the sea. In Ireland the evidence secured by marking clean fish seems to point to a rather different conclusion, as described by Mr. Holt.* Out of thirteen recaptured Irish clean fish there is evidence that three were in the sea in the interval. These fish were numbered 433 D, 858 D, and 861 D, and the last two were presumably feeding in the sea, since each on recapture showed an increase in weight, 858 of $2\frac{1}{2}$ lb. with an interval of thirty-seven days, 861 an estimated increase of 1 or 2 lb. and an interval of thirty-nine days. Mr. Holt further states that this is in conformity with the belief held at Lismore that these winter fish make only a temporary stay in fresh water, and are by those who catch them commonly called "droppers," from their habit of dropping down stream. This view is moreover strengthened by the fact that 858 D was recaptured in the sea, in Youghal harbour, about eighteen miles below Lismore weir in the Blackwater, where the fish was marked. I am not aware that anywhere in Scotland the view is held that clean winter fish are only temporary visitors to fresh water.

* Report for 1901, Part II., "Scientific Investigations," p. 195.

That such fish may drop down stream after making a comparatively short ascent and meeting floods, as stated, is believed by netsmen, since after cold winter floods they not infrequently catch coloured fish in the lower reaches and estuaries; but it also happens that occasionally such fish are found to be affected by disease, and to be therefore in a weakened condition. The early running Tay fish ascend to Loch Tay about fifty miles, and there yield regular sport till May, when they begin to ascend still farther. The early Ness fish run quickly through the six miles of the river, and in the same way yield sport in Loch Ness, from which at an early date they also ascend the Oich to Loch Oich and the Inverness-shire Garry. These upper waters are well stocked with fish on the opening day of the rod fishing, February 11, and continue to be so. The same may be said of rivers farther north, the Thurso and Loch More at its head, or the Naver with Loch Naver at its head. In all such localities there seems no indication that the fish, once well up the rivers, descend again. On the contrary, the indications all seem to point to the conclusion that these fish remain in fresh waters during the whole of the ensuing fishing season.

In the Spey 150 clean fish were marked during the close time of 1896–97, and of this number 67 were recaptured after the opening of the fishing season. The lower reaches of the Spey are very rapid, and the winter in question was exceptionally severe, so that one would expect ascent to be slow and that not a few would descend these

lower reaches to some extent. As a matter of fact, 34 had moved up, 25 had dropped lower, and the 8 remaining fish were found in the position in which they had been marked. Only 1 fish out of the 25 which had dropped back was reported as having in the interval of thirty-eight days gained $\frac{1}{2}$ lb. in weight, and one naturally hesitates to state that with so slight a change one has evidence of sea feeding and not rather of inaccurate weighing. All others of this series showed decreases from 0 to 2 lb. In the Tay 24 clean marked fish (spring fish) have been recaptured within short intervals. They were marked between Perth and the Linn of Campsie, about nine miles above Perth. Of this number 8 fish which had dropped back were diseased, with one exception, No. 9100. This fish was marked at the Linn, and recaptured in a quite healthy condition about 13 miles farther down in the upper tidal waters of the estuary. The interval was two months and ten days, and the fish was reported as having lost 5 lb. in weight (the greatest decrease recorded for a clean fish in fresh water—27 lb. to 22 lb.). In the interval a heavy flood of snow water had occurred. Two fish were found in the same position as before, and two had ascended between 30 and 40 miles, while others had made a less ascent. A few recent Dee recaptures of clean fish show in every case an ascent, and in all but one instance an ascent to the top waters of the river. In these Scottish records there seems nothing to indicate any return to the sea, as has been shown by Mr. Holt to occur in Ireland.

PLATE IV.—A male salmon in full spawning livery, fresh from the sea in November. The fish has just been marked on the dorsal fin, and is being photographed before its return to the River Tay at Almondmouth.

CHAPTER IV

THE SCALES OF THE SALMON AS RECORDS OF THE SALMON'S LIFE

Age of salmon to be told from their scales—Progressive growth of the scales—Lines of growth on scales—The spawning mark—Records of marked smolts as shown on scales—Records of small spring fish marked as smolts—Infrequency of the spawning mark—Scales of kelt recaptured as clean fish—The average number of lines added—Scales of large salmon—Salmon disease—The bacillus of origin—Fungus spreads quickly on dead fish

During the last three years or so we have been gradually and with increasing certainty realising that a study of the scales of the salmon yields a most valuable addition to our knowledge of the fish's life.

We have long been able to tell the age of a horse by looking at its teeth. In like manner we can now tell the age of a salmon by looking at its scales. Other hard tissues, such as the bones, would no doubt show corresponding information—the ear bones or otoliths have already been used for the purpose with regard to many species—but in the case of the salmon a properly selected scale is by far the most convenient tablet to consult and is at the same time a very satisfactory one.

When a female fish spawns she rapidly loses 23 per cent. of her weight and a corresponding diminution of body girth. As a kelt the descent to the sea is then made, and thereafter, with a sudden accession of feeding, a marked growth begins, so that the fish may soon be double its kelt weight. If this greatly increased bulk is to be provided with a scale covering, it is clear that one of two things must happen: either new scales must grow amongst the old ones, or the already existing scales must become enlarged—must, in fact, have the power of growth which the body of the fish possesses.

It has been supposed by some that a shedding of scales takes place at certain periods of the fish's life, and that new scales are formed. It has even been thought by some that the male salmon at the breeding season has not a covering of scales. It is true that at this time the male fish is remarkably smooth and slippery, and that the surface is not imbricated in any way by scale edges. This is not, however, from any loss of scales, but because the whole condition of the skin has altered and become thickened and toughened. The scales are now deeply embedded in their skin pockets, and cannot be got hold of properly unless the thick skin covering is lifted or punctured. But at no time of the fish's life are young growing scales found amongst the existing scales, except in places where repair after injury is going on. There is no arrangement of growing rows of scales ready to take the place of the older scales, as teeth do in the jaws of a Green-

land shark. Moreover, salmon, young and old, small and great, are found with the same number of scales when certain rows are counted, and this character is so constant as to be one of the most trustworthy for the identification of salmon from other species.

On the other hand, the progressive growth of the scale as viewed in fishes of different age, the increase of size and the definite system upon which this increase of size is clearly brought about, the impress of the young condition still visible on the old fish's scale, and the comparison of scales taken at different times from salmon which have been marked and afterwards recaptured, all impress the mind with the conviction that not only does the scale grow as the fish grows, but that the periodic nature of the salmon's growth is stamped upon the scales.

In early life the scales are merely circular patches on the integument of the post-larval fish. These centres of growth gradually have more and more scale matter added to their peripheries, till intervening spaces are all covered and the scales commence to overlap. The young salmon is barely two inches long when the growing scales begin to overlap. The scale matter added to the growing surfaces appears in a succession of ridges which under the microscope give the appearance of concentric lines round each centre of growth, the whole being covered by a membrane or outer skin.

By the time the smolt is ready to depart to the sea the overlapping portions of the scales have become less distinct in their line formation than the portion

closely associated with the under skin in the skin pockets in which all scales lie. In all subsequent appearances it is this covered up portion of the scale which chiefly supplies the records of growth, of migration, and of spawning. The exposed or posterior area of the scale—which is a small portion of the whole—becomes, as life goes on, a mere irregular half-moon shaped area of comparatively featureless surface.

For our information respecting the scales of the salmon and their interpretation we are indebted to Mr. H. W. Johnston, who in two papers to the Reports of the Fishery Board for Scotland * has dealt with the subject exhaustively.

The experiments made at Fochabers on the rearing of smolts have constantly shown that, even amongst those young fish, food is freely taken during spring and summer, but much less freely taken at other times of the year. Dr. Hoffbauer, who studied the scales of a German carp in 1899, and Mr. Stuart Thomson, who wrote on the periodic growth of cod scales in 1902 and 1904, have each shown that this habit is common to other fishes, and that there is a distinct result in the appearance of the scales: that while summer feeding and growth is in progress the lines or ridges on the scales are added in greater numbers than at other times, and that between the ridges the spaces are greater, and that while the more moderate feeding of winter is in progress the

* H. W. Johnston, "The Scales of Tay Salmon as Indicative of Age, Growth, and Spawning Habit." Twenty-third Annual Report, Fishery Board for Scotland, Part II. Appendix II. *Ibid.* "The Scales of Salmon." Twenty-fifth Annual Report, Fishery Board for Scotland, Part II. Appendix II.

ridges are few and close together. The result is that each summer and each winter leaves its indelible trace on the scale.

In the case of the salmon the same is true, and in addition there are periods when, through the forsaking of the sea for fresh water, where no regular nourishment of the body takes place, a complete cessation of scale growth results. Also, when spawning has taken place, with its consequent shrinkage of the body girth in the kelt, a record—called the "spawning mark"—is stamped upon the scale, due in part to the apparent fraying of the scale edges and in part to the healing or mending of their frayed edges when feeding is recommenced. The spawning mark is therefore analogous to the "scar tissue" of pathologists.

But there is in all cases a certain irregularity in the amount of growth, due directly to the varied amount of feeding. Even parr and smolts show differences in the number of ridges added at similar times. A parr growing in a river which flows through richly wooded country, and which has water of a comparatively high temperature, receives many more chances of food than the parr growing in the rocky stream of some cold mountainous district. Nevertheless, the number of ridges in each period of life is found to be the safest guide to the understanding of the growth, the separation of summer and winter areas being at the same time clearly kept in view.

In Mr. Johnston's second paper (*loc. cit.*) several tables are given showing the number of lines of

growth in parr and smolt scales, and from these it is seen that when the smolt is fully two years old and has reached tidal water, preparatory to the first migration to the sea, the number varies from 23 to 28. The scale is well defined, and bears upon it the traces which, as we shall presently see, remain in all older scale appearances.

It is of special interest to note that in connection with the smolt-marking experiments in the Tay, to which reference has already been made, evidence as to scale growth was collected, and that when those wired smolts again turned up as grilse, and subsequently also as small spring fish, the record of the scales was obtainable. It may be said at once that this record, as interpreted by previous study, was in complete harmony with the evidence obtained from the marking.

I subjoin Mr. Johnston's table, which refers to thirteen of the grilse recaptured in 1906 with smolt wires *in situ* :—

SOME "WIRED" SMOLTS RECAPTURED AS GRILSE

Date.	Lb.	Number of Lines on Scale.							Remarks.
		Up to Smolt Stage (River.)				After Smolt Stage (Sea).			
		Total.	1st Year.	2nd Year.	3rd Year.	Total.	3rd Year.	4th Year.	
1906.									All these grilse were marked with wire when migrating as smolts between April 25 and June 6, 1905 (none marked between May 3 and 16).
June 1	$2\frac{15}{16}$	24	8	14	2	35	29	6	
„ 26	$4\frac{1}{2}$	25	6	15	4	42	31	11	
„ 28	$4\frac{3}{4}$	28	16	12	–?	45	32	13	Parr lines doubtful.
July 4	$5\frac{1}{2}$	23	9	12	2	44	30	14	
„ 10	$4\frac{1}{4}$	23	9	11	3	43	30	13	
„ 14	$5\frac{3}{4}$	20	8	12	–	43	29	14	
„ 14	7	24	9	12	3	47	32	15	
„ 16	$6\frac{1}{2}$	25	7	13	5	48	30	18	
Aug. 4	5	22	7	12	3	47	29	18	
„ 14	$3\frac{1}{2}$	24	10	11	3	45	31	14	Exterior ridges close.
„ 14	$6\frac{1}{2}$	22	8	12	2	47	29	18	
„ 17	$6\frac{1}{2}$	26	7	14	5	47	28	19	
„ 17	9	22	10	9	3	48	31	17	Ridges broad.

