XVIII. *On the Breeding of Salmon from Parents which have never descended to the Sea.*
By FRANCIS DAY, F.L.S.

(Plates LIII. & LIV.)

Read March 5th, 1885.

CONSIDERABLE attention has been paid in this country to the life-history of the Salmon, but many so-called "facts" heretofore accepted and that still pass current have no better foundation on which to rest than the dogmatic assertion of a self-termed "practical" individual, the theory of an ichthyologist, or the unsupported statement of a museum naturalist; or, as Russel* observed, "the nonsense about the Salmon that has been published under the name of natural history, and thrust down the throats of Parliamentary Committees, is, when looked back upon, appalling in amount, variety, and worthlessness."

It is consequently a subject of great moment that the various asserted facts upon which any doubt still lingers should be accurately sifted, not by a partisan of one party or another, but an independent individual who would, regardless of expense, time, and trouble, undertake such a task in the sole interest of scientific truth and for the good of the fisheries. Such tests have been for the last few years and are still being steadily and unremittingly carried on at Howietoun, and in due time the results, whether in accordance with or opposed to existing theories, will, it is to be hoped, be given to the world.

Pre-eminent among the questions of practical moment, as bearing upon the race of so-called "land-locked Salmon," is whether the *Salmo salar* can be permanently retained and finally breed in fresh water without descending to the sea.

I propose examining this principally from a fish-culturist's point of view, as, owing to the kindness of the owner of Howietoun, I have had the opportunity of witnessing most of the interesting and instructive experiments which are being carried on in that large and well-conducted establishment, and consequently am in a position to give a reply to this question so far as it has there been solved. I have also thought that it would be interesting were I to collect the chief opinions which have been published in the British Isles on this subject, as well as a synopsis of a few of the various experiments which have been undertaken but have failed.

In 1653 Izaak Walton published the first edition of his 'Compleat Angler,' wherein the opinions of the most reliable authors of previous or contemporary times on Salmon-breeding are condensed. He remarks that the Salmon "is said to breed or cast its spawn in most rivers in the month of *August*: some say they dig a hole or grave in a safe place

* 'The Salmon,' by A. Russel, 1864, p. 32.

in the gravel and there place their eggs or spawn, after the milter has done his natural office, and then hide it most cunningly and cover it over with gravel and stones. 'Kippers' have bony gristle growing out of their lower jaws, and may live one year from the sea, but pine and die the second year. Little Salmon called 'Skeggers,' which abound in many rivers, are bred by such sick Salmon that might not go to the sea, and though they abound they never thrive to any considerable bigness."

Willughby*, quoting a communication to Gesner, tells us that generally about the end of November Salmon ascend for breeding purposes up rivers to their affluents, where the eggs are deposited and the young born; these latter are termed "samlets," while the old fish descend to the sea.

Ray† observed that Salmon are born in the rivers, whence they descend to the sea.

Pontoppidan ('Natural History of Norway,' 1755, Chapter vi. p. 131) remarks that Willughby "also confutes Gesner's opinion, concerning the Salmon's breeding in the sea: he thinks that is done in fresh water, from whence they afterwards go to the sea; but in this he is certainly mistaken. The Salmon unquestionably breeds in the sea, though it is not entirely to be denied that they may sometimes breed in rivers also, for they are found in the midst of Germany, and upper parts of the Rhine, about Basel; but we are very well assured that the Salmon chiefly ejects its roe at the mouth of rivers, where they empty themselves into the sea, or a little way beyond, in the salt water, in this manner: they bend themselves crooked, in order to eject the roe at an aperture under the belly, and in the mean time they stick their heads down in the sand, that they may have the more strength. The male comes presently after, to keep off other fish from devouring the roe, and he then bends his head towards the tail, and ejects his sperm upon the roe."

Passing over the numerous authors who have merely reproduced the remarks of those who have preceded them, we are told by Yarrell‡ that about the end of 1830 water was first turned into a certain pond 3 or 4 acres in extent, situated in Scotland, and in April 1831 one or two dozens of small Salmon fry, 3 or 4 inches long, were taken out of the river and turned in. In 1833 the first fishing was allowed and several Salmon were taken with the fly from 2 lbs. to 3 lbs. in weight; all were perfectly well shaped and filled up, of the best salmon-colour outside, the flesh well flavoured and well coloured, though a little paler than that of new run fish. The same author § remarked that "a knowledge of the growth of young Salmon in a freshwater lake may be useful to those gentlemen who possess lakes near Salmon rivers, from which they can supply them with Pinks: whether the Salmon thus prevented going to salt water will still retain sufficient constitutional powers to mature their roe, and by depositing it in the usual manner, as far as circumstances permit, produce their species, would be a subject worthy of further investigation."

Knox observes (Proc. Linn. Soc. ii. p. 358, Dec. 19, 1854) that "From the time the Salmon enters the fresh water it ceases to feed, properly speaking, although it may occasionally rise to a fly or be tempted to attack a worm or a minnow, in accordance seemingly with

* 'De Historia Piscium,' 1686.

‡ 'British Fishes' (Edition 2), ii. p. 17.

† 'Synopsis Methodica Piscium,' 1713, p. 63.

§ *L. c.* (Ed. 2), ii. p. 16.

its original habits as a smolt. But after first descending to the ocean and tasting its marine food, it never again resorts to its infantile food as a constant mode of nourishment." He further says, "The absence of this [marine] kind of food forms an insurmountable obstacle to the preservation of Salmon and of some kinds of Sea-Trout in freshwater lakes."

It has been suggested that a sojourn in fresh water, even should such be only temporary, may give the first impetus towards the seasonal development of the sexual organs.

Shaw remarked that solitary instances have occurred of large female parrs having been found in Salmon rivers with the roe considerably developed, and he ascertained that by detaining the female smolt in fresh water until the end of the third winter, individuals are found in this comparatively mature condition. Davy* says:—"I have examined hundreds of parrs. . . . Male parrs I have frequently found with mature milt, but never a female with roe correspondingly developed; on the contrary, in the female fish, without exception, the ovaries have been so small, that had they not been sought after carefully they would have escaped notice." Russel† asks of Mr. Young, "Did he ever see a female parr with a developed roe? He never did and never will"‡.

In this search for roe developed in young Salmon that have not descended to the sea, experiments would appear to have ceased in this country; but after an interval of about 45 years it was intended to carry them on at Howietoun. Still as it would not be improbable that some objection would be raised to young fish for this purpose being removed from rivers to ponds, it was determined to rear the parr from the eggs and see if smolts or grilse when thus raised in suitable ponds and properly cared for would or would not breed in fresh waters.

Brown§ observed that "no female parr has yet been discovered with roe developed." This, I think, must be taken to read that no young female Salmon in the parr livery that has not been to the sea had been discovered with ova fully developed. For, as I shall presently endeavour to show, parr or rather smolt with well-marked parr-bands have given fully developed ova at Howietoun. Brown|| determined to endeavour to rear the ova up to the smolt stage, and obtained certain ponds, into one of which the sea ebbed and flowed, at Stonehaven in Kincardineshire. They consisted of two ponds, a freshwater one 40 × 20 yards, and a saltwater one 60 × 30 yards. The distance between the ponds was about 30 yards with a fall of eight feet. An iron pipe 18 inches in diameter communicated with the sea. Spawning fish were put into the freshwater pond and afterwards made their way to the sea-pond, but unfortunately poachers destroyed the experiment, which was not renewed.

