On the food of certain gregarious fishes / by R. Knox.

On the Food of certain Gregarious Fishes.

By R. Knox, M.D., F.R.S.E., &c.*

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At an early period of my inquiries into the natural history of the Salmonidæ, I was much struck with the difficulty there seemed to be of arriving at the truth in a matter so simple in appearance as the determination of the food on which certain interesting gregarious fishes live and thrive. The conflict of opinions on this point which then existed, and strange to say still exists, induced me to devote a good deal of attention to it; and as I find my views still opposed to many, and especially to those of my esteemed and distinguished friend M. Valenciennes, I have thought it might serve the cause of science and of truth to submit a memoir on the subject to a society, venerable as well by its name as by the services it has rendered the sciences of observation.

The inquiries, of which the results are merely given here, were commenced about 1824, or about thirty years ago; and although I have repeated them on many occasions, I do not find it necessary to alter or modify the statements originally made on this point to the Royal Society of Edinburgh, in whose 'Transactions' a mere notice of my researches and observations were published.

My attention was first directed to the fact, for such it is beyond a doubt, that in the stomachs and intestines of fresh-run salmon, that is, of salmon fresh from their best, indeed their only true feeding-ground, the unknown recesses of the ocean, nothing is ever found but a peculiar reddish substance (and that in small quantity), unlike anything known to possess life. The reddish coloured matter is also found in the intestine. On applying to practical fishermen, that is, to those who had seen, I shall not say examined, hundreds of salmon opened and gutted, I found that they had but one opinion on the subject, namely, that the food of the salmon, whilst a resident in the ocean, was altogether unknown.

On inquiring of the same class of persons as to their knowledge of the food of the herring, I found them equally at fault. They spoke vaguely about the herring living by suction, but they were agreed as to the main fact, namely, that food discernible to the naked eye was rarely to be found in the stomach of the herring. Whilst reflecting on

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these circumstances, so singular in the natural history of fishes playing an important part in the economic history of Great Britain, Holland, and the Scandinavian nations, I learned accidentally that in South Scotland, in a lake or lakes near Lochmaben, there was, in great abundance, a small gregarious fish, which could not be tempted by any bait, and whose food was entirely unknown. These lakes, of various extent and depth, are situated at no great distance from the river Annan, with which they all communicate directly or indirectly, but not all with each other; they contain many kind of fish, as the vendace, of whose food I am about to speak, which are not found in the river Annan; neither am I aware that the salmon and sea trout, which, at certain seasons, abound in the river, make their way into these lakes. Thus many curious questions are opened up for the consideration of the philosophic naturalist. The jack or pike abounds in the Castle Loch, and yet has not destroyed the vendace, a fish not found, so far as I know, in any other part of Britain. With the food of this fish, the vendace, I resolved to commence the inquiry. Confined to certain lakes, and never quitting these, abiding in waters which I could command with the net, the property of gentlemen whom I had the pleasure to call my friends, I felt that the inquiry ought to commence there. The facts, moreover, were reported as being, *without exception*, an important point in every physical inquiry. Far otherwise, I saw, would be the inquiry into the food of the herring and salmon; questions surrounded by numerous difficulties, and overlaid with prejudices, extending even to the naturalist.

The mass of mankind love mystery now, as they once did anything which bore the semblance of a miracle. This foolish and silly passion can only be met and stemmed by philosophy, by science. The case between the lovers of mysterious untruths and truth-seeking science has been well stated lately by the illustrious Faraday. In the matter of the food of the vendace of Lochmaben, a gregarious fish, now arranged by naturalists with the Corregoni, I found, on reaching the village of Lochmaben and its pleasing lakes, many vague and mysterious stories afloat as to the vendace, which even naturalists had taken the trouble to repeat. One forenoon's inquiry destroyed the whole illusion or delusion. Dozens of the vendace were opened immediately on being removed from the lake, by means of nets, for they are not to be caught in any other way: on their stomachs being examined they were found to be crammed with thousands of Entomostraca, or microscopic shrimps as they may be called, the class of microscopic shell-fish so beautifully described by Müller. The solu-

tion of the mystery depended simply on the placing a portion of the contents of the stomach under a strong lens, which I took care to be provided with. Strange as it may seem, nevertheless, the fact is certain, and now I believe admitted by all, that no one had ever thought of this before.

The species of the Entomostraca first discovered belonged to the genus Lynceus, but several other genera were observed; and in winter (14th December, 1832, for I had the lakes fished expressly for this inquiry), the Cyclops of Müller of several species most abounded. Thus, instead of living on air and water, the vendace consumes daily, no doubt, thousands of shell-fish, a highly nutritive food; the roe of these Entomostraca, being swallowed with the parent, contributing to render the food still more nutritious.

The mystery was now at an end. I have sometimes thought that the villagers were not over well pleased at so simple a solution of what they had so pleasantly and so frequently discussed. A dissenting clergyman of the place wrote an article against my views, or rather against myself, which article was published in a work * so replete with error as to stand, I believe, unparalled in the history of compilations. Another parson,† a man of common sense and fond of science, recommended the dissenter to see me *first*, and examine with me *the food* of the vendace, for himself; in other words, "to test the fact by an appeal to the materials." This he declined doing, for reasons I need not state. The contempt of the class I speak of for physical truths is extreme, but this lamentable frailty, so detrimental to the best interests of mankind, does not fortunately extend to all theologians.