"From the marking we are sure that the fish in the above table were smolts in the spring of 1905, and that they returned to the river as grilse in the summer of 1906, weighing from $2\frac{15}{16}$ lb. in June to 9 lb. and more in August. From the scales we learn that all the specimens were a little over two years old in the spring of 1905, when they were migrating as smolts; that all had spent one summer and one winter in the sea, and before returning had com-

menced the feeding of the second summer, which is represented by six lines in the June capture and by nineteen rather large lines in one of the August captures."

In following out the scale record we have also evidence as to the history of three of the small spring fish which were, like the grilse just referred to, marked when smolts in 1905. Here again the evidence of the scales bears out the deductions arrived at by the marking. The recaptures were made in the spring of the present year (1907).

SOME "WIRED" SMOLTS RECAPTURED AS SMALL SPRING SALMON

Date.	Lb.	NUMBER OF LINES ON SCALE.							Remarks.
		Up to Smolt Stage (River).				After Smolt Stage (Sea).			
		Ttl.	1st Yr.	2nd Yr.	3rd Yr.	Ttl.	1st Yr.	2nd Yr.	
1907.									
Feb. 18 . .	9½	22	12	10	?	55	28	27	Exterior ridges very broad. All marked with wire when migrating as smolts between April 25 and June 6, 1905.
„ 21 . .	9	21	13	9	?	52	29	23	
Mar. 15 . .	10¼	20	10	10	?	59	30	29	

"An apparent break in the lines of the second summer is nearly always visible on the scales, and looks like a voluntary or compulsory diminution of feeding for some time. Another point seems evident from the marking, and that is that these small springers are returning for the first time, and have consequently never spawned. This corresponds with

PLATE V.—*Description.* Scales of grilse and small spring salmon recaptured in 1906 and 1907 respectively, each fish having been marked as a smolt in 1905.

The smolt scale is very clearly defined in the centre of the grilse scale. Thereafter the wide area denoting summer feeding in the sea is conspicuous. A darkish band denoting slight winter feeding then succeeds, and at the commencement of the second summer the fish enters fresh water and is killed.

In the scale of the small spring fish, in addition to the area shown on the grilse scale, a second summer's feeding in the sea is to be noticed, and, close to the edge, the winter thickening.

The unlined portion of each scale is the portion which projects on the surface of the skin.

what the scales show, but it must be remembered that salmon similar in size and appearance that have spawned during the previous winter as small grilse are also caught at this season, and it is only by the spawning mark on the scales and sometimes maggots in the gills that the difference can be detected, though it sometimes becomes apparent when the fish comes to table.

" These small unspawned fish constitute the bulk of the spring run in the northern rivers, and are comparatively more important to them than to the Tay, where larger fish a year or more older come in during the winter and the spring."

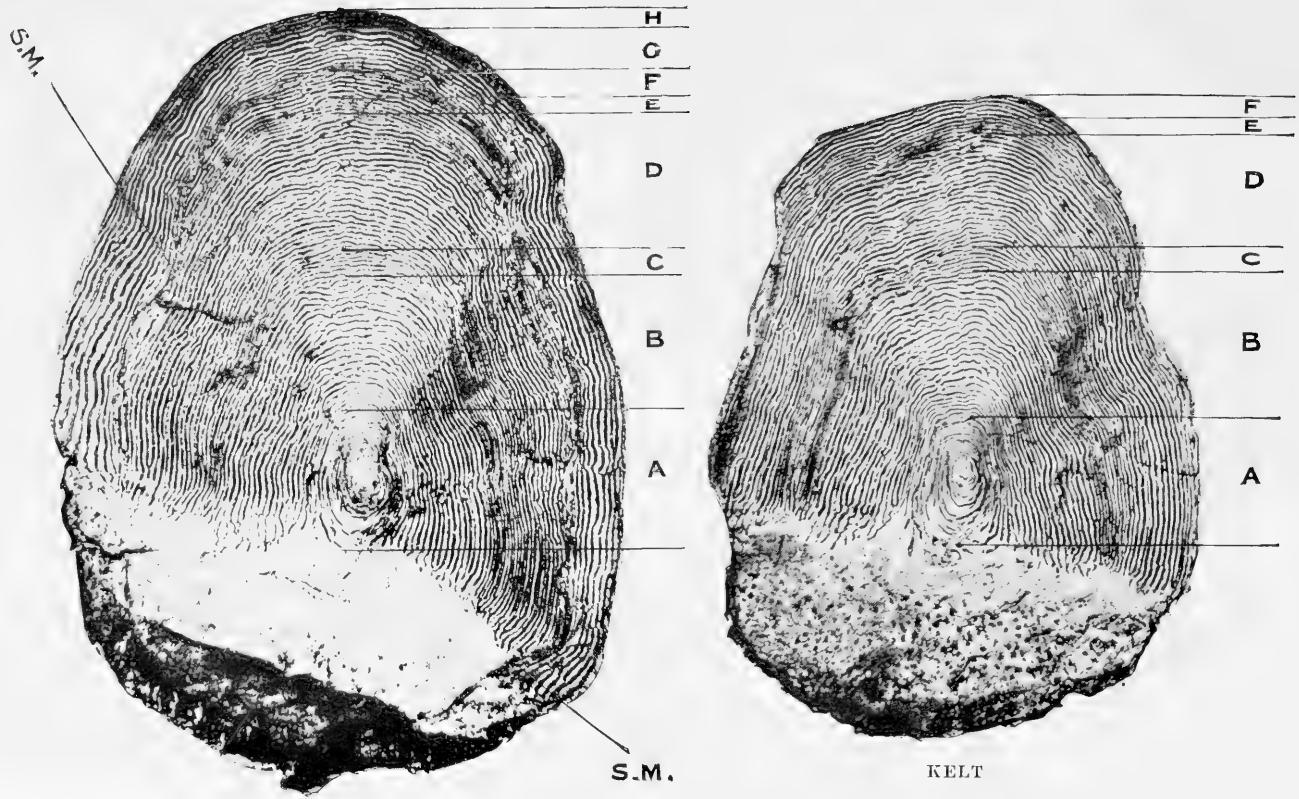
Illustrations of those wired grilse and spring fish scales are given in Plate V. In each case the smolt scale will be noticed in the centre, and as the eye passes from the centre of growth along the long axis of the scale to the anterior border, will be seen the large area of growth resulting from the first summer of feeding in the sea; then subsequently the contracted-looking band of small growth, marking the first winter in the sea. In the grilse scale a short period of spring feeding in 1906 is represented by only six lines, after which the fish entered the river Tay and was killed. In the small spring fish scale, on the other hand, the second summer in the sea is seen to have been completed and followed by a second winter, making an addition of 27 lines, after which the record of this fish ends like a tale that is told.

The grilse which enter our rivers spawn in the autumn. Those fish which do not enter our rivers

as grilse but remain in the sea till the grilse stage is past are of course still maiden fish, and after entering such a river as the Tay as small spring salmon will spawn a year later than their fellows. They merge into the run of 10–16 lb. summer fish of the Tay which have completed their two annual rings. The summer class of fish are, however, apt to be mixed in a large river like the Tay, as we have now reached a stage in the salmon's development when fish which have previously been in the river as grilse and which have spawned and descended for the short period of marine sojourn may be once more in the river. The proportion of such fish is, however, comparatively small, at least in the large rivers of Scotland.

The study of the scales has prominently called attention to the infrequency of spawning amongst heavy fish. It comes as a surprise, for instance, to learn that very many of the large spring fish of the Tay—fish almost invariably about 20 lb. in weight —have never spawned. The scale shows the third annual ring in course of formation subsequent to the two-year-old smolt stage ; *i.e.*, they are approximately five years, yet their scales bear no spawning mark. They are entering fresh water for the first time, although many fish of smaller size have already propagated their species. Such information makes us realise with additional force the value of protecting fish when they do breed.

Now let us deal with the records of adult salmon marked in fresh water as kelts and subsequently recaptured as clean fish. And first I will take the



CLEAN KELT

PLATE VI.—Two scales from a salmon at different stages of growth, when the fish was marked as a kelt and recaptured as a clean fish.

case of a Helmsdale fish which was marked on December 12, 1904, when a kelt of 5 lb. weight. The number of the mark was 1180 B, and other particulars respecting it are given in the chapter on marking (p. 65). The fish was recaptured, clean and 14 lb. in weight, on April 30, 1906.

I have included two photographs with which Mr. Johnston has kindly supplied me, showing first the scale at time of marking, and second the scale at time of recapture. Horizontal lines have been drawn to show the progressive development, and each stage or interval has been lettered consecutively. In the photograph of the scale from the kelt the history of the fish is at once seen.

A.	Parr and Smolt Stage, 1900–02.		River.
B.	1st Summer .	1902	Sea.
C.	1st Winter .	1902	
D.	2nd Summer .	1903	
E.	2nd Winter .	1903	
F.	3rd Summer (till May or June)	1904	River.

The fish then spawned in the winter of 1904, and was marked in December as stated.

In the photograph of the scale from the same fish on its recapture as a clean salmon we have, in addition to the appearance already seen in the smaller photograph, first the spawning mark on recovery from the condition succeeding that shown in F., and then two additional areas :—

G.	5th Summer . .	1905	Sea.
H.	5th Winter . .	1905–6	Sea.

The fish returned to the Helmsdale river in the

spring of 1906, and was caught on the date already given.

This Helmsdale fish is typical, and the photographs show more plainly than any description can do the characteristic appearance of the kelt and adult clean fish scales. The magnification is in each case 12 diameters. The additions G. and H. on the later scale may appear slight in comparison with those seen in the kelt scale, but it is to be recollected that as the age of a salmon increases the rate of growth decreases. The first two summers in the sea invariably show the greatest growth in the fish.

Evidence from scales of fish which have been marked and recaptured is evidence of the most reliable kind, and several instances might be cited similar to the Helmsdale fish marked 1180. On account of the nature of the evidence also, I consider that there need be no hesitation in deducing evidence from scales of fish for which no marking record is available, provided always that the observer has a competent knowledge of the subject and the scale be taken from a suitable part of the fish, *e.g.*, the "shoulder."

With regard to the number of lines which will be found on the scales of fish of different ages, it may be said that from marked kelts recaptured as clean fish, a scale having been obtained only at time of recapture, Mr. Johnston has found that after the smolt stage is passed a grilse may add 25 to 28 lines the first year; if then it enters the river to spawn as a grilse the lines will vary according as it enters in

early or in late summer or autumn, the variation being from 7 to 24 lines. If in this second year the fish remains feeding in the sea—the long migration habit —the addition, in the case of Tay fish, may be from 20 to 31 lines. If thereafter the fish enters the river as a summer fish, very few additional lines may be added at the commencement of the third year, though a later fish may show 12 or 15 lines. If in this third summer the fish still does not enter the river, but delays till the following winter or spring, 17 to 28 lines may be added in the sea.