Clean Salmon having only a thread of milt or roe in them are found in Salmon rivers during December, January, and February. These would seem to be temporarily sterile¶, because ova and milt may be detected by means of the microscope. Mr. F. Ffennell gave evidence that these fish do not spawn until the November or December following,

* 'Transactions of the Royal Society of Edinburgh' (Dec. 1854), vol. xxi. p. 253. † 'The Salmon,' 1864, p. 39.

‡ Yarrell is said to have adduced two instances of parr containing ova in the month of March.

§ 'Stormontfield Experiments,' 1862, p. 89.

|| *Op. cit.* p. 116.

¶ Siebold has found that certain individuals are not sexually developed; and he supposed that this sterility extended throughout their existence. Widegren and others have opposed this view, contending that such sterility is temporary, merely affecting a few individuals.

remaining for 12 months in the fresh water, their ova developing until they are ready to breed; and although the fish are discoloured, due to their residence, are very good eating. Brown caught one of these fish in a Sutherlandshire river and gave the same report*.

Many have held the opinions which Rasch so fully detailed in 1866 when he commenced by the inquiry why it is that all the male fish, including those that have gone to the sea and those that remain behind in fresh water, have their reproductive organs fully developed, while the female is under the necessity of making the journey to the sea before being able to spawn. He considered that the female in order to reach maturity requires far more nourishment than the male, the formation of eggs necessitating more materials than that of the milt; that in the ovary of the female the eggs are formed nearly simultaneously, and their development is uniform, one being enveloped by as large an amount of albumen as the other. But in order to produce this albumen a far greater amount of nourishment is needed than the little female fish can possibly procure in fresh water—enough for the formation of the embryo, but not sufficient to provide the nourishment necessary to its proper development. He considered that if smolts were prevented going to the sea they would readily accustom themselves to a freshwater home, if the piece of water were sufficiently extensive; and should the water be a very large lake, such as Ladoga, Wenern, or Peipus, and as rich in nourishing food, the freshwater Salmon will then attain about the same size as the Salmon of the sea. He also observed that Hetting hatched out numbers of Salmon ova, which he subsequently turned loose in the Tyri-fiord: and during the two years after, fish had been caught in that lake resembling in every respect Salmon proper.

“The question whether any of the migratory species [of the genus *Salmo*] can be retained in fresh water, and finally accommodate themselves to a permanent sojourn therein, must be negatived for the present. Several instances of successful experiments made for this purpose have been brought forward; but all these accounts are open to serious doubts†, inasmuch as they do not afford us sufficient proof that the young fish introduced into ponds were really young migratory Salmonoids, or that the full-grown specimens were identical with those introduced, and not hybrids or non-migratory Trout of a somewhat altered appearance in consequence of the change of their locality. We have seen the experiment tried at two places in South Wales, by the Rev. Augustus Morgan and W. Pell, Esq., of Taliaris, and in both cases the Salmon and the pure Sewin‡ died when not allowed to return to the sea. However, the latter gentleman pointed out to me that the hybrid fishes from the Sewin and the Trout§ survived the experiment, and continue to grow in a pond perfectly shut up from communication with the sea. In that locality neither these hybrids nor the trout spawn.” (Günther, Catal. of Fishes, vi. 1866, p. 9.) Without alteration, the above passage has been introduced by the same author into his ‘Introduction to the Study of Fishes’ (1880, p. 639).

* ‘Stormontfield Experiments,’ 1854, pp. 94, 95.

† Lloyd (‘Field-Sports North of Europe,’ i. p. 301) remarks that near Katrineberg there is a valuable fishery for Salmon, 11,000 or 12,000 of these fish being taken annually. They are bred in the lake; and, in consequence of cataracts, cannot have access to the sea. They are small in size and inferior in flavour. The year 1820 furnished 21,817. The question is open to discussion whether these fish are true *Salmo salar*.

‡ *Salmo trutta*.

§ *Salmo furio*.

Much of the foregoing seems to me simply hearsay evidence, and several points require elucidation. First, did any stream flow into these ponds? and, if so, of what size? or were they more or less stagnant pieces of water? Secondly, did suitable food exist in these ponds, or were the fishes fed? Thirdly, how was it ascertained that no spawn was deposited?

Respecting this last question, a very interesting observation was made by Mr. C. L. Jackson, Honorary Naturalist to the Southport Aquarium ('Land and Water,' June 10th, 1876), that the "Salmon-trout cast their ova in the salt water in the Southport Aquarium without assuming the appearance of kelts or even leaving off feeding greedily on shrimps. They did not attempt to make a bed, and the spawn was immediately eaten by their fellows."

It will now be necessary to follow out briefly the different stages of growth of these fish, which occurred during the several changes from parr to smolts or grilse. Dr. J. Davy says * "that parr put into a pond from which they could not escape, have grown in two or three years to be about half a pound in weight, and when caught were found to be in excellent condition, and still retaining their original transverse markings." He also (*l. c.* footnote p. 220) remarks:—"The milt of the young fish, so far as I have observed, is always shed before the parr becomes a smolt." It seems evident from the foregoing that by parr he did not intend to include silvery smolts with parr-bands; and if such was his meaning, it is not in accordance with the changes shown by the parrs and smolts at Howietoun, where fish in the smolt † livery gave milt; and the same series of experiments have shown that individual variations in size among those artificially reared, and under identical conditions, can neither be due to the age of the parents nor the character of the stock from which the ova or milt has been procured.

A Committee of the Tay Proprietors, on May 2nd, 1855, was held at the Stormontfield ponds, "to consider the expediency of detaining the fry [which had been hatched March 31st, 1854, and were 3 or 4 inches in length] for another year or allowing them to depart. A comparison with the undoubted smolts of the river then descending seawards, with the fry in the ponds, led to the conclusion that the latter were not yet smolts, and ought to be detained. Seventeen days afterwards, viz. on the 19th May, a second meeting was held, in consequence of the great numbers of the fry having in the interim assumed the migratory dress. On inspection, it was found that a considerable portion were actual smolts, and the Committee came to the determination to allow them to depart. Accordingly, the sluice communicating with the Tay was opened, and every facility for egress afforded. Contrary to expectation, none of the fry manifested any inclination to leave the pond until the 24th of May, when the larger and more mature of the smolts, after having held themselves detached from the others for several days, went off in a body. A series of similar emigrations took place, until fully one half of the fry had left the pond and descended the sluice to the Tay. . . . as the shoals successively left the pond, about one in every hundred was marked by the abscission of the second dorsal fin. A greater number were marked on the 29th of May than on any other day, in all about

* Davy, 'Physiological Researches,' p. 221.

† It is difficult in the following description of the Howietoun experiments to separate the term smolts from grilse, as these fish do not descend to the sea, on the first return from which, in a normal condition, they would be grilse. Anyhow, after the deposition of ova they may be termed grilse.

1200 or 1300 . . . Within two months of the date of their liberation, viz. between the 29th of May and 31st of July, twenty-two of the young fish so marked when in the state of smolts, on their way to the sea, have been, in their returning migration up the river, recaptured, and carefully examined. This fact may be considered as still further established, by observing the increased weight, according to date, of the grilse caught and examined: those taken first weighing 5 to $9\frac{1}{2}$ lbs., then increasing progressively to 7 and 8 lbs., whilst the one captured 31st July weighed no less than $9\frac{1}{2}$ pounds. In all these fish the wound caused by marking was covered with skin, and in some a coating of scales had formed over the part"*. This question of smolts returning or not the same year as they migrated to the sea, I do not propose entering on here.

Respecting one half of the parrs migrating seaward one season, and the remainder not doing so until the next year, Russel observes, "A new hypothesis was brought out, to the effect that the females descend the first year and the males the second" (*op. cit.* p. 47). But on investigation it appeared "that the fish remaining during the second year consisted of both males and females, the milt of the males being fully developed, while the roe of the females was discernible only by a microscope" (*l. c.* p. 48).