From the evidence at command it appears to be somewhat unusual for a fish to remain till its fourth sea year without spawning, but a few instances are on record. Fish which on recapture are from 30 to 35 lb. show either five or six years' growth on the scales after the smolt condition, and have spawned either once or twice. A record of a 42 lb. fish shows six years' sea life, or in other words is eight years old and has spawned twice. The fact that the recapture was made in fresh water points to the conclusion that spawning, or rather reproduction of the species (for the majority of those large fish are males), would be engaged in for a third and probably last time.

The few records of marked fish which have been recaptured when 40 lb. or more than this weight have, from the information gained from marking alone, been set down as of eight years old, and in this connection it is interesting to recollect that trout kept in rearing ponds for hatchery purposes are found to become poor as regards fertility after their eighth year.

If salmon live much longer than eight years they apparently need not be looked for in the fresh water spawning places of their species, and the fact that the majority of the very large salmon captured are males would seem to indicate that in all probability the male, as in other animals, remains fertile longer than the female. So far as I know, the record weight for a Scottish salmon is 84 lb., but the fish was taken in the estuary of the Tay, though both in the Dee and in the Tay fish of over 70 lb. have been taken in fresh water.

From the study of the scales alone do we gain this information as to the infrequency of spawning, and the consequent benefit to our stock of salmon in preserving most religiously the breeding fish which enter our rivers. From the study of the scales also it is possible to note early running fish. Mr. Johnston has, for instance, found the kelts of spring fish only a short distance above the tide, as early in the spawning season as November. Mr. Berrington, formerly Assistant Secretary to the Board of Trade, has specially noted in his official reports that when a river is becoming over-fished the first runs of fish to disappear are the spring runs. Now the spring fish are not only of great value in any river, because they are fish in beautiful condition, which afford the best sport to the rod, and are the best river-caught fish for the table, but also because they are the fish which ascend to the highest tributaries of our large rivers, and by so doing deposit their eggs in the purest waters at the commencement of the spawning season before frosts and spring floods can impair the

redds or destroy the eggs in the early and delicate stages. If these high tributaries, where in many cases the finest spawning grounds are to be found, are not occupied by the spring fish, it sometimes also happens they are not occupied by the quick running summer fish which follow, and at the same time it is well known that the available lower spawning grounds are not infrequently occupied by successive runs of late fish, so that to some extent one set of spawners undo the work of fish which have preceded them by turning up gravel already protecting eggs.

The kelts of the spring fish by getting away down stream at an early date have also a better chance of reaching the sea before the time at which salmon disease makes its worst appearance. Such kelts should be respected and carefully handled by any into whose hands they may fall. Like the bread cast upon the waters, they will return after many days.

The observations of Mr. Hume Patterson * on the subject of salmon disease show that it is possible for an apparently healthy fish to be infected by the real cause of salmon disease—the *bacillus salmonis pestis*—since, if the fish has been previously diseased in fresh water, a sojourn in the sea, although it kills *saprolegnia ferax*, does not kill the bacillus. His observations also show, however, that the entrance of the bacillus to the tissues of the salmon is most readily gained when fish are injured and sickly. The organism itself has been found in river water,

* "The Cause of Salmon Disease," Fishery Board for Scotland, 1903.

and more plentifully in certain places and under certain conditions than others. It is natural, therefore, to suppose that the kelts which remain longest in a river after spawning are, in their sickly and often wounded state, more likely to become infected than those fish which quickly leave fresh water for the sea. The fungus spreads quickly when fish begin to die, since *saprolegnia* flourishes much better on dead than on living tissue. It is noticeable that diseased fish are very commonly of large size, and that salmon disease is most conspicuous in large rivers. It is in large rivers that large kelts remain longest after spawning, and there is considerable evidence to show that these late kelts are fish which ascended fresh water in summer and autumn. Hence I would offer the observation that loss of fish from salmon disease is less likely to injure the stock of a river when the river maintains a good run of spring fish. In the immense rivers of British Columbia, Alaska, and California the kelts of salmon which have ascended many hundreds of miles are reported to die without exception; only those fish which do not ascend to the upper waters seem to be able to return to the sea. The great runs of fish in those Pacific coast rivers do not occur till late summer, but the expenditure of energy necessary for so great an ascent must produce a much greater drain upon the systems of the fish than is found in any upper water fish in our country, and in all probability exceeds the lost of nutriment sustained by our spring fish which remain long in fresh water. But for the excessive fishing of salmon traps in the Pacific coast

rivers, it would appear, however, that the extraordinary loss of kelts can be disregarded in the upkeep of stock.

With us, it seems to me, the value of a kelt is not sufficiently recognised. Because a kelt is an unclean fish and very often a nuisance to the angler, the disposition frequently seems to be to treat the fish with contempt, to drag the hooks out of his mouth and to throw "the dirty brute" back anyhow. I have seen a ghillie lift a kelt as a sea fisherman commonly lifts a dead cod-fish, by sticking the thumb and middle finger into the two eye sockets. What chance of survival, one may ask, has a sickly kelt with bleeding gills, or one subjected to treatment as described? *Bacillus salmonis pestis* is waiting for him, and *saprolegnia* has every chance to flourish. The fish has been reproducing his species in the river, and is willing to do so again if he is only allowed to go to the sea and become once more a silvery clean salmon. If he is carefully handled, and not only treated with respect but decorated with a silver medal bearing a distinguishing number which corresponds with his weight and length at time of marking, he is, in my opinion, of much more value than a clean-run fish which is knocked on the head and put in the boiling pot.

CHAPTER V

THE FEEDING OF THE SALMON AND GROWTH OF THE GENITALIA

Absence of food in salmon taken in fresh water—Feeding habits of fry—Food of salmon in the sea—Nutriment in tissues of estuary as against upper water fish—Transference of nutriment from muscles to reproductive organs

THE scales and the signs of growth and of spawning, as well as other points in the life of the salmon, are intimately connected with the feeding and non-feeding periods of the fish.

It is recognised on all hands that the stomach of the salmon when taken in fresh water is invariably, or all but invariably, empty. A further examination also shows that the intestine is empty, and shows no indication of nourishment having been taken for some time previously; and that the gall bladder is collapsed. Hoek * in the lower Rhine examined 2000 salmon, and found food remains in only seven, which were taken in the months of March and April. Meischer Ruesch † at Basle, 500 miles up the river, examined 2162 salmon in four years in connection

* Rapport over Statistische en biologische onderzockingen ingesteld met behulp van in Nederland gevangen Zalmen.

† Statistische und biologische Beiträge. Zur Kenntniss von Leben des Rheinlachses in Susswasser. (Metzger und Wittig, Leipzig, 1880.)

with his important physiological investigations, and found food in only two male kelts. The food was believed to be, in the one case, the remains of a roach, and in the other the scales of a cyprinoid fish. In our country and also on the Atlantic coast of America, hundreds of salmon have been from time to time examined, and always with the same result. It is needless to dwell on this or to give references in detail, for several writers have already done so in recent publications. For details of the examination of the intestinal tract of such salmon, reference may be made to the report by Dr. Noël Paton and others, published by the Fishery Board for Scotland,* and to the writings of Dr. Kingston Barton. In the investigation of the stomach and intestine of salmon from fresh water, made by one of Dr. Noël Paton's collaborators, a mistake was no doubt made owing to post-mortem changes having affected the tissues examined. From the pathological condition, thus unhappily accepted as normal, the inference was drawn that salmon were unable, when in fresh water, to absorb nourishment if any food were taken. Mr. W. Earl Hodgson in his book on "Salmon Fishing" says that the Fishery Board are committed to this desquamative catarrh theory. This is a little hard on the Fishery Board, and, moreover, is not quite accurate, since, after the error had been pointed out by Dr. Kingston Barton, sufficient acknowledgment was surely made in asking the critic to continue the investigation and to

* Report of Investigations on the Life History of the Salmon. 1898.

contribute a paper to the Fishery Board's Reports, which paper was published in 1902.

The main point is, however, that food is not taken in any regular manner in fresh water, and that the fish is in no sense nourished. In support of this it may be added that the marking and recapture of clean run fish during their stay in fresh water has invariably shown a loss of weight. I think, moreover, that it is right here to add that those who in our country corroborated the results of Hoek and Meischer in this matter expressly stated, when they demonstrated the non-feeding of fish in fresh water, that much depended on what is meant by the word "feeding." The "taking" of fly, minnow, or worm was freely admitted, and it was also admitted that worms and other objects were occasionally swallowed.* The interpretation of "feeding" (Report, p. 170) was the "digestion, absorption, and utilisation of material by the body." Some reference to this seems necessary, for so many appear, by their criticisms, to have supposed that, by declaring salmon did not feed in fresh water, Hoek, Meischer, Noël Paton, Kingston Barton, and others meant that the taking of the angler's lure had no connection with feeding. The Jock Scott or Silver Doctor may certainly be like nothing in the heavens above or the earth beneath, but the minnow or gudgeon is after all a fish, even though it smacks of formalin. Such lures are found by experience to attract the salmon,

* In 1885 a small trout was taken from the stomach of a grilse caught in the river Thurso, and sent by Mr. Robertson to the *Field* office.

and the impulse to take them is in all likelihood the same impulse which enables the salmon to nourish himself at other times. In this sense the fish may be said to feed, while at the same time there is nothing unnatural in allowing that the wobbling of an apparently half-dead dace or sprat over a salmon's head may incite the poor fish's rage, or that the exquisite colouring of what is called a fly may produce a flash of keen emotion, as has been said by some.

When the digestive tract of the salmon taken at the mouth of the river is examined, it is natural to suppose, since the fish is more recently from the sea than is the upper water fish, that more trace of feeding will be found. Grey and Tosh, in 1894 and 1895, examined 1694 salmon in the Tweed, 1442 of the fish being taken at the mouth of the river in the nets of the Berwick Salmon Fisheries Company.* Of those Berwick fish 128, or 9 per cent., contained food. The following table shows in a condensed form the times at which the fish with food were taken :—

Month.	Number examined.	Number with Food.	Per Cent. with Food.
February . . .	7	1	14·3
March	46	20	43·4
April	133	53	36·9
May	215	36	16·7
June	236	31	13·1
July	283	5	1·7
August . . .	210	8	3·8
September . . .	106	2	2·0

It is noticeable at once that the greatest number

* Fourteenth Annual Report, Fishery Board for Scotland, Part II. Note 2.

with food is found in the fish taken during the months of April, May, and June. A careful examination was made as to the nature of the food, and a detailed table is given on pages 77 to 80 of the report referred to. Herring remains figure most largely, while other fish reported are sand-eels, whiting, and haddock. In a considerable number were found crustacean remains, in a few fish marine worms, while amongst curious oddments—and these are interesting when we recollect the nature of the salmon fly—we have a caterpillar, four feathers, a leaf of a beech tree, moss, blades of grass, and spikelets of sedge. The staple food, however, seems to be the herring, which, amongst all fish in our seas, has been shown to be at once the most nourishing and the most easily digested. Concerning the small crustacea (mostly amphipods), we may probably be not far wrong in assuming that they were ingested; in other words, that the herring swallowed the amphipods, and the salmon swallowed the herring.

It is interesting to notice that from the commencement of the salmon's life the feeding habit waxes and wanes with the seasons. Every angler knows how persistently parr will keep rising to the fly, how greedy and troublesome they are in the spring and early summer. When fry are reared in ponds and hand fed they show the same peculiarities which seem to mark the "taking" proclivities of the adults. Some time since interesting notes, taken by the keeper of the rearing ponds at the mouth of the Spey, to which I have already referred, were supplied to me. During the first year in the life of the fry

food is taken freely through the summer, but when the first frosts of autumn set in feeding becomes intermittent. In December many days will pass without any food being taken, and in January and February the amount of food consumed is very slight. If open weather comes with spring the small parr will recommence feeding, but frosts or unsteady conditions will still check them. By the month of April the little fish are feeding steadily and vigorously, and simultaneously their growth becomes more rapid. All through summer this steady feeding goes on, and it is a beautiful sight to see the shoals of active little fish flashing to the surface as the food is thrown in. Their appetites are those of lusty youngsters, and food never seems amiss at any time.

In July, if the temperature of the water rises to about 70° F., they become less keen, and if a spell of hot weather continues feeding will cease. In thundery weather they will not rise from the bottom of the pond.

With the advent of winter a distinct lessening of the desire for food again manifests itself, although during this second winter entire cessation of feeding for several days does not seem to occur so frequently as amongst the fry.

By the month of March the fish are two years old, and feeding is again freely maintained. As the silvery dress is assumed the smolts become very keen and active, and feed at any time. Under natural conditions they should now descend towards the sea.

Even when a plentiful supply of food is obtainable,

therefore, the young salmon in fresh water does not incline to feed freely in winter; and when the smolt stage is passed and the fish has reached the great feeding place—the sea—this peculiarity, which is shared with other fishes, is still obvious. In the formation and growth of the fish's scales these periods of feeding and non-feeding are recorded, as we have seen; while, with regard to the length of time during each summer in which the salmon continues to feed, it is found, both by observations as to food remains and by observations on the state of nutriment in the tissues of estuary fish, that feeding continues without cessation till September.

An interesting letter bearing upon the subject of the food of the salmon was read by Dr. Dunlop, in his evidence before Lord Elgin's Salmon Fisheries Commission. It was written by Mr. Rae, one time superintendent of the Duke of Richmond and Gordon's fisheries, and is as follows: "When salmon were boiled and kitted I had great facility for observing the contents of their stomachs, and I have invariably found that in all places the character of their food, as a whole, has been the same. At Lochinver in 1847; Carloway, in Lewes, in 1848, 1849, 1850, and 1851; at Loch Ewe and Loch Broom in 1852, 1853, 1854, 1855, 1856, I had occasion to open many thousands, and found that the principal contents were herrings. As many as half a dozen in one fish, more or less decomposed, in many cases reduced to pulp; in others as many as six or eight herring bones decomposing. I also found sand-eels in many cases. . . ." Day mentions seeing

sand-eels and herrings in the stomachs, and reports that Jardine states that salmon are often taken on the coast of Sutherland, on haddock lines baited with sand-eels. Other observers have made similar reports. Even in fish shops where sea-caught salmon are sold, after being cut across, one may sometimes notice that herring had been the food last taken.

There is, then, a great contrast between the condition of the stomach and intestines of fish caught in the sea and the condition observed in fish caught in rivers. In the former case the stomach is commonly found full of herring or sand-eel food, the intestines being correspondingly filled with fæcal matter, while in the latter both stomach and intestines are empty. We have, therefore, well-defined periods in the life of the fish, and long intervals during which no food is taken.

One of the main objects of the investigations undertaken by Dr. Noël Paton and his colleagues was to determine whether salmon in fresh water require food, and in the event of corroboration of the results obtained by the Continental physiologists, to study the changes which must necessarily take place owing to the growth of the genitalia during a period of starvation. In the female salmon the growth of the reproductive organs is very great. It has been ascertained that in April and May the ovaries constitute about 1·2 per cent. of the weight of the fish, while at the spawning season they represent as much as 23·3 per cent. In the male fish, the actual increase is not in so great a proportion

the contrast between spring fish and autumn fish is also well marked.

In dealing with fish from different rivers, it was necessary to calculate a standard fish length with which to make comparisons. This having been arrived at, not only weights of fish but weights of muscle and genitalia could be dealt with on one basis. In estimating the nutrition of fish in estuaries as compared with those from upper waters, Drs. Noël Paton and Dunlop received material from the Spey, the Helmsdale, and the Dee. The weight of the muscle was worked out in every case, and the following *table showing the average weight of muscle for fish of standard length* gives the ultimate results :—

	Estuary.	Upper Water	Difference.	
	grms	grms.	grms.	
May and June . .	6326	5839	487	
July and August . .	6901	5887	1014	
Oct. and Nov. . .	6055	4116	1939	

In the upper water fish a loss in weight of muscle works out to nearly 28 per cent.

In contrast to this, the increase in weight of the ovaries of female fish is most marked. In the Tweed, Grey and Tosh, treating this subject in percentages to the weight of the fish, had already shown a change from 0·75 per cent. in March to 17 per cent. in November. *The average weight of ovaries per fish of standard length* is given by Noël Paton and Dunlop in this form :—

	Estuary.	Limits of Variation.	Upper Water.	Limits of Variation.
May and June . .	121	53–175	263	104–415
July and August . .	284	109–479	510	353–691
Oct. and Nov. . .	1439	1310–1930	2230	1851–2888

"This gives an increase from May to November of from 1 to 11·9 in the sea, or 1318 grms. per fish of standard length, and from 1 to 8·5 in the river, or 1967 grms. per fish of standard length. It will thus be seen that although in the upper waters a greater amount of material per fish of standard length is laid on by the ovaries, their *rate of growth*, considering the weight with which they start in May, is quite as great in the sea as in the river."

For the growth and development of those ovaries a very large amount of fat is necessary, since the constitution of the ovaries is very largely of fat.

Now the average amount of fats per fish of standard length is given for both muscle and ovaries as follows (Report, p. 97):—

	Ovaries.		Muscle.	
	Estuary.	Upper Water.	Estuary	Upper Water.
May and June . .	12	29	768	448
July and August . .	18	46	770	476
Oct. and Nov. . .	145	204	426	159

Here we see very plainly how with the decrease of muscle fat the ovary fat increases. Taking the

whole season into account, the fat per fish of standard length in the ovaries of upper water fish is about double that in estuary fish. In the early months, May to August, the increase is comparatively small, but in October and November the increase is four and a half times.

From the results obtained the deduction is "that the fat which the salmon has stored in its muscle when it leaves the sea is not only amply sufficient to yield all the fat required for the fats of the growing ovary, but also abundantly sufficient to yield energy for an enormous amount of muscular work." In point of fact, the amount used apparently in energy is very great.

In dealing with male fish, it was found that the storage of muscle fat is as great in those entering our estuaries as in the case of females, and that this fat is used up to as great an extent, although less goes to the male organs than to the ovaries. The presumption is that the amount required for energy is greater.

Without entering upon further details which would weary the reader, it may be said that the fat in process of being utilised by the ovaries is to some extent changed in character, being largely combined with phosphorus, and that the other essential element in development of the genitalia, the proteids (which include the familiar "curd" of the fresh run fish), are found to be stored in large quantities in the estuary fish, and to be reduced in the muscle and transferred to the ovaries in upper water fish.

Such then, in brief, is the chemistry of this matter.

But in order to increase the scientific value of the demonstration a thorough microscopic investigation into the physiological conditions of the muscles and their contained fats was undertaken by Mr. Mahalanobis. In the highly charged condition of the estuary fish the fat cells were found not only between the muscle fibres, but within the fibres themselves. In the upper water fish the gradual disappearance of the fat was most clearly established, thus supporting in every way the deductions drawn from the wider chemical study.

From these investigations it appears, therefore, that the feeding which the salmon does in the sea is much more than enough to enable the fish to grow and develop in the manner usual with animals of a steady feeding habit. The feeding is so excessive that the health and energy of the fish is more than supplied, and as a result the excess of nutriment is stored in the tissues. Reference here has alone been made to the muscular system, but it has to be understood that the abdominal organs and their connecting membranes are likewise loaded with fat under ordinary conditions. After the cessation of feeding and the entrance of fresh water this source of nourishment is drawn upon for the supply of the reproductive organs and for the supply of energy necessary to the fish in ascending rivers and performing the reproductive functions.

That this supply for energy is ample will be readily understood by the fisherman who has had the keen joy of testing from the end of his rod the sort of fight which a well-nourished salmon can put up.

That salmon do not invariably enter fresh water in an excessively over-nourished state I have already noted. A season occurs now and again during which fish in comparatively poor condition leave the sea for our rivers. This in all probability means that the nature of the food taken in the sea has been poor in quality, or, less probably, scarce. Further, the common occurrence of so-called bull-trout entering our rivers from the sea, pale in flesh, often of great size, and having both the gill maggots common to the kelt and the sea lice of the fresh run fish upon them, suggests the belief that amongst fish which adopt the short migration there are those which do not adopt the generous feeding habits of the silvery well-conditioned migrant.

Such considerations as these seem to me to prompt a certain reserve in accepting the conclusions of Dr. Noël Paton that it is the state of nutrition alone which is the factor determining migration towards the river. We have dwelt at considerable length, in the chapter on the results of salmon marking, on the habit of long and of short periods of sojourn in the sea. Since a salmon in any year can clearly become fully nourished during the time of a short sojourn in the sea, why should it stay an extra year in salt water? The state of its nutrition does not supply a sufficient reason. The corollary to the view advanced by Dr. Noël Paton is expressed by him thus: "When the salmon has accumulated the necessary supply of material it tends to return to its original habitat." That the salmon is a native of fresh water, in the sense of being born there, I of

PLATE VII.—A salmon-marking crew on the Helmsdale, Sutherland, the river just clear of ice.

course freely admit ; but, as suggested in the chapter on grilse, it is possible to regard the first seaward migration as a movement to the salmon's original habitat, *i.e.*, the habitat from which our salmon as we now know it, along with its near allies, took its origin in remote times. The shad is a sea fish which visits our rivers to spawn. The sparling or smelt must be similarly regarded, and is more nearly related to the salmon than the shad. Attempts at producing fertile salmon without allowing them to visit the sea easily fail, and when successful, result in degenerate creatures which do not support the idea that they represent the prototypes of fish from which the evolution of our salmon has sprung. The vigorous growth and development in the sea, on the other hand, and the fact that the salmon spends most of its time in this element, along with the arguments already cited in the chapter on grilse, from the systematic study of the salmon family, incline me to the view that the sea was the original habitat of *Salmo salar,* as it undoubtedly was of most of the salmon family.

If this is so, there is nothing forced in the belief that the long migration fish, continuing in the sea as it must do long after its tissues have become fully nourished, and as the study of the scales certainly indicates, is simply living in its natural habitat. At the same time, I do not consider that the *nisus generativus* prompts the spring fish to enter fresh water. The late running fish which has already developed its genitalia in the sea may be said to visit the river for the purpose of spawning, but the

species *Salmo salar* I regard in general terms as a sea fish which freely enters fresh water after it has received the nourishment and stimulus the sea alone affords, which frequently, owing to the highly charged state of its nutrition, spends many months in fresh water, and which spawns before again returning to the sea.