Mr. Dunbar, who annually hatches about 500,000 Salmon ova in the Thurso river in the county of Caithness, informed Mr. Young that about 8 per cent. became smolts at the end of the first year†, and about 60 per cent. at the end of the second year, and the remainder, or 32 per cent., at the end of the third year. The fish which were hatched in the spring of 1837 at Drumlanrig did not assume the migratory livery and seek to depart in May 1838 as Mr. Shaw expected, but did so in May 1839‡. It has been argued that young Salmon may have their growth stunted and their instinct overruled by being kept in a state of comparative confinement.

"Until the parr takes on the smolt scales it shows no inclination to leave the fresh water. They cannot live in salt water. This fact was put to the test at the ponds, by placing some parrs into salt water—the water being brought fresh from the sea at Carnoustie—and immediately on being immersed in it, the fish appeared distressed, the fins standing stiff out, the parr marks becoming a brilliant ultramarine colour and the belly and sides of a bright orange. The water was often renewed, but they all died—the last that died lived nearly five hours. After being an hour in the salt water, they appeared very weak and unable to rise from the bottom of the vessel which contained them, the body of the fish swelling to a considerable extent. This change of colour in

* Report of Committee on Stormontfield Ponds to British Association, 1856, p. 453.

† I conclude he meant to say at the termination of the first year after being hatched, for they do not descend seawards in their first year.

‡ "It was said of Mr. Shaw's experiments that the two-years' freshwater residence of the fry was ascribable to the 'difference of temperature between the waters of the Nith from which the ova were taken, and the waters of the ponds in which they were hatched and reared.' But where is the evidence as to what was the difference in temperature, or whether there was any at all? On inspecting Mr. Shaw's *Observations*, for information on this point, we can only find that the temperature of the ponds, as compared with that of the river, was on one occasion three degrees below and on another six degrees above. So whatever difference there was, seems to have been in favour of the ponds stimulating, not retarding, as compared with the river or natural habitat. Put suppose it were otherwise, what then? We know that a lower temperature might retard the hatching of the fry by a week or two, or their growth by half an inch or half an ounce; but we have no ground for supposing that it would retard for a whole year such a change as that of assuming the migratory dress." (Russel, *l. c.* p. 48.)

the fish could not be attributed to the colour of the vessel which held them, for on being taken out they still retained the same brilliant colours" *.

In the Brighton Aquarium about 20 small Salmon parr were received from Mr. Berrington, the Chairman of the Usk Board, and these were placed in fresh water, where they soon began to feed and took to their tank. In the succeeding May, about eight months after they had been received, most of them commenced to assume the smolt livery, but four remained as parrs. Salt water was gradually introduced; but this did not prove fatal to the parrs, as it was feared it might, while the smolts became quite rampant with pleasure as the water grew more and more salt, until at last no fresh water was left and it became purely salt. Then the parrs, which had remained parrs up to this time, began to assume the smolt livery, and the change is described as truly marvellous. They ate five times as much as previously, were in incessant and rapid motion all day, and their growth became perfectly astonishing †.

Bertram remarked of the Stormontfield smolts, in 1861, "One fish which had been detained for three years for the purpose of discovering whether the species will grow in fresh water without being permitted to visit the sea, was found to be fully twice the size of the largest smolt" ‡.

The Duke of Buccleuch's gamekeeper at Bowhill was for some years in the practice of putting a few smolts into a freshwater pond, and feeding them regularly with bullock's liver. He reported that the smolts which grew into Salmon thrive for about three years and then died, but that Bull-trout smolts kept in good condition for a longer period.

"Into a deserted stone-quarry near Coldstream, filled with rain-water, two smolts, about 3 inches long, were put by boys out of mere amusement. One of these grew into a Salmon, which when 5 years old, weighing 1½ lb., was caught and sent to Mr. Stoddart of Kelso, who had it boiled for dinner. He reported that it was not unpalatable. The other smolt grew into a Bull-trout and lived for seven years. It died during a very severe winter when, on account of the water being frozen, it could not be fed" §.

"Shaw has demonstrated, in the most conclusive manner, that those small Salmonoids which are generally called Parr, are the offspring of the Salmon, and that many males from 7 to 8 inches long have their sexual organs fully developed, and that their milt has all the impregnating properties of the seminal fluid of a much older and larger fish. . . . No Parr has ever been found with mature ova" ||.

"In the Exe, parr-marked fish (graveling or smolt so-called) have been taken with ova actually exuding from the fish, on and previously to its being handled to remove the hook. Some were sent to me by Mr. England, fishing in the Exe, some four years since, and preserved in glycerine, most certainly as a novelty, since which many such cases have come before me" (Frank Gosden, 'Land and Water').

I think I can adduce conclusive evidence so as to remove any doubt respecting smolts or grilse giving ova without descending to the sea, as they have done so in the

* Brown, 'Stormontfield Experiments,' pp. 61, 62.

† Francis Francis, 'Field,' 1879.

‡ 'Harvest of the Sea,' p. 110.

§ Extract from 'Report of Experimental Committee to Tweed Commissioners.'

|| Günther, 'Introduction to the Study of Fish,' 1880, p. 639.

Howietoun establishment. But the assertion that the milt of parrs has *all* the impregnating properties of the seminal fluid of a much older and larger fish must be received with a qualification, at least if the foregoing is intended to signify that it *always* has such.

It is frequently stated to be the rule that Salmon deteriorate on entering rivers; but this view must be modified by observing that such is also, partially at least, due to their being mostly in a breeding condition, at which period they would naturally fall off in condition, even were they to remain in the sea. At other times some ascend without deterioration, demonstrating such to be possible, owing to the state of health or condition which they were then in.

Shaw mentions * that in January 1837, he took a female Salmon, weighing 14 lbs., from the spawning-bed, from whence he also took a male parr weighing one and a half ounce, with the milt of which he impregnated a quantity of her ova and placed it in a stream connected with a pond, where, to his great astonishment, the process succeeded in every respect as it had done with that which had been impregnated by the adult male Salmon, and exhibited, from the first visible appearance of the embryo fish, up to their assuming their migratory dress, the utmost health and vigour. In January 1838, he took another female Salmon weighing 14 lbs. and two male parrs from the same spawning-bed and impregnated two lots of parr-ova with the milt from the two parrs, and afterwards placed them in two different streams enclosed in boxes, open at the top, temperature 45°. In December 1838 he took a female Salmon from the river weighing 11 lbs., and four male parrs from the same spawning-bed. After impregnating four different lots of ova, one lot to each individual parr, he placed the four parrs in a pond, where they remained until the following May, at which period they assumed the migratory dress. The ova were placed in streams to which no other fish had access, and where they became mature in a similarly progressive manner to those already detailed, thus clearly demonstrating that the young Salmon of 18 months old †, while yet in the parr or early state, actually performs the duties of a male parent before quitting the river. While the males of the three several broods which occupied ponds No. 1, 2, 3 continued in a breeding state, which lasted throughout the whole of the winter of 1838–39, he impregnated the ova of three adult female Salmon from the river with the milt of a male taken from each of the three ponds, and the whole of these ova matured. This, he deemed at once, removed any doubt which may have been entertained regarding the constitutional strength of individuals reared under such circumstances.