CHAPTER VI

THE SALMON AND WATER TEMPERATURE

Early and late rivers—Rivers made late by man—Temperature of the sea round Scotland—Temperatures of early and late Scottish rivers—Temperature of water no indication of seasonal character—Effects of temperature on fish ascending rivers—Early runs of fish in upper waters, Garry and Orchy—Effects of cold water upon ascending fish—The entrance of tributaries from main river—Rapid ascent of summer fish—Sea lice may remain attached for four or five days

THE theories which have been advanced to explain the diverse seasonal runs of salmon into fresh water—why in some rivers there should each year be early runs of fish, and in others only late runs—have, with I think one exception, been based upon considerations of water temperature. The exception is the ingenious but unsupported theory of the late Frank Buckland, that the seasonal character of a salmon river depends on the length of the river in proportion to the square mileage of its drainage area.

At the outset, in the consideration of this question, I would point out that we are at the present day by no means certain that the real seasonal character of some rivers can be properly interpreted by the existing conditions. Certain rivers are described as late rivers, and have no doubt been found to be late

rivers for a very long period; but it is quite possible, and I would venture to say in many cases very probable, that the cause of the late character has nothing whatever to do with the physical conditions of the rivers, but is purely the result of the influence of man in his treatment of the fisheries, and that as the treatment has continued on the same lines within the memory of man, so no one has ever known or heard of early runs of fish in those rivers. One might instance the case of the river Leven, which flows out of Loch Lomond into the Clyde at Dumbarton. This river has for a very long time been considered a late river, and there are old records of Dumbarton fisheries which point to this conclusion. A thriving dyeing and bleaching industry has long been established, gross pollution has resulted, and net fishing at the mouth of the river has been steadily carried on. But of late years an active and I may add a philanthropic angling association, which allows all anglers to participate in the sport which the loch affords, has done something to improve the general conditions and the stock of fish, with the result that early fish are appearing. In other cases where serious over-fishing has been allowed to continue rivers have naturally acquired a late character. With over-fishing, or other causes of reduction of breeding stock, the first class of fish to disappear is the spring run. We are therefore not safe in presuming that in all cases when we do not find a spring run the river is a late one. We must satisfy ourselves first that the river has every chance of bearing a full stock of fish.

In Scotland—and concerning questions of tem-

perature in relation to salmon fisheries I write exclusively of Scotland—we may say broadly we do not find a regular run of spring fish in small rivers, even although these rivers are well stocked, and pure, and in no way over-fished. In rivers of moderate size we, for the most part, find only occasional runs of rather late spring fish. But in the larger and more important rivers, Tay, Dee, Ness, Beauly, Brora, Helmsdale, Thurso, Naver, we have regular and steady runs of spring fish. In these rivers also we have, besides considerable volume of water, comparative purity—in the Highland rivers named we may say complete purity—and an apparent absence of over-fishing. In a river like the Tweed there is too much netting to allow of the entrance of many springers, or of their passage upwards to the safer head waters. Other rivers might be mentioned which like the Tweed should, in my opinion, have many more spring fish; but to mention individual cases would be to depart from the question of temperature.

The fact that the first-class rivers above named flow either to the east or north has suggested the theory that the cause of the early entrance of salmon lies in the fact that the sea on this side of the country—the North Sea—is a colder sea than the Atlantic Ocean on the west coast, and that the rivers, flowing, as many of them do, through long stretches of not very high land, are comparatively warm, being free from the great admixture of snow water which in spring passes off from the high West Highland hills, and that the salmon therefore prefer to leave this cold North Sea at an earlier time than

do the salmon in the warmer Atlantic. The theory sounds plausible, but in accepting it one has to presume that the salmon prefers warm water to cold. The more crude idea that early rivers are those which flow out of large lochs is an offshoot of the same theory, and may be dismissed at once by merely noticing how many early rivers do not come out of large lochs, and that practically all the late rivers of the West Highlands do. A third idea which has been developed at considerable length, more especially in magazine articles, is that the ascent from sea to river takes place when the temperatures of the salt and fresh water approximate. We have therefore the physiologist stating that the condition of nutrition determines the "return" from the sea, and the physicist stating that the influence of temperature alone determines the same movement. I have already referred to the question of nutrition, and have shown that in my view it is not a complete explanation of the habit of ascent from sea water. In examining the theories as to temperature it is remarkable how much of theory and how little of fact is to be found. Only in arguments as to the approximation of sea and river temperatures do we find a genuine attempt to deduce from thermometric readings. When such readings are taken in sufficient numbers to show the real conditions which usually obtain, it becomes at once evident that the idea that salmon are drawn, as it were, from a cold sea by and to a warm river must be given up. The facts show that at the time when early fish are running all our rivers are much colder than the sea on either coast.

A most exhaustive series of sea temperature records are available, and, as shown at some length in the nineteenth Annual Report on the Salmon Fisheries of Scotland, the monthly means for January, February, March, and April range on the east coast from 39° to 44° F., the lowest monthly mean of the whole year being in March, while on the west coast it is evident, on the high authority of the late Dr. Buchan, that "from October to March the west is at least 2° above the east, and in January it amounts to 3·9°. It is an event happening only once in a number of years for the temperature of the sea in the west to fall below 40°, but in the east this happens every year." * In the west the three coldest months of the year are in order February, March, and January. The statement that the North Sea is, as compared to the ocean water on the west coast, a cold sea in the early months of the year, when spring fish run, is therefore supported by facts. It is when we examine river temperatures during those early months —which the theorisers referred to omitted to do— that we find an entire absence of any warm water to draw fish as supposed.

A series of maximum and minimum morning and evening readings taken from instruments kept constantly immersed for four years—1880–1884 inclusive—in the Helmsdale and Brora, early rivers of east Sutherland, were kindly placed at my disposal by the Scottish Meteorological Society. From these we find † that the Helmsdale and Brora waters

* Jour. Scot. Meteor. Soc., vol. i., N.S., 1863–66, p. 263.

† Nineteenth Annual Report, Fishery Board for Scotland, II. p. 70.

are in January and February from 5° to 10° colder than the sea. In March and April the conditions become more unsettled, and sudden and rather violent fluctuations are common (melting snow, frost, rain floods). A variation of 8° in the twenty-four hours is not uncommon. On an average, however, the river water is 4° colder than the sea. The Thurso is another well-known early river. Temperatures for the complete year 1886 were taken at three points, at the mouth, half-way up, and at the head, together with sea temperatures for the same period.* In January and February the river mean is 6° to 9° colder than the sea, and not till April do the river and sea temperatures equalise. Readings from the Dee show the same result, as also do readings from the Tay and Shin, although from these rivers the series of temperatures is not so long as from the Helmsdale and Brora. A series of valuable readings for ten years taken in the Ugie bear out, however, a precisely similar result.† Lest, however, it should be imagined that, with the greater fluctuation in river than in sea, periods occur, even in the early months of January and February, when river temperature equalises with sea temperature, it may be said that, the daily readings show that the river water is constantly colder than the sea. In those east coast rivers, therefore, the early running fish leave a cold sea for a considerably colder river in their migration to fresh water.

* Jour. Scot. Meteor. Soc., III. No. iv., 1886.

† Nineteenth Annual Report, Fishery Board for Scotland, II. p. 72.

With regard to the west coast rivers, which were supposed to be colder in the early months of the year, I may cite first the Laxford in west Sutherland. I have complete readings from this river, taken in 1880, and am therefore able to compare it with the Helmsdale, Brora, and Shin in east Sutherland in 1880. The Laxford flows out of Loch More, is considered the finest salmon river of the North-West Highlands, but is late. A comparison of the daily means of those rivers shows that the Laxford is subject to rapid fluctuations, as the Helmsdale is, and in this respect differs somewhat from the Brora and Shin. The latter, it must be recollected, has a very large reservoir at its head in the shape of Loch Shin, while the actual readings for the former were taken at a constriction of Loch Brora. When, however, curves are plotted representing the daily means of each river,* it is noticeable that they do not separate from one another in any marked way, and that the inclination of the Laxford curve, the western late river curve, is very similar to that of the Brora curve. In other words, the temperature conditions ascertained to exist in the Laxford are very similar indeed to the temperature conditions of the three early east coast rivers with which it is compared.

The great advantage of being able to compare late and early rivers on opposite coasts of the same country in the same year is further enhanced by the fact that the Helmsdale, Brora, and Laxford are first-class natural rivers, each bearing a full stock of

* Twentieth Annual Report, Fishery Board for Scotland, II. p. 12.

fish, each unspoilt by man. In a search for a really warmer river, I have been fortunate in obtaining a valuable series of temperature readings from the Nith, which flows into the Solway. These were taken for me by Rev. Mr. Andson, of Dumfries, in 1902, and I am able to compare them with Tay readings for the same year. In the early months of the year the Nith is distinctly warmer than the Tay, and the Nith is a late river, but unhappily it cannot be said to be a river in which the natural supply of salmon is unimpaired. The salmon fisheries of the Nith district have suffered much at the hands of man. In this same year, however, 1902, temperatures were taken in the river Ness, which is a well-stocked early river, supplied from one of the largest and deepest lochs in Scotland, and the Ness temperature shows a marked difference from that of the Tay. Curves have been plotted for each river,* from which it is at once noticeable that while the Ness shows a comparatively flat curve never falling below 42°, the Tay curve at Perth shows acute inclination with a minimum at freezing point (32°).

We see therefore, from a comparison of the ascertained thermal conditions of those rivers, that east coast early rivers do not show any marked difference from late west coast rivers when the selection is made in Sutherland alone; and second, that east coast early rivers in different parts of the country, subject to different physical conditions, show widely different temperatures with minimi as much as 10° apart. It

* Twenty-first Report, Fishery Board for Scotland, II. pp. 76 and 82.

has therefore seemed to me that the natural deduction may be said broadly to be that temperature has nothing to do with the seasonable character of a river in Scotland, in so far as the actual entrance of salmon from the sea is concerned. The primary causal factor in the existence or absence of an early run of fish is not the prevailing condition of temperature. Once a fish has entered the mouth of a river fluctuations of temperature exercise a distinct influence, as we shall presently see, but in the making of an early or of a late river temperature does not appear to play a part. Large and deep lochs naturally exercise their influence on the temperatures of rivers which flow out of them—such lochs have relatively high mean temperatures; but apart from such conditions, the temperature of a river follows close, so to speak, upon the heels of the air temperature of the surrounding district; and if a warm river were the chief cause of early runs of fish the small streams of the western isles should of all others be early streams, and the rivers in the south-west of Scotland should also be all early rivers. As observed at the commencement of this chapter, however, small streams are never early streams. A certain volume of water and a good stock of fish are essentials for the early run. Given these two conditions, the time at which early fish will enter fresh water may still be subject to some variation in different districts. On the east coast and in the Pentland Firth salmon may draw to the shore rather earlier than they do on the west coast, the habit in the sea where circumstances determining the growth

and movements of marine creatures, including salmon, and the forms upon which they feed, may be in some slight degree different, but given these two conditions an early run will be present. The main circumstances of life in a small country like Scotland are, however, practically the same.

We may now regard the influence of temperature upon the salmon when the mouth of the river has been entered. In this connection there are two aspects of the question which may be considered, first the ascent of the main river, and second the entrance of tributaries. Apart from the test of temperature, it will be recollected that at the close of the last chapter the results of marking clean run fish were dealt with, and evidence produced to show that such fish may remain two or three months in the rapid lower waters of a river such as the Spey without making material ascent. From the Tay similar evidence was gathered, but the pause in the ascent appeared to be less prolonged. In now extending the range of observation, and considering the application of the temperature test to this question, we are able to see that there are other rivers in which this pausing habit does not apparently obtain. The habit of the early fish seems to vary considerably in different districts. We have already noted that Tay fish ascend to Loch Tay and remain there till May, when they continue their ascent by entering the Dochart. As a contrast to this we have early Ness fish passing quickly through the short river Ness into the loch of the same name (which is the deepest but one in Scotland), but, unlike the Tay fish, passing on out of Loch Ness

into the river Oich, out of the Oich into Loch Oich, and out of Loch Oich into the famous river Garry, which forms the head waters of the Ness system. The Garry is the spring fishing river of this district. On the west coast we have an analogous condition appearing in the Awe district. Early fish pass through the river Awe into Loch Awe, and are checked in this ascent only after they have entered the river Orchy above the loch. The Garry and the Orchy are rivers of considerable size, although each is some distance from the sea. In each there is a fall, beyond which fish do not commonly pass till about May. Now, why do Tay fish remain in the lower river and loch during the spring months, and Ness and Awe fish ascend to the upper feeders of their districts ?

In order to ascertain the thermal conditions of the river systems referred to, I arranged for the taking of morning and evening maximum and minimum readings from thermometers kept constantly immersed in the Ness and the Garry and in the Awe and the Orchy. At the same time temperatures were taken in the Tay and in one or two smaller river systems. The Garry rod-fishing opens early in February, and at that time each year the river is well stocked, although in exceptionally cold springs there may be more fish in Loch Oich than in the Garry. In the Awe, fish do not usually ascend till March, and are not expected in any numbers in the Orchy till April. It is highly probable that with a fuller stock of fish in the district more earlier fish would appear. The readings procured from these districts

are of great interest as showing that in each case the lower river which flows from the large loch into the sea has a markedly higher temperature than the river above the loch. It is noticeable also, when the charts which were prepared * are studied, that the curves representing the mean weekly temperature of the Ness and Awe (the lower rivers) are more uniform in line or less quickly fluctuating than are the curves for the upper waters. The Ness curve during January, February, and March shows a wonderfully flat inclination. The temperatures were taken November 1901 till end of May 1902. I will refer first to the Garry and Ness readings. From the middle of December to the end of March the weekly mean of the Garry never exceeds 40° F., and in the middle of February, when the river was very low after four weeks of continuous frost, the reading reaches 35°. In April and May there is a steady rise of temperature. The curve for the Ness runs, however, at a distinctly higher level. In December, January, February, and March there is constantly from 2° to 8° difference in the readings. By the middle of April the temperatures of the two rivers have approximated by the rise in temperature found in the Garry, the upper and early river. On referring now to the curves representing the Orchy and Awe temperatures, we notice first a much greater fluctuation in both curves, but the same general result. The Orchy is colder by 2° to 9° than the Awe, and by the middle of April the curves approximate by

* Twenty-first Annual Report, Fishery Board for Scotland, II. p. 76.

the rise in temperature of the lower line, which represents the Orchy or upper water.

Now, from a constant record of temperatures taken in the Tay at Grandtully by Mr. Johnston between 1895 and 1903, coupled with statements as to the results of spring angling, it has been possible to produce a table showing the maximum and minimum readings for each of the early months of the years referred to, and to compare the seasons in respect of the ascent of spring fish.* The year 1896 was a good spring fishing year, when "fish were early and ran quickly." Only once, in January, did the temperature reach as low as 36°, the lowest readings in February, March, and April being respectively 39°, 40°, and 43°. The highest readings for the four months were respectively 41°, 44°, 43°, and 51°. The average of the maximum readings is 44·7°, and of the minimum readings 39·5°. Poor fishing years when compared to this show at least 3° lower temperature in both maximum and minimum averages. In other words, with the river temperature commonly above 40° in the first four months of the year salmon are running up freely and quickly, and the stock of spring fish is largely dependent upon favourable conditions for ascent in January before the opening of the netting season. This is exactly the condition we find in the Ness and Awe, and we are not surprised to find that the early fish of those rivers run quickly through the few miles of water (each river is only about six miles long) into the large lochs, where the temperature of the water is

* *Loc. cit.*, p. 78.

not greatly different, except possibly at the extreme upper ends. When, however, the fish essay to ascend farther, they are met by distinctly colder water, and their progress is at once checked, till, the particular time when the winter conditions of those upper rivers having passed, they find themselves once more willing to travel and overcome obstacles in their course. The rivers Garry and Orchy are the early rivers of their districts, therefore, because all the lower waters are of such a relatively high temperature as induces rapid ascent, while the Garry and Orchy are of a temperature which in Scotland produces a check upon early ascent. Added to this we must not forget that small falls exist in each case. Spring fish are no jumpers till summer conditions have come about.

Apply this interpretation to the Tay and its upper water, the Dochart, and we see that while the main river, with its course of some 50 miles, receives various large tributaries, and has a general temperature in the first four months of the year which at times induces fish to run and at times checks their running, thus naturally securing to this fine river a distribution of spring fish, the Dochart—which has a fall upon it a short distance above Loch Tay—is exactly analogous to the waters of the Garry or Orchy above their respective falls. Fish therefore, if we argue by analogy, should, as in the Garry and Orchy, ascend the Dochart fall when the wintry conditions have passed. This is, as a matter of fact, exactly what happens, for the Loch Tay fish begin to go up the Dochart in May.

Reference in this connection may be made to one other river, the Helmsdale, which, since it differs in physical features from the rivers already referred to, may stand as a further example of how this conception of salmon ascent as affected by temperature works out in Scotland. Here there is no large loch in the course of the main ascent. Two streams come from two lochs at practically the extreme head waters, and unite to form the main river, which has then a course of about 20 miles to the sea. About half-way down this main river, however, there is a fall. What we find here is that the early fish enter freely from the sea and slowly make their way upwards, but do not ascend the fall. All the spring fishing is between the fall and the sea. When, however, the wintry conditions of water have passed, the ascent of the fall is freely made, as in the upper waters previously referred to, so that summer angling is carried on in the entire length of the river. Falls such as we have been referring to are therefore not serious obstructions to fish when the water is comparatively warm, but are total obstructions when the water is cold. Such a statement, I must again remind the reader, applies to Scotland; it would, I believe, be entirely erroneous in a country like Norway, where all salmon, although late, ascend obstacles in the cold water which comes from melted snow. Salmon passes on such Scottish falls, to be of any use, must be of extremely easy gradient, so that fish may readily swim them, and at the same time they should contain a large body of water.

We have now to consider the part water tempera-

ture seems to play in the entrance of tributaries by salmon which have ascended a main river. This subject has been chiefly studied in the Tay, and no river in Scotland seems to offer better facilities, since the tributaries of the Tay are numerous, and are in several instances rivers of considerable size, which present varying physical conditions. Readings were taken in the main river at Perth—which is at the mouth, but at the top of tide reach—and at Grandtully about forty miles up stream. Above Grandtully the river Lyon enters, and in this readings were taken. Below Grandtully the river Tummel enters, carrying with it the water of the Perthshire Garry, and in both of these were readings also taken. Curves were plotted for each series of readings. Of the two from the main river it is noticeable that the curve from the mouth of the river is lower than that for the upper river. This is no doubt caused by the entrance of the large tributaries below Grandtully, the Tummel and Garry, and the Isla, but especially perhaps the Almond, the waters of which are found to be colder than the waters of the other Tay tributaries. The Lyon alone shows a curve of temperatures very similar to the Tay. All other tributaries for which readings are available are found to be colder. Loch Tay, from which the main river springs, is $14\frac{1}{2}$ miles long, and has a mean depth of 199 ft. and a maximum depth of 508 ft. The water which flows from this large loch is naturally much more uniform in temperature than is the water of rivers draining high surrounding land. A chart of curves showing

weekly means for the Tay at Perth and at Grandtully, and for the Lyon and Garry, is given in Part II. of the Twenty-first Fishery Board Report, and it seems unnecessary to enter here upon a detailed account of the readings from each locality.

In general terms the results show, as compared to the main river, the Grandtully curve of which is comparatively high, that in descending order of temperature we have first the Lyon, then the Tummel, and last the Garry. It is therefore of some interest to realise that early fish in ascending the Tay are found on the opening of the angling season, January 15, not only in the loch, but in the river Lyon, which, as we have seen, has a temperature closely approximated to that of the upper Tay and loch. Next, a limited number of fish are found to be already entering the mouth of the Tummel and pausing in the deep pools of Easthaugh Water there, but that as the temperature of the colder Garry rises so as to approximate to that of the Tummel, fish more freely ascend the Tummel and then enter the Garry. This last emigration does not usually take place till April, although a few fish may be found in the deep pools of the Pass of Killiecrankie in March. Moreover, in unusually warm springs, when all the tributaries are, as it were, advanced in temperature, the times at which fish ascend are, while unaltered in order of river, earlier in point of season; and conversely in cold seasons the stock of early fish is delayed in their ascent of the tributaries. If therefore in early winter much snow lies on the hills drained, say, by the Lyon, so that that river

has a temperature a few degrees lower than the Tay water, a good stock of spring fish may not be expected in Glen Lyon at the opening of the season; but, other things being equal, it is found by actual thermometric readings that the order in which fish enter the Tay tributaries, in cases where free access is at all times possible, is precisely the order of descending temperature. To state the case in more general terms, it may be said that the tributaries referred to are not entered by early fish till their temperatures have become approximated to the temperature of the main river near the influx of the tributaries.

It might further be noticed that the tendency of the early salmon in making his steady ascent of such a river as the Tay seems to be to pass by tributaries which enter the lower reaches, and especially to pass by tributaries of small size. I know of no instance in Scotland of early fish entering tributaries near to the mouth of the main river, as autumn fish undoubtedly do. In the Spey, for instance, the tributaries of Fiddoch and Avon are frequently crowded with late running spawners, but they never contain spring fish. In the Tay the tributaries Almond and Isla, both large enough to hold spring fish, are passed by, but there may be other reasons, since the former, as we have seen, is a cold river, and moreover is too much obstructed to make the ascent of spring fish possible, while the latter, for which I have no temperature records, is provided with a poor mouth.

In other cases which might be cited there is some uncertainty in determining whether a river

should be considered a tributary or a separate river entering a common estuary. This is the case with the Earn, which enters the tidal waters of the Tay, and but for obstructions in the Earn I believe that spring fish would ascend more freely than they do. In the case, however, of the Lochy on the west coast we have another instance worth referring to. The river Lochy formerly flowed naturally from Loch Lochy into the sea near Banavie; when, however, the Caledonian Canal was constructed the course of the Lochy was to some extent utilised, and the river was given a new and artificially cut channel from the loch into the Spean at Muccomer. The Spean, coming as it does from the very high land to the north and east of Ben Nevis, is a cold river, while the Lochy water, like the Ness at the northern end of the great chain of lakes which form the Caledonian Canal, is warm. Early fish ascend the Lochy to Muccomer, and there pause. They are, unfortunately, obstructed by a fall with a very inadequate fish pass from farther ascending the Lochy, so they remain in the large Muccomer pool till the Spean water has lost its forbidding temperature, when they ascend that river. Such fish as do manage to ascend the Lochy do not do so before the ascent of the Spean is well begun. The reason for this has already been explained. We see, therefore, that while early as compared with late rivers appear to present no definite distinction of temperature, the habits of ascent in all rivers are very considerably influenced by thermal conditions. All our Scottish rivers are colder than the surrounding

seas in the winter months, but by the month of April have risen in temperature so that the readings in fresh water and the sea become equalised. Subsequently, through summer, our rivers attain a temperature considerably above that of the sea, but by the month of September their temperature has again fallen so that the conditions of sea and river again equalise—although now at a higher temperature than in April. From September onwards the winter conditions again become slowly established.