At Stormontfield, in the season of 1857 (November or December), milt from a parr was used to fertilize the ova of a 16-lbs. Salmon, and in 1858 they had fry of Salmon, fry of grilse and Salmon, fry of grilse, and the fry of the Salmon and parr. “On the closest inspection, no difference was perceptible either in the form, colour, size, or markings of any of these fish. There were larger and smaller fry to be seen amongst all these hatchings” (Brown, ‘Stormontfield Experiments,’ p. 74).

* ‘Transactions of Royal Society of Edinburgh,’ xiv. p. 561.

† As young Salmon hatch at the latest in March, these young fish must have been at least 21 months of age, if in their second season.

At the same establishment a suggestion which had been advanced—that the anomaly of some parrs migrating at the end of one year after hatching, and the remainder after two seasons, must have been caused by the first being the produce of Salmon, and the second of grilse—was clearly refuted. The fry, which numbered about 200,000, were solely the produce of 19 male and 31 female Salmon, spawned in 1859; and of these some remained in the ponds as parr, while others migrated seawards as silvery smolts. These same experiments showed that marked grilse of one year return as Salmon the next; that all the smolts of one year do not return the same year as grilse, the one half returning next spring and summer as small Salmon (*l. c.* pp. 92, 93); also that marked smolts were caught as grilse the first season and Salmon the second (*l. c.* p. 94).

Again, some authors have held that were Salmon able to migrate into large freshwater lakes, where a sufficiency of suitable food existed, they would be able to return to the streams where they had been reared as well-developed Salmon, a theory denied by others, who assert that Salmon never increase in weight in fresh water; but if this were so, how do they grow at Howietoun?

Dr. Murie (*Proc. Zool. Soc.* 1868, p. 249) gave an account of some Rhine Salmon (*Salmo salar*), hatched in the Gardens of the Zoological Society, in February 1863, and which lived in fresh water up to 1868. In May 1865, at the usual period of migration, those which were smolts tried to leap out of the tank; similar phenomena occurred in 1866, and “it was further observed that those which had assumed the silvery dress in the beginning of the year, again lost it in the autumn and became distinctly parr-marked.” In this autumn a good many died, some in the smolt, others in the parr-livery; and 1867 was a repetition of 1866. During the first and second years the young fish seemed to grow, and attained a length of from 3 to 6 inches. During the third and fourth year they grew much slower, and attained to from 5 to 7 inches in length; only two lived to the fifth year. These fish were kept in a small tank with a running stream of fresh water, a fact which is very necessary to bear in mind, because, although the conclusion drawn that the fishes retained in fresh water were subject to an arrest of growth, such may have been due to the small space in which they were confined, or the limited amount of water which they obtained, irrespective of which, the changes of temperature may have been great.

Yarrell (*Growth of Salmon in Fresh Water*) remarks that the view that “the rate of growth in young Salmon has some reference to the size of the place to which they are restricted, receives further confirmation in these river, lake, and well specimens. The smolt taken from the well in July 1838, where it had been confined for eight months, was rather smaller in size at that time than the smolts in the preceding April, though both were Pinks of the same year, namely 1837. The smolt taken from the lake in August 1838, which then measured $7\frac{1}{2}$ inches, had also grown more rapidly than that in the well, but had not acquired the size it would have gained had it been allowed to go to sea. Further it may be observed, that the Salmon parr from the lake in August 1837, then 18 months old, though perfect in colour, is small for its age; while that of July 1838, or 29 months old, is comparatively still more deficient in growth, supposing both fish to have resulted from Pinks of the year 1836, and been put into the lake at the same time; of which there

was no doubt, since the lake, the formation of which, though commenced in the autumn of 1835, was not finished till February 1836, soon after which the first Pinks were put in."

Before detailing the experiments I would wish to draw especial attention to the necessity of complete segregation of the fishes experimented upon, and the produce reared. Crowding many forms into one tank, and from this crowd selecting various varieties or so-called species simply from their appearance, and hybridizing from them, is likely to occasion irreparable errors and do more injury to investigation than if the subject were left quite alone.

I do not propose giving a detailed account of the Howietoun ponds, how care is taken that no one can have unauthorized access there, nor how the segregation carried on is most complete, as I have reason to believe that a distinct paper on this interesting subject may be expected, the contents of which I should not wish to anticipate.

In December 1880, Sir J. R. Gibson-Maitland, F.L.S., obtained some Salmon in the Teith, from which he procured eggs and milt, and they hatched at Howietoun in March 1881. In due course these young fish were transferred to pond no. 7 at Howietoun, which has its sides and bottom lined with wood, is 100×15 feet in surface extent, 8 feet deep in the centre and $6\frac{1}{2}$ at either side, while the average supply passing through it is a million and a half gallons of water a day.

In July 1883, in the presence of the foreign and other Commissioners to the Great International Fisheries Exhibition, this pond was netted, when it was seen that some of the Salmon-fry, then 2 years and 4 months old, were of a general golden colour, spotted, and in the banded parr-stage livery, while others were beautiful silvery smolts, similar to such as we generally find descending to the salt water, and in which, in certain lights, parr-bands were visible. Although, as a rule, the smolts were the largest, still some few of the parrs exceeded smolts in size. All present were convinced that these fish were the young of the Salmon, and in excellent condition.

October 10, 1883. One of these fish under a pound in weight, in the smolt livery and showing parr-bands in certain lights, jumped out of the pond and was found dead on the path. On being opened it proved to be a female with comparatively large ova, which were of a deep reddish colour, thus almost disposing of the statement already alluded to that "no parr has ever been found with mature ova." I say "almost," because as yet the ova were not quite mature, although they would have become so had not the fish met with an untimely fate; also the objection might be raised that it was a smolt, not a parr. Now although the parr-bands were present certainly the golden tinge seen in the young of the Salmon was absent. Up to the end of November 1883 several of these fish, during the night or early morning, had jumped out of the pond, and it was surmised that some might have been carried off by vermin, as birds or rats, in the early hours. On the 29th two more, one being $11\frac{1}{2}$ inches in length, were found dead, and some vermin had devoured the lower part of its head. It was of a silvery smolt colour with parr-bands. On being opened it proved to be a male full of ripe milt*. A net having been put into the pond three fish were examined. The first was a silvery smolt,

* For descriptions of the specimens see Proc. Zool. Soc. 1884, p. 21.

10·8 inches in length, which in certain lights distinctly showed ten parr-bands, one black spot on the preopercle, three on the opercle, while the upper two thirds or half of the body was spotted with black, as was likewise the lower half of the dorsal fin, which had a white anterior and outer edge. There were some red spots on the body. In this fish the generative organs were not developed. The second was more distinctly parr-marked, but otherwise very similar; it was 9 inches in length. The third was in the parr-livery with 10 well-marked parr-bands on either side and three black spots on the opercle; it was 6·3 inches in length and a male full of milt. As a rule the females in this pond were silvery, with ova which were not quite ripe, while the males on the contrary, being pressed, gave ripe milt. As to colours the fish seemed to be more spotted than is seen in specimens from rivers*, while their bodies were well formed although not of a large size, the largest being 13½ inches long. Those in the golden parr livery appeared to be males, while the silvery smolts were generally females; in all the finger-marks were visible. These fish rendered it very evident that the relative growth of the fry does not depend on the size of pond, quality, quantity, or variety of food, or amount of water, as all had been treated alike, yet they varied in length from four inches to thirteen and a half.

During the month of May 1884 sixteen of these fishes jumped out of the pond and were found dead, and the breeding-organs in all were found to be developing in a satisfactory manner.

August 28, 1884. An examination was made of pond no. 7 and a smolt 1¼ lb. in weight was removed†. On being opened it proved to be a female with its ova well forward, the largest being 0·1 of an inch in diameter; the total length of the fish was 14·1 inches.

October 3rd. A smolt 13 inches in length, which had jumped out of pond no. 7, or had been dragged out by vermin, also proved to be a female, and the eggs were 0·2 of an inch in diameter.

Now some of these fishes tried repeatedly to jump out of the pond‡ and these generally met with fatal injuries; they sprung out towards the upper end near where the water entered, as if wishing to *ascend* the stream. Wire netting one foot in height was now fixed around the upper half of the pond, which prevented the fish springing over the bank. About the middle of October, fungus (*Saprolegnia ferax*) broke out among these fish, possibly due to injuries occasioned by striking themselves against the wire netting. It was also observed that they showed signs of ceasing from feeding, so a number of small Lochleven Trout were added to vary the diet, but they did not appear to consume many of them.

* The beautiful illustrations of grilse in Sir W. Jardine's magnificent 'Salmonidæ' do not resemble in colour the Howietoun fish, which latter are more spotted than his 2 lbs. 13 oz. specimen from the Solway Firth, taken in July, and even more so than his 3½ lbs. captured in August.

† Described in Proc. Zool. Soc. 1884, p. 581.

‡ Brown ('Stormontfield Experiments') observes that he "in the month of February 1836, caught a dozen and a half parrs in the Tay, and kept them confined in a stream of running water, and by the month of May the whole of them had become smolts; but some had leaped out of their confinement in their struggle to find their way to the sea, and were found dead on the side of the pond" (pp. 7 and 8).

November 7, 1884. A smolt, or more properly a grilse, $1\frac{1}{4}$ lb. weight, was found lying almost dead by the side of pond no. 7, and from it about one hundred apparently ripe eggs were taken, and milted from a Lochleven Trout. On January 23, 1885, eighteen hatched, and when I saw them on February 10 they looked remarkably well and vigorous, while there did not appear to be any deformities among them. So far as I am aware, this is the first successful attempt in Great Britain at breeding from Salmon which have undoubtedly passed their entire existence in fresh water, while it is likewise interesting as a case of hybridization, and in a form which, so far, at Howietoun had been productive of sterile offspring.

November 11, 1884. About 12,000 eggs of the Lochleven Trout were fecundated from the milt of a grilse, and were placed in hatching-tray no. 1. They did very well, only 87 dead ova being picked out, and hatched on January 28, 1885.

November 14, 1884. The water was let off from pond no. 7, in which the young Salmon had been kept, as it required being re-charred this year, while the contained fish were taken to pond no. 5, just re-done up, and previously inhabited by Brook-Trout, but which were now turned into the burn, as they were too old to be worth further preserving. Sixty-eight young Salmon were transferred, the majority being males, while these fishes showed all the gradations in colouring from the golden and banded parr to the silvery smolts, these latter, however, not having lost their parr-bands, while some of the large smolts or grilse were distended with ova. All the fish in the full parr-livery were males, but smolts and grilse in some instances also had milt. About two dozen eggs were obtained from one of the females, but they did not germinate, probably not being quite ripe. Three smolts which were too much injured to live, due to their persistent attempts to escape, were opened, and the ovisacs were found distended with eggs, almost but not quite ripe, being still slightly adherent to the ovisac.

As these young Salmon became ready for continuing their species, in December the following were obtained and laid down in the hatching-house :—

December 1, 1884. 1500 eggs from two smolts or grilse which were treated with the milt of one of the males. These eggs averaged each 0·22 of an inch in diameter, and were placed in hatching-tray no. 104 *a* : about 400 of these eggs hatched on Feb. 21, 1885.

December 9, 1884. About 4000 ova of these grilse were impregnated with the milt of one of the males. These eggs were each 0·20 of an inch in diameter and were placed in hatching-tray no. 108 *a* : about 2200 of these eggs hatched on Feb. 27, 1885.

On the same day 400 ova of these grilse were treated with the milt of a Lochleven Trout. These eggs were each 0·22 of an inch in diameter, and were placed in hatching-tray 108 *b*. The milt appeared to be strong enough where it acted, but only appeared to do so in half the eggs.

December 13, 1884. About 2500 eggs of the grilse were milted from the same lot in the pond, and placed in hatching-tray 84 *c*. The diameter of each egg was 0·22 of an inch, and about 200 of these eggs hatched on March 5.

At nearly the end of December the remainder or 48 young Salmon which had been bred from, were removed from the wooden-lined pond no. 5 into the earthen pond no. 10, it being of larger size, and none jumped out.

I have already shown that the fact of parr having milt prior to descending seawards has been generally recognized, but that smolts or grilse kept under similar conditions have been almost always on the contrary declared not to give ova. But now we have the experiments made at Howietoun to consider, and these have undoubtedly proved that young male and female Salmon kept in suitable freshwater ponds may develop milt or ova. These fish were hatched in March 1881, and most of the male parr had milt in November 1883, or when 2 years and 8 months old; also two or three smolts of the same age had ova which probably would have matured, but they jumped out of the pond and so met with their deaths. In November or December 1884, or at 3 years and 8 or 9 months' age, all these fishes seemed to be ready to breed, and it appears probable then that Salmon-parr do not possess milt for the purpose of impregnating the ova of the old Salmon, or "to mingle with the River-Trout," as Dr. Günther suggests, but to be ready to fertilize the eggs of any ascending grilse; for in some localities these latter deposit their ova prior to the usual period when adult male Salmon are present for breeding purposes.

Some authors hold that Salmon are freshwater forms that proceed to the sea, and that there is a physiological necessity for their doing so in order to be able to produce ova. Others, who I believe are more correct, consider these fish marine forms that ascend into fresh water to deposit their eggs and rear their young. As it is evident from the Howietoun experiments that these fish can give eggs without descending to salt water, such disposes of the "physiological necessity" theory. Possibly this migration may be classed among the instances of "inherited instinct" and may be lost in such a race of Salmon as have been reared for a few generations in fresh water. It may be that in some such manner the "land-locked Salmon" of various countries have been originally differentiated from their fellows, an interesting instance of which I propose to adduce in this place.

Mr. Douglas Ogilbie in 1881 took about 100 Sea-Trout and Salmon smolts, which he turned into Lough Ash, Co. Tyrone, which has no access to the sea. April 30, 1883, he captured a grilse $14\frac{1}{2}$ inches long in this lake, where Salmon had not previously been seen. Its abdomen was so distended that he considered it would have spawned very shortly, more especially as it was taken at the mouth of the only stream that enters this lough. The specimen is in the Natural History Museum at South Kensington, and there I examined it. I do not hesitate considering it a true *Salmo salar**, while the eggs in spirit as measured by me were each 0.25 of an inch in diameter. Provided there had been a ripe male in the vicinity, there seems no reason why this fish should not have deposited her eggs, and such would thus have given rise to a land-locked race.

"On the approach of autumn," observes Shaw (Trans. Roy. Soc. Edinb. xiv. p. 559, footnote), "the whole of the Salmonidæ, resident as well as migratory, while in fresh water acquire a dusky exterior, accompanied by a considerable increase of mucus or

* Described Proc. Zool. Soc. 1884, p. 584.

slime. The fins also become more muscular. However, on the return of spring, they resume their wonted beautiful silvery colouring, and the fins, the cartilaginous portions of which are frequently damaged during the winter floods, grow up and acquire their former outline."