During the warm conditions of summer, fish ascending from the sea run up much more rapidly than when the river temperature is low. Even in May, fish are not infrequently taken well up our rivers, *i.e.*, thirty to even forty miles up, and still bearing sea lice upon them, and with other unmistakable signs of having only very recently left the sea. By this time the spring fish are making their way to the head waters, where, as the season advances and their reproductive organs develop, they become distributed in the manner so valuable for the river's future stock. The summer fish having rapidly moved up from the lower waters, the late running fish, which enter from the sea with their genitalia already well advanced—the male fish being at the end of the season not infrequently highly coloured, as they come from the sea—have, as it were, those lower reaches left to them. In this way, therefore, the waters of a well-stocked pure river are fully taken advantage of for spawning, and are able to return their best percentage of fry from all classes of fish.

In the summer of 1906 an experiment was made at my request in the laboratory of the Fishery Board at Bay of Nigg, near Aberdeen, to test the length of time sea lice will remain attached to those summer fish which so rapidly ascend in the comparatively warm conditions referred to. Two grilse were obtained from a bag-net in the Bay of Nigg, and placed in sea water in a tank of the hatchery. The temperature of the water was 52·9° (11·6° C.). Each fish had attached to it a number of sea lice. The density of the water was then reduced by allowing fresh water to enter. This operation was regulated so as to represent approximately in time the period of a single flood tide. The fish showed considerable distress at first, from which it is natural to suppose that the transference to brackish water was too rapid, and that in all probability an interval of some twenty-four hours or so—as had originally been intended—would have been more natural.

The sea lice may also have been adversely affected by the rapid transference in eight hours to pure fresh water, but in spite of this some of the sea lice remained attached for six days. Dating from the time when the water was quite fresh, the sea lice remained on one fish for four days and on the other for five days. The fresh water temperature was 55° F.

The constant action of the current of a river under natural conditions of a fish's ascent may cause the parasites to drop off somewhat sooner, but the experiment shows that a fish taken in upper waters with one or two sea lice attached may have occupied at least three or four days in its passage from the tide.

APPENDIX

A RECORD OF SALMON-MARKING OBSERVATIONS IN SCOTLAND PREVIOUS TO THE OPERATIONS OF THE FISHERY BOARD IN 1896.

Marking salmon for the purpose of gaining information as to their migratory movements and their increase in weight has been practised for a considerable time. Izaak Walton in his "Compleat Angler" (1653) alludes to experiments of this kind in which ribbons were tied to the tails of young salmon, and by which it was ascertained that salmon return to the same locality after visiting the sea. Writers of a later date do not always specify the method of marking, although they state results which would be of great interest were the proofs of their infallibility absolute. A considerable amount of reliable information has, however, been obtained from time to time in Scotland—exclusively, I think, on migration and increase of weight—and I have attempted to collate this information in the form of a list with tables. I omit from the list references to smolt marking, as well as any records which are without such particulars as alone can render them of value.

Previous Scottish Salmon Marking.

1823. In March, Mackenzie of Ardross marked a grilse kelt of $3\frac{1}{2}$ lb. The mark was of brass wire.

In twelve months the fish was recaptured as a salmon of 7 lb., showing an addition of $3\frac{1}{2}$ lb. in weight.

1824. Mackenzie of Ardross marked a salmon kelt. The mark was wire round the tail.

In 1825 he reports it as having been recaptured "double the size."

1829. In February, Fraser ("On the Salmon") reports marking a number of grilse kelts, estimated as of 5 to 6 lb. Marking was done by cutting off the adipose fin.

In nine months he reports the capture of one as a salmon of 13 lb., showing an addition of 8 lb. in weight.

This return must be received with caution.

1830. In February, Mr. Fraser (*ibid.*) reports the marking of grilse by fastening wire round the tail. Grilse presumably 5 to 6 lb.

In six months one was recaptured as a salmon of 14 lb., two witnesses being cited who saw the fish and wire.

1834. Shaw at Drumlanrig marked 524 sea trout in the herling stage. Marking was done by fin cutting. One fish is reported to have been recaptured in the three successive years in a cruive in the Nith. The markings were:—

1834, adipose fin removed.
1835, third of dorsal fin removed.
1836, half of anal fin removed.
1837, fish was killed,

being afterwards exhibited at the Royal Society of Edinburgh, *vide* Trans. R.S.E., vol. xv. part iii. p. 369; weight 6 lb.

Of the 524 marked in 1834, 68 were reported recaptured in 1835, averaging $2\frac{1}{2}$ lb. in weight.

1835. The 68 recaptured sea trout above referred to were remarked by fin cutting.

One in 20 are reported as recaptured in 1836, averaging 4 lb. in weight.

Also 120 sea trout were marked by Shaw in this year, 60 being marked with copper wire on the dorsal fin, and 60 with copper wire round the right maxillary bone.

Of the latter group five recaptures were made in the summer of 1836, the average increase of weight being stated as $1\frac{1}{2}$ lb.

1841. and 1842. Young of Invershin marked grilse and recaptured salmon as under (Trans. Royal Society, Edinburgh, read January 9, 1843). The manner of marking is unfortunately not specified.

LIST OF GRILSES MARKED IN THE RIVER SHIN, AND RECAPTURED AS SALMON ON THEIR SECOND ASCENT FROM THE SEA IN THAT RIVER.

MARKED.	RECAPTURED	WEIGHTS WHEN	
		Marked.	Recaptured.
February 18, 1841 .	June 23, 1841 . .	4 lb.*	9 lb.
February 18, 1841 .	June 25, 1841 . .	4 ,,	11 ,,
February 18, 1841 .	June 25, 1841 . .	4 ,,	9 ,,
February 18, 1841 .	June 25, 1841 . .	4 ,,	10 ,,
February 18, 1841 .	July 27, 1841 . .	4 ,,	13 ,,
February 18, 1841 .	July 28, 1841 . .	4 ,,	10 ,,
March 4, 1841 . .	July 1, 1841 . .	4 ,,	12 ,,
March 4, 1841 . .	July 1, 1841 . .	4 ,,	14 ,,
March 4, 1841 . .	July 27, 1841 . .	4 ,,	12 ,,
January 29, 1842 .	July 4, 1842 . .	4 ,,	8 ,,
January 29, 1842 .	July 14, 1842 . .	4 ,,	9 ,,
January 29, 1842 .	July 14, 1842 . .	4 ,,	8 ,,
March 8, 1842 . .	July 23, 1842 . .	4 ,,	9 ,,
January 29, 1842 .	July 29, 1842 . .	4 ,,	11 ,
March 8, 1842 . .	August 4, 1842 .	4 ,,	10 ,,
January 29, 1842 .	August 11, 1842 .	4 ,,	12 ,,

1845. Lord Glenlyon, afterwards Duke of Atholl, marked on March 31 a kipper fish of 10 lb. It was marked with a *zinc* label, and is reported by Ramsbottom to have been recaptured in less than six weeks weighing 21¼ lb. (? W. L. C.)

1847. March 27, the Duke of Atholl marked a 15 lb. kelt in the Tay. It was recaptured on February 20, 1848, as a clean fish of 20 lb.

March 28, marked a kelt of 11 lb. It was recaptured on July 24, presumably the same year, as a clean fish of 18 lb.

March 3, marked a kelt of 14 lb. It was recaptured on September 7, presumably the same year, as a clean fish of 21 lb.

1851. The Duke of Atholl marked, on February 26, a kelt of 10 lb. It was recaptured, a clean fish of 12 lb., on February 17, 1852.

* Grilse of weights other than 4 lb. were rejected.

1854. The Duke of Atholl marked an 11 lb. kelt on March 21. It was recaptured as a clean fish of 17 lb. near Montrose on August 24, 1854.

1851 to 1872. During those years a large number of fish were marked by the Experimental Committee of the Tweed Commissioners. The table which follows (pp. 152 to 156) is taken from the Tweed Salmon Reports, 1866. It is given in full, although it contains reference to a few marked smolts. I have added a column as to the nature of the mark used, so far as this can be determined from the Report.

1857. On November 12, Mr. Buist, Stormontfield, river Tay, while netting for ova, marked 89 salmon and 78 grilse with copper wire (where on the fish is not stated).

On September 6, 1858, one was caught in Largo Bay, 13½ lb. in weight. No particulars of each fish seem to have been taken.

1858. March 31, Young of Invershin reports that a grilse marked on that date was recaptured as a salmon of 8 lb. on August 2 in the same year.

1859. The Duke of Atholl marked fish on the river Tay. A numbered copper disc, an inch in diameter, or¦ gutta-percha ticket fastened by copper wire round the tail was used. The following fish were marked as kelts and recaptured as clean fish the same year :—

MARKED.	DATE.	WEIGHT.	LENGTH.	DATE OF RECAPTURE.	WEIGHT.
No. 21	Feb. 14	10 lb.	36 in.	Aug. 18	17 lb.
,, 76	Mar. 2	11½ lb.	35½ in.	Aug. 18	17 lb.
,, 95	Mar. 29	12½ lb.	37 in.	Aug. 12	19 lb.

1860. Through the kindness of the present Duke of Atholl I am able to add particulars of another fish, the mark taken from which I have seen. I add also the lengths of the three fish above referred to.

No. 133, marked on February 12, 1860, a kelt, 8 lb., caught at The Rock, Dunkeld, 34 inches long by 12 inches girth. This fish was taken again in the river Tay, but the mark and the particulars at time of recapture were not sent to Blair Castle.

1861. Also, on February 25, a kelt of 13 lb. was marked. It was recaptured as a clean fish of 26 lb. on August 11, 1862.

1863. On March 30, at Dunkeld, one of the Duke of Atholl's marks was attached to a kelt $5\frac{1}{2}$ lb. in weight and 28 inches long. It was recaptured at Rossie, in Montrose Basin, on July 17 of same year—a lanky male "bull trout" of 7 lb.

TWEED EXPERIMENTS—1851–1872.

Date of Marking.	Kinds Marked.	Recaptured.	Where.	Kind and Weight.	Nature of Mark.
1851, April or May	Smolt	1852, August 17	Wilford	Grilse, 4½ lb.	—
„ „	Two Salmon Smolts	„	——?	Grilse 3½ and 4 lb.	—
1852 „	Salmon Smolt	„ July 26	Ethermouth	Grilse, 7 lb.	Fin cutting.
„ „	"Orange-fin" or Trout Smolt	1854, May 11	Finchey	Clean bull-trout, 5 lb.	—
„ „	Two „ „	„ March 28	Newmills	Trout Kelts, 3 and 3½ lb.	Fin cutting.
„ March 29	Bull-trout Kelt, 3 lb.	1852, April 2	Yarmouth	Trout 3½ lb.	Numbered gutta-percha label attached above tail by india-rubber ring.
„ „	„ „ 3 lb.	„ „	Shields	„ 4½ lb.	
„ „	„ „ 10 lb.	„ August	Eyemouth	„ „	
1854, Spring	Smolt of one ounce	1855, July	Wilford	Grilse, 3½ lb.	Wire in tail fin.
1855, January 17	Bull-trout Kelt marked at Floors	„ April	Finchey	Kelt, 3½ lb.	Numbered label on operculum.
„ May	Sea trout Smolt	1856, August	Ethermouth	Sea trout, 1¾ lb.	Silver wire in operculum.
„ „	Salmon Smolt	„ August 6	Meadowhaven	Grilse, 6½ lb.	„ „
„ „	„ „	„ „	Goswick	„ „	—
„ „	Two Salmon Smolts	„ Summer	—	Grilse, 5½ and 6½ lb.	Probably wired.