Different authors have assigned various reasons why a parr on becoming a smolt (which it does, as a rule, when commencing its seaward journey) assumes a silvery livery. Davy * suggested "that the young remain in fresh water until they have acquired not only a certain size and strength, but also additional scales, fitting them, in their smolt stage, to endure without injury the contact of the saline medium." Couch demurred to such an opinion in 1866, observing that the silvery colour of smolts is not due to their acquiring additional scales, but owing to a deposit of bright soft matter which shines through the transparent scales. Dr. Günther † remarks, respecting the River-Trout, that they "frequently retain the parr-marks all their lifetime; at certain seasons a new coat of scales overlays the parr-marks, rendering them invisible for a time, but they reappear in time, or are distinct as soon as the scales are removed. When the Salmons have passed this parr-stage . . . a new coat of scales overlays the parr-marks." But as these fish do not shed their scales, Dr. Günther appears to hold to the untenable proposition that an additional coat of scales is developed on these fishes at certain periods ‡. It was likewise stated in one of the conference papers read at the "Great International Fisheries Exhibition" in 1883 §, that the young of the true Salmon "do not venture into the sea till another skin of glistening scales has been formed over their first skin. They then receive the name of *smolts*. If put into salt water before getting this silvery dress they die." I do not propose here entering upon the discussion of these opinions, so wide spread, but nevertheless entirely erroneous. Any one who will examine a series of specimens can readily verify for himself that there never is an extra coat of scales as above stated.

Before concluding this portion of my paper, I may observe that the teeth in the vomer of a parr generally are as follows:—three on the head of that bone, below or behind that a pair, next two placed one at an angle to the other, and subsequently eight in a single row, but with their points somewhat divergent. There is very little change seen in those of the smolt, while in a grilse 13 inches long, that spawned this year, the same dentition prevails. This raises the question whether the loss of teeth, as generally seen, is not partly due to the hardness of the food they consume; this, however, is not the case in the Howietoun pond, as what they are fed upon is soft.

I omit any detailed description of the grilse, and decline entering upon a lengthened discussion of the decision of a Committee of the Commissioners of the river Tweed,

* 'Physiological Researches,' 1863, p. 250.

† 'Introduction to the Study of Fishes,' 1880, p. 632.

‡ See Proceedings of Zoological Society, 1884, p. 22, showing the impossibility of an extra coat of scales being developed.

§ "Salmon and Salmon Fisheries," by D. Milne Holme. (Conference Papers, p. 4.)

who stated, in their report for 1863, as follows:—"Our opinion, from the experience of the last twenty years, is, that grilse never become Salmon of any stage whatever." As grilse were reared from Salmon-ova at Howietoun, it may well be asked in reply, if such were a fact, how it is that grilse may be raised from Salmon-eggs. Russel, when refuting this argument of the Tweed Commissioners, and also of Mr. Mackenzie, remarked upon the difficulty of obtaining conclusive evidence after the fish has assumed its migratory habits and can no longer be kept under inspection to see if the grilse becomes a Salmon. But, as I have now shown, the reverse experiment has been successfully carried out at Howietoun, and eggs of Salmon have been proved to give birth to fishes which in time become smolts and then grilse.

A difference of opinion respecting the persistent or variable size of the eggs of Salmonidæ appears to prevail, a difference which could not exist if the authors would take the trouble to measure them when freshly removed from the parent fish, or as lying in the hatching-troughs. For these eggs do not increase in size during the process of incubation, although such as die become sodden, white, and somewhat distended. Unimpregnated eggs do not, as a rule, take on this opaque white aspect, but remain clear throughout the nesting-season, neither do they augment in size.

I propose offering a few remarks upon whether the eggs of the Salmonidæ, of the same species, are invariably of the same size, and especially if the age of the parent has any connection with such differences as may be perceived; also, if any variations in the size of the eggs from a single fish are to be seen.

Harmer in 1767* gave a table showing the number of eggs which he had observed in certain forms of fishes, among which the Salmonidæ were not included. He remarked, "From this table it appears that the size of the eggs is nearly the same in great and small fishes of the same species, at the same time of the year." And these observations may be found, with but little variation, in the writings of authors from that period up to recent years, as perhaps in no branch of biology are assertions once made more adhered to without re-investigation than in Ichthyology. Passing on to the 'Zoological Record' of 1864, p. 179, we find that Professor Malmgren, having observed that certain Salmonoids in a lake in Finland were descendants of the common Salmon, whose access to the sea had been cut off owing to an elevation of the land, mentioned as one of the present differences that this freshwater and dwarfed breed gave smaller ova than *Salmo salar*. In this conclusion Dr. Günther did not coincide, remarking that "the last character [or size of the ova] will be considered very significant by all who may have a more extended knowledge of fishes, as the size of the ova is not only invariably the same in individuals of whatever size, but, as far as our experience reaches, is even often characteristic of the species of a genus." This opinion, slightly modified, Dr. Günther still apparently held in 1880, for he asserted† that "the ova of Teleostean fishes are extremely variable in size, quite independently of the size of the parent species. The ova of large and small individuals of the same species, of course, do not differ in size."

* Transactions of the Royal Society, "On the Fecundity of Fishes."

† 'Introduction to the Study of Fishes,' p. 159.

On the other hand, Mr. E. Blanchard in 1866* observed that the ova “of the grilse are always sensibly smaller than those of the adult Salmon.” Livingston-Stone, 1877 †, remarked that in American Trout (*Salmo fontinalis*) that reside in spring-water, which is equivalent to a diminished supply of food, smaller eggs are developed than in such as reside in brooks. On the McCloud river ‡ “it was noted, in 1878, that the parent Salmon were unusually small, their average weight being under 8 lbs.” This small size was stated to be undoubtedly caused, in whole or in part, by the fishery at the canneries of the Sacramento, where the 8-inch meshes of the innumerable drift-nets stopped all the large Salmon, but let all the small ones through. The eggs when taken proved to be at least one third smaller than those of most previous years, and the average number of eggs to the fish was about 3500 against 4200 in the previous year. Livingston-Stone in 1882 §, writing respecting the eggs of *Salmo fontinalis*, observes that those from the small fish of the elevated rivulets are not so large as those of the finer breeds from warmer streams, concluding that the ova of these last are fully twice as large as those found in the race residing in mountain rivulets. From this period, observations have been frequently recorded to show that the eggs of the Salmonoids undoubtedly differ in size consequent upon certain physical causes; hence the assertion that in this family “the small size of the ova [in *Brachymystax coregonoides*, Günth.] is of sufficient importance to separate these fishes generically from *Salmo*” || may be questionable, especially as the typical specimens examined in London were only 18 and 21 inches respectively in length.

The following figures are all taken from examples in the Howietoun fisheries, unless otherwise noted; and in order to make the statement plainer, the eggs of the various species or crosses of these fish are given:—

<i>Salmo salar</i> , 16 lbs. weight.	General size of eggs	0·24 of an inch.
“ “ ?	“ “	from 0·25 to 0·30 “
“ “ small	“ “	0·20 “
“ “ grilse reared in ponds	“ “	from 0·20 to 0·22 “
“ <i>trutta</i> , small	“ “	“ 0·175 to 0·18 “
“ <i>levenensis</i> (var.) 8 years old, from one pond, the general size		0·24 “
	but some are 0·22, and a few 0·21, and in three or four	0·20 “
“ “ 7 years old. General size		0·19 “
“ “ 6	“ “ “	0·18 to 0·19 “
“ “ 2 and 3	“ “ “	0·17 “
“ <i>fontinalis</i> 4	“ “ “	0·18 “
“ “ 3	“ “ “	0·17 “
“ “ 2	“ “ “	0·14 “
Hybrid <i>S. fontinalis</i> , <i>S. alpinus</i> 2	“ “ “	0·13 to 0·15 “

* ‘Poissons des Eaux Douces de la France,’ p. 461.

† ‘Domesticated Trout,’ 3rd edition.

‡ Report of United States Fish Commission.

§ Bulletin of the United States Fish Commission, ii. 1882, p. 11.

|| Catal. Fishes Brit. Museum, vi. 1866, p. 163.

The foregoing are only some out of the many measurements which I have made, but they tend to show very conclusively that the size of the eggs in Salmonoids increases with the age and probably the condition of the parents; thus the ova of grilse are inferior in size to those of the Salmon. And in large Trout as in the older Lochlevens there is an augmentation in the thickness of the shell*, a rather important question to the fish-culturist, because such shells require a strong embryo to readily hatch, which is obtained by giving an increased supply of water during their "eyed" period. Whether it was accidental or otherwise, still the Trout eggs obtained latest in the season were of rather larger size than such as had been taken in the earlier months.

Next we come to the consideration of whether any difference is perceptible in the eggs of two parents of the same age that have been kept under identical conditions. Among the young Salmon reared at Howietoun from eggs obtained from the same parents, and reared in the same pond, some taken on December 1st, and again on the 13th, 1884, averaged 0·22 of an inch; some from similar fish on December 9th averaged 0·20 of an inch, while others taken the same day were 0·22 of an inch. The same phenomenon has been observed among the Lochleven Trout, wherein, although the diameter of the eggs of fish at 8 years of age was generally 0·24 of an inch, in some it was 0·22, in a few 0·21, and in three or four 0·20; whilst in six-year-olds it has been observed to vary from 0·18 to 0·19 of an inch. That such variations might theoretically be anticipated most of us must admit, for whatever causes deficiency of nutrition might occasion diminution in the size of the ova. Also the size of the parent ought possibly to be taken into account, for disease, crowding them when young, and other causes may dwarf these fishes, and such would probably give comparatively small eggs.

Can we detect any variation in the size of the eggs given by a single fish? I have already adduced an instance of this among the Lochleven Trout. In November 1884, I placed 80 unimpregnated eggs of one of these fish in a tube of water, wherein they were kept for a week, the water being changed daily. At the end of this period I measured each ovum, and found 75 were 0·25 of an inch in diameter, three were 0·20 of an inch, one was 0·175 of an inch, and one 0·15 of an inch. Looking through the hatching-troughs at Howietoun it appeared that from 4 to 5 per cent. of the eggs are less than the normal size of the remaining 95 or 96 per cent.

I must here refer to the grounds on which I believe that offspring raised from the large eggs are superior to such as are reared from the smaller ones. Two batches of Lochleven Trout were spawned on November 2nd, 1882, the parents of one lot having been hatched in 1875, and of the other in 1876; these ova were similarly treated and the young came out during January and February 1883. At Craigend are two ponds which have been constructed for the reception of young Salmonidæ, each being 100 feet long and about 25 wide: one is nearly on a level with the other, and the same stream passes through both. Into these two ponds the two lots of fry were turned, those from the older (1875) or

* The micropyle in the Salmon's eggs has nine pits or depressions around the opening, whereas there are none in the ova of Trout, including Sea-Trout.

seven-year-old parents having the lower pond, those from the younger or six-year-old fish having the upper pond, while both lots were similarly treated. At the end of November 1883, those in the lower pond were about one fourth larger than those in the upper pond, and as they received the stream after it had passed through the upper pond, this gave reason to suppose that the large eggs produced superior fish to those from the smaller eggs. In 1884 a second experiment was tried in the same two ponds, which were stocked with young Lochleven Trout, bred from parents of the same age, spawned the same day, and hatched in the same room. By the end of the year no difference in size or appearance was perceptible between the two lots. It would thus seem that the larger eggs given from older parents produce fry which grow faster than do those from the smaller eggs furnished by younger parents.

Mr. Francis Francis (Fish Culture, 1865, Appendix, p. 309), when alluding to the Salmon fishery at Doohulla in Ireland, has stated, "A curious fact occurred also, which is worth noting, showing that big smolts make big fish. Among the smolts marked were thirteen which had far outstripped the rest in size; and among the grilse were some which had also considerably outstripped the rest. Most of these smolts were marked. Among the rest was one very fine fellow, which Mr. Ramsbottom had to hold in both hands while he was marked. They were cutting off the adipose or soft fin, and the operator, who held the scissors, remarked as they came to this fish, 'What a pity to mutilate such a fine fellow! We will only cut off a piece of his fin.' And the fin was cut in halves, leaving a small triangular piece. This very fish was caught, and as he was the largest smolt, so it was the largest grilse and weighed $7\frac{1}{2}$ lbs."

The immediate and possibly remote result of having eggs from young fish for stocking purposes is one which requires the earnest consideration of the fish-culturist. For I have already shown that by selection a more rapidly growing race may be reared, and I now propose examining whether small eggs from young parents may not give bad results as to the number hatched or the quality of the young.

For several seasons it had been remarked that eggs from young mothers are subject to a greater percentage of deaths than those taken from older fish. On November 13th, 1884, about 500 eggs having a diameter of 0.17 of an inch were taken from a rising two-year-old Lochleven Trout and they were impregnated from another of the same race of the usual size. Out of these eggs only about a dozen hatched on January 28th, and seven lived to be turned into the rearing-pond. In this instance the immaturity was on the mother's side.

On November 29th, 1883, 4500 eggs of the Lochleven Trout (of the season of 1875) were milted from the parr of a Salmon raised at Howietoun and which had been hatched in March 1881, and consequently were a little over $2\frac{1}{2}$ years of age. The mortality of these ova was only about 2 per cent.; but such by no means gave a true index of the experiment, for when the young hatched January 15th, 1884, nearly all were seen to be suffering from what has been termed dropsy or blue swelling of the yelk-sac*. As the same cross had been made December 24th, 1881, but with older parents, and that without

* Proc. Zool. Soc. 1884, p. 376.

occasioning dropsy, one is irresistibly led to the conclusion that hybridization had nothing to do with these results, which may reasonably be attributed to the immaturity of the male parrs*. As a further confirmation of this view, parrs in 1884 taken from the same lot were found prolific, but with comparatively few cases of dropsy occurring. Among these 4000 dropsical fish, only about 100 lived out the year.

Thus the great mortality from eggs of young mothers was during the incubating stage, but from young males one season older it seems to have shown itself among the fry; passing over another year, we do not find so great a mortality among the eggs nor disease of the young. Bearing on this I may allude to the ova of American charrs having been milted from a Scotch charr in November 1882; one of the progeny gave 146 eggs on November 12th, 1884, or a little under 2 years of age. Only six feeble little ones hatched on February 3rd, 1885. At the same time milt was obtained from some of these hybrids and used to impregnate 4500 eggs of Lochleven Trout; these hatched on February 2nd, but the mortality was large, being upwards of half the eggs, while there were many deformities and some dropsies among the offspring. Males are evidently more matured for breeding-purposes than are females of the same age. I would here advert to a remark I published in 1883 †, that in the fresh waters of India due to indiscriminate net-fishing the young (of many forms of fish) have to be raised from ova of such as are merely one or two seasons old, while the younger the parent the smaller the eggs, and this is probably one mode in which races of fish deteriorate.

We now arrive at the question, Why is it that Salmon reared in ponds of fresh water or where they are unable to descend to the sea are variously spoken of? Yarrell tells us of Salmon fry being turned into a pond in 1830, and in 1833 several were taken 2 lbs. to 3 lbs. in weight and perfectly shaped, but he seemed to be in doubt whether they could mature their roe in such localities. Rasch thought that fish thus imprisoned, if the lake were very large, would attain about the same size as the Salmon in the sea. Dr. Murie has shown that an arrest of growth occurred in an aquarium at the Zoological Gardens among young Salmon kept in restricted areas.