TWEED EXPERIMENTS—*continued.*

Date of Marking.	Kinds Marked.	Recaptured.	Where.	Kind and Weight.	Nature of Mark.
1857, May 15	Bull-trout Smolt	1858, May 25	Carr Rock	Bull-trout, 3 lb.	Silver wire in upper jaw.
„ „	Salmon Smolt	„ August 9	Hallowell	Grilse, 3½ lb.	„ „
„ „	Bull-trout Smolt	„ „ 28	Hallowstell	Bull-trout, 3¼ lb.	„ „
1858, January 19	Baggit Grilse at Tweedmill	„ April 10	Abbotsford	Grilse Kelt	Gutta-percha label?
„ March 31	Grilse Kelt 2 lb., at Scotch New Water	„ August 2	Carham	Salmon, 8 lb.	„ „
„ May 12	Salmon Kelt 9 lb., at Scotch New Water	„ July 8	Finchey	„ (clean), 13 lb.	„ „
„ Autumn	Three "Blacktails,"	1861 „	*Aberdeen	Whitling, 2 to 3 lb.	Galvanised wire in upper part of "nose."
1859, October	"Blacktail," 8 to 12 oz.	„ March 16	Horncliffe	Whitling, 1½ to 2 lb.	Copper or galvanised wire in "nose."
„ „	„ „	„ August	North Esk	„ „	Silver wire in "noses."
1860, Spring	"Trout" Kelt (Bull?)	„ July 1	South Bells	Trout, 6 lb.	Label on wire through operculum.
„ „	"A Fish"	1864, May	—	Salmon, 9¾ lb.	„ „
„ „	„	1861, May 9	Scotch New Water	„ 6½ lb.	„ „
„ „	„	„ August 21	Hugh Shiel	„ 6¼ lb.	—

* Montrose 2¾ lb., River Don, and Cove.—W.L.C.

TWEED EXPERIMENTS—*continued.*

Date of Marking.	Kinds Marked.	Recaptured.	Where.	Kind and Weight.	Nature of Mark.
1862, Spring	"Orange-fin" or "Silver-white" Smolt	1863	—	Blacktail	Probably wired.
„ Autumn	"Blacktail"	1864, July 4	Wilford	Clean Trout, 3¼ lb.	Wire in "nose."
1864, Spring	"Trout" Kelt	„ „ 2	Needle Eye	„ 3½ lb.	Wire in upper jaw.
„ „	„ „	„ „ 5	Meadowhaven	„ „	„ „
„ „	„ „	„ „ 20	Yarrow	„ 3¼ lb.	„ „
„ „	„ „	„ „ 28	Bailiff's Bet	„ 2¾ lb.	„ „
„ „	Grilse Kelt	„ August 16	Low Bells	"Grilse," 5 lb.	„ „
„ „	——?	1865, November 9	Teviot River	Whitling or Albus, 4½ lb.	Copper wire in jaw.
„ October	"Blacktail"	„ July 9	Tillmouth	Whitling, 1½ lb.	„ „
„ „	„	„ March 11	Carr Rock	Clean Trout, 2¼ lb.	Wired.
„ Autumn	"Silver-white"	„ July (end of)	——?	Trout	„
„ April	„	„ August	——?	Female *Salmo trutta*, 17 inches	—
„ Spring	„ or Orange-fin	1866, July 6	English New Water	Whitling, 2 lb.	Wired.

TWEED EXPERIMENTS—*continued.*

Species of Fish	Date of Marking.	Where Marked.	Weig h.	Lgth. in Ins.	Species of Fish when Recaptured.	Date of Recpture.	Where Retaken.	Weight.	Lgth. in Ins.	Difference in Weight.	Differnce. in Length.	Intvl. btwn. Marking and Recapture.	
	1870.					1872.						Mths.	Days.
Whitling.	Sept. 29.	Start.	1¾ lb.	17	Whitling.	July 26.	Hallowstell.	2½ lb.	18¾	12 oz.	1¾ in.	21	27
Salmon.	do.	do.	21½ lb.	37	Salmon.	1870. Nov. 12.	Galashiels.	25 lb.	—	3½ lb.	—	—	44
Blacktail.	do.	Scotch New Water.	16 oz.	13	Bull-trout.	1871. Sept. 25.	North Esk, Montrose.	2 lb. 1 oz.	18	1 lb. 1 oz.	5 in.	11	27
Bull-trout.*	do.	Start.	3¼ lb.	18	do.	Aug. 15.	Cove.	5½ lb.	24	2¼ lb.	6 „	10	17
Yellow Trout.	Oct. 13.	Yardford.	9 oz.	9	Yellow Trout.	July 15.	West Ord.	—	—	—	—	9	2
Bull-trout.	do.	Ethermouth.	2 lb.	16	Bull-trout.	Aug. 15.	Broad.	2 lb.	18½	None.	2½ in.	10	2
Do.	do.	South Bells.	3¼ lb.	20	do.	Nov. 30.	Coquet, Warkworth.	4 lb. 13 oz.	24	11 lb. 9 oz.	4 „	13	17
Blacktail.	do.	Ethermouth.	12 oz.	12	Whitling.	June 1.	Sandstell.	17 oz.	13	5 oz.	1 „	7	19
Do.	Nov. 10.	Scotch New Water.	12 oz.	14	Blacktail.	Mar. 29.	Watham.	12 oz.	15	—	1 „	4	19
Do.	do.	Start.	13 oz.	13	Bull-trout.	Aug. 15.	Hallowstell.	11 lb. 14 oz.	17¼	11 lb. 1 oz.	4¼ „	9	5
Bull-trout.	do.	Scotch New Water.	2¾ lb.	20	do.	Mar. 11.	Teviot.	2 lb. 2 oz.	20½	10 oz. Decrease.	½ „ Increase.	4	1
Whitling.	do.	do.	1½ lb.	15	Whitling.	June 26.	Ford.	2 lb. 4 oz.	—	12 oz.	—	7	16
Grilse	do.	Start.	4½ lb.	23	Grilse.	Feb. 22.	Watham.	4 lb.	—	8 oz. Decrease.	—	3	12
Orange-fin.	1871. June 7.	Low Bells.	1½ oz.	6	Orange-fin.	June 9.	English New Water.	—	—	—	—	—	2
Yellow Trout.	do.	Ethermouth.	2¼ oz.	7¼	Yellow Trout.	1872. Aug. 27.	Ethermouth.	5 oz.	9	2¾ oz.	1¾ in.	14	19
Blacktail.	Oct. 12.	Scotch New Water.	11 oz.	11½	Blacktail.	1871. Oct. 15.	Scotch New Water.	11 oz.	11½	—	—	—	3

* This particular case seems open to some doubt.—W. L. C.

TWEED EXPERIMENTS—*continued.*

Species of Fish.	Date of Marking.	Where Marked.	Weight.	Lgth. in Ins.	Species of Fish when Recaptured.	Date of Recpture.	Where Retaken.	Weight.	Lgth. in Ins.	Differnce. in Weight.	Differnce. in Length.	Intvl. btwn. Marking and Recapture.	
												Mths.	Days.
Blacktail.	1871. Oct. 12.	Scotch New Water.	21 oz.	14½	Whitling.	1872. Aug. 19.	Broad.	2¼ lb.	18	15 oz.	3½ in.	10	7
Do.	do.	do.	16 oz.	11½	do.	Aug. 7.	Twizel Boat House.	1 lb. 7 oz.	16	7 oz.	4½ „	9	26
Do.	do.	Start.	16 oz.	12	Bull-trout.	Aug. 13.	Fallin, near Stirling-on-Forth.	1 lb. 7 oz.	15	7 oz.	3 „	10	1
Do.	do.	do.	8 oz.	10	Blacktail.	Mar. 4.	Yardford.	6¼ oz.	11	1¾ oz. Decrease.	1 „	4	21
Do.	do.	Cove.	16 oz.	13	Whitling.	June 4.	Sandstell.	18½ oz.	14½	2½ oz.	1½ „	7	23
Do.	Nov. 1.	Clayholes.	16 oz.	13	do.	July 30.	Hollywell.	1½ lb.	17½	8 oz.	4½ „	8	29
Do.	do.	Hornwell.	16 oz.	14	do.	July 1.	Shoreside.	1 lb. 12½ oz.	16	12½ oz.	2 „	8	—
Do.	do.	do.	12 oz.	12½	Blacktail.	April 8.	Broad.	8¾ oz.	12½	3¼ oz. Decrease.	0	5	7
Do.	do.	Eithermouth.	12 oz.	11	Whitling.	Aug. 5.	Tweed Mill.	16 oz.	14	4 oz.	3 in.	9	4
Do.	do.	Start.	20 oz.	15½	do.	July 31. 1871.	English New Water.	2½ lbs.	18¾	1¼ lb.	3¼ „	8	30
Whitling.	do.	Hornwell.	1 lb. 12 oz.	17	do.	Nov. 4. 1872.	Lees.	1 lb. 12 oz.	17	0	0	—	3
Blacktail.	do.	Start.	14 oz.	14	Blacktail.	Mar. 13.	Watham.	9¼ oz.	12½	4¾ oz. Decrease.	1½ in. Decrease.	4	12
Do.	do.	Low Bells.	12 oz.	11	Whitling.	July 24.	Twizel Boat House.	2¼ lb.	16	1½ lb.	5 in.	8	23
Do.	do.	Eithermouth.	10 oz.	12	do.	Aug. 1.	Tweed Mill.	19½ oz.	16	9½ oz.	4 „	9	—
Grilse.	1872. Feb. 28.	Scotch New Water.	3¾ lb.	24	Grilse.	Aug. 28.	Finchey.	8 lb.	29	4¼ lbs.	5 „	6	—

Orange-fin is parr of bull-trout. Blacktail is smolt of bull-trout or of whitling.

It will be noticed from a study of the table that "blacktails" are recaptured both as whitling and as bull-trout, but that fish marked as representatives of either of these latter stages are in each case recaptured as whitling and bull-trout respectively. That is to say, so far as the table shows, a whitling does not become a bull-trout, even, as in the case of the first fish mentioned on the list, after an interval of about a year and ten months. The fish referred to seems, on recapture, to have weighed 2½ lb., and may therefore be more correctly described as a sea trout. We may perhaps fairly infer from this result of marking "blacktails" that the young stages of the bull-trout and of the whitling were indistinguishable to the observer who conducted the marking, or are practically indistinguishable.

Another fish worthy of special remark is the last on the list, a grilse which on being captured after an interval of six months is still described as a grilse, and has gained 4¼ lb. in weight. From the date of marking we may infer that the fish was a kelt, and that we are dealing with a minimum fresh water weight as contrasted with a weight after feeding.

1873. The Tweed Committee conducted further marking observations. The results, published as a special report in 1875, deal almost exclusively with "blacktails" recaptured as blacktails and whitling. The only exceptions are two grilse recaptured as grilse kelts before leaving the river.

INDEX

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