I have had the opportunity of examining Salmonoids kept in artificial pieces of water of different extents for various periods of time, the results of some of which I propose alluding to as bearing on this subject.

In October 1879 I received from Mr. J. Carrington, F.L.S., of the Westminster Aquarium, an American charr (*Salmo fontinalis*) 9 inches long, which had been hatched from eggs sent from Lake Huron, and which had been reared by the late Mr. Frank Buckland in his tanks at the Horticultural Gardens, South Kensington. This fish of

* As corroborative of the above view that the milt of these young Salmon-parrs was deficient in marital powers, I may mention that on the same date 1000 eggs of the common Brook-Trout were milted from one of these Salmon parrs which had been dead a few hours. But not a single egg fructified; only 3 turned white in December, 3 in January, and 15 in February, or a total of 21. On March 12th the remainder were still quite clear, but destitute of any sign of a contained embryo.

† 'Indian Fish and Fishing.' Great International Fisheries Exhibition 1883 series, p. 27.

several (? 6) years of age had a head of a longer proportion * than is seen in these fishes kept under normal conditions. In short the fish was not well grown—there had been an arrest of growth due to its various surroundings. At the same time I received from Mr. F. Buckland four examples of undoubted *Salmo salar*, reared by him from eggs received from Huningen, and which were collected from Salmon captured for this purpose from below the falls of Schaffhausen†. As year after year passed by and these fish were still retained in the comparatively small amount of fresh water which sufficed to fill the tanks in the Horticultural Gardens, they became lanky and apparently half-starved fishes, similar to those which have been described by Dr. Murie (*l. c.*, and in his 2nd paper P. Z. S. 1870, pp. 30–50, “Irregularity in the Growth of Salmon”).

Can Salmon be reared in small pieces of water or ponds through which a good current of water is kept flowing and wherein there is a sufficiency and variety of suitable food? To this we have a reply from Howietoun, to which I shall presently allude, that Salmon can be so kept and reared, but the size to which they will yet attain time only can demonstrate.

Certain hybrid Salmon have been reared and kept for some years in the Howietoun ponds: so far most have proved to be sterile, and the size to which they have attained has been unsatisfactory; but the fish have all been well formed and not shown that kelt-like appearance usually deemed so characteristic of Salmon retained in fresh water. The experiments have been as follows:—

On November 25th, 1879, some eggs from the Lochleven Trout were fertilized from the milt of the Salmon. Although many hatched, up to this period none have been found fertile; the largest I have seen was on November 14th, 1884, and it was $16\frac{1}{2}$ inches in length. They were kept in the island pond (which is 210×90 feet and from 10 to 11 feet deep in the centre). On November 28th, 1883, these fish were removed to pond No. 11, where they now remain. On December 24th, 1881, some Lochleven-Trout eggs were similarly fertilized with Salmon milt, and they hatched March 9th, 1882. The young fish were kept in a planked pond, 20 feet long by 5 feet wide, until March 13th, 1884, when they were removed to the octagon pond at Craigend ‡, and the largest taken has been 10 inches long.

It seems to me that at Howietoun those hybrid Salmon raised under the same conditions as some *Salmo salar* do not augment in size so rapidly as these latter fish; thus among the hybrids between the Lochleven Trout and Salmon hatched in March 1882, in November 1883 the largest was a little over 7 inches long, while the young *Salmo salar* in the next pond, a year older, were from 4 to $13\frac{1}{2}$ inches long. If future observations shall give the same results it will be necessary to ascertain whether this arrest of growth is due to hybridization (which is unlikely), paucity of space or of water supply, character of the ponds, or has any connection with the food.

* Day, British and Irish Fish. ii, p. 119, pl. cxx, fig. 2.

† Journ. Linn. Soc., Zoology, xvi. 1882, p. 397.

‡ These fish began to show symptoms of commencing fertility in May 1885; and on July 4th, owing to the stream giving out due to the hot weather, all but one died.

I may now finally remark upon the facts that pure Salmon have been raised from eggs in the Howietoun fishery, that the young have grown to be parr, smolts, and grilse, and that these have given eggs and the eggs so obtained have been successfully hatched. Many sportsmen and fishermen are now reopening the old question that grilse are not young Salmon*.

The general bearing of the preceding authorities quoted has been in favour of the evidence that Salmon confined in fresh water, and especially within that of limited areas, were incapable of reproducing their kind. On the other hand, the fact obtains that land-locked Salmon, both in Europe and America, certainly reproduce their species in fresh water.

As touching the question at issue, the Howietoun experiments, then, have shown the possibility of not only rearing parr and smolts, but also obtaining ripe ova and milt from them, without their ever having gone to the sea. Thus it is demonstrated that descent to the sea is not, as has been asserted, a dire physiological necessity.

I would here further observe that although time will be necessary before a definite reply can be given as to how these young Salmon raised from the eggs of parents which have not gone to the sea will thrive and how large such fish will become in freshwater ponds, still any unbiassed investigator must admit that, so far as they have gone, the experiments made at Howietoun among the Salmonidæ are pretty conclusive on the following points:—

(1) That male parrs and smolts may afford milt competent to fertilize ova, but when from fish of the second season, or up to 32 months old, it is (? always) of insufficient strength for strong and vigorous fry to be raised.

(2) That female smolts or grilse may give eggs at 32 months of age, but those which are a season older are better capable of producing vigorous fry; while for the purpose of developing ova a visit to the sea is not a physiological necessity.

(3) That young male Salmonidæ are more matured for breeding-purposes than are young females of the same age.

(4) That although females under 24 months of age may give ova, such are of little use for breeding-purposes, the embryos not becoming well developed or vigorous, while the young when hatched are frequently malformed.

(5) That the size of the eggs of Salmonidæ varies with the age and condition of the parent; but, as a rule, older fish give larger ova than do younger and smaller ones.

(6) That among the produce of every female fish there may be found variations in the size of the eggs.

(7) That from larger ova finer and more rapidly growing fry are produced: consequently that, by selection of breeders, races may be improved; while it is only where segregation is well carried out that such selection is possible.

* On the table, exhibited at the meeting when this paper was read, was a specimen reared at Howietoun from a Salmon egg, the identity of which with grilse I think was beyond dispute. There were also a parr and a smolt shown from the same hatching, evincing the untenableness of the assumption that the latter have an additional coat of scales to what obtains in the parr.

DESCRIPTION OF THE PLATES.

PLATE LIII.

- Fig. 1. *Salmo salar* in the parr livery, a male with ripe milt, hatched March 1881, killed November 27th, 1883. Drawn of natural size.
- Fig. 2. Caudal fin shown in two conditions of expansion; natural size.
- Fig. 3. *Salmo salar* in the smolt livery, a female with eggs only just visible, hatched March 1881, killed November 1883; natural size.
- Fig. 4. Caudal fin; natural size.

PLATE LIV.

- Fig. 1. *Salmo salar*, a grilse that had been just spawned, hatched March 1881, killed December 9th, 1884. Sketched from the specimen, and of natural size.
- Fig. 2. Caudal fin; natural size.
- Fig. 3. Scale from above lateral line and below adipose dorsal fin, magnified 20 diameters. From a photograph of the specimen on a glass slide.

A. Hammond del. et lith.

1. SALMO SALAR ♀ SPAWNED GRILSE. 2. CAUDAL FIN. 3. SCALE MAGNIFIED.

Hanhart imp.