This unlooked for discovery opened up at once a vast field of inquiry; in fact I commenced with the vendace knowing the difficulties which awaited its extension to some other gregarious fishes larger than the vendace, that is, the herring, the early spring trout of Loch Leven, and the char.

Before proceeding to these, I shall allude to several facts made out as to the natural history of the vendace, facts ascertained during the course of frequent journeys to Lochmaben; they may be useful to the naturalist who may hereafter more fully describe the Corregoni. The notion that, like the herring, the vendace dies immediately on being removed from the lake was disproved at once, by bringing them to the

* 'The Statistical Account of Scotland.' Blackwood.

† Dr. Macknight.

village in buckets of water: it is by no means a very delicate fish, and could easily be transplanted to other lakes; but it is not a high-seasoned fish, and in this respect also what has been said of its singularly good qualities is a pure exaggeration. The object of science is to destroy mystery and popular delusions.

Mr. Harkness, of Lochmaben, who assisted me greatly in these inquiries, had the kindness to have the vendace caught for me in the depth of winter, that is, on the 16th of December. The rivers Annan and Æ were fished for me on the same day for parr, and specimens of both were sent me. There were twenty-four vendace; of these twenty-two were females and two males; they were taken in the Castle Loch of Lochmaben, as usual with the net. In nineteen of the female vendace the ovaries were small, very soft, and the ova mere points; but the fish themselves were in good condition: in three females the ova were very large, and the fish just about to spawn; in the two males the milts were progressing in size, but not much enlarged.

The vendace is found in two of the system of lakes near Lochmaben, namely, the Castle Loch, so called from the ruined castle of the Brus on its banks, and the Mill Loch: this latter is a deeper loch, but not so extensive. As it seemed to me that the vendace of the two lakes differed somewhat from each other, my brother, at my request, examined them very carefully; the result of that inquiry is as follows:—

Examination of the Vendace of the Castle Loch and Mill Loch, February 26, 1837.

"The mouth being fully closed, and the specimen laid on a flat board, the following dimensions were taken:—

	Castle Loch.	Mill Loch.
Snout to centre of tail	6¾ inches.	6¾ inches.
„ dorsal fin	3 „	3 „
„ mort fin	5⅛ „	5⅛ „
„ pelvic fin	3 „	3 „
„ anal fin	4¾ „	4¾ „
„ extremity of gill-covers	1⅜ „	1½ „
Breadth of eye	⅜ „	⅜ „
Length of head, dorsal line	1 1/16 „	1⅛ „
Greatest depth of body	1⅝ „	1¾ „
	oz. drs. grs.	oz. drs. grs.
Weight	1 5 40	1 9 40

"Lateral line precisely mesial in the Castle Loch vendace, but one-eighth nearer the dorsal line than the abdominal line in the Mill Loch.

"A section shows both these specimens to be female, with the ovary more fully developed in the Mill Loch vendace; the liver is evidently larger in the vendace of the Mill Loch: these differences, however, will not account for the great additional weight of 4 drs., and which evidently arises from the greater depth and thickness of the Mill Loch vendace. This greater depth and thickness of the body, and the larger head, seems to me to constitute the only specific differences between these two fishes. The difference in colour is very striking; but this seem to me to depend on the greater number of minute black spots of the rete mucosum in the Mill Loch vendace: the dark shade is so strong on the head as to obscure almost, if not entirely, the brain; and thus the peculiar and much-dwelt-on heart appearance observed in the Castle Loch vendace is not seen in that of the Mill Loch. The scales, which I took from the lateral line and near it, of both specimens present precisely the same appearance when placed under the microscope: I counted 30 rays on that part of the scale, in both specimens, which is exposed: the number of rings on the part concealed by the superimposed scale is greatly more."

The largest vendace I have ever seen was 9 inches in length.

Another delusion in respect of the vendace was the supposition that the males lived apart from the females in deeper water, and hence beyond the reach of the net. Like everything else in the history of the fish this also seemed a delusion; for the net being drawn in the Castle Loch of Lochmaben, and near the castle, in presence of Mr. Murray and myself, of fifteen vendace which I examined nine were females and six males: this was in October. Nevertheless, I feel disposed to think that the males are not so numerous as the females, for of forty taken in the Mill Loch at one time only two were males. The males are lighter coloured than the females.

(Thus terminated a popular delusion which had no doubt maintained its ground for centuries. The discovery of the food of the vendace, and of countless millions of other fishes to be spoken of immediately, was a gift of the microscope to science: it illustrates and perhaps explains many obscure points in the natural history of such fishes, and may one day lead to important results.—*Added to the original MSS. April* 20, 1855.)

The Food of the Char.

Having thus successfully solved the problem as to the food of the vendace, and removed all doubts from even the most prejudiced, I next turned my attention to that of the char. Some fine specimens were obtained from Windermere, and the food, which proved to be the Entomostraca, with which the lakes abound, was exhibited to the Royal Society of Edinburgh. The char is a gregarious, deep-swimming fish, shy of taking any bait; nevertheless, it will rise to a fly, and the common food of the trout may be found in its stomach, although I have not found it to be so; nevertheless, it does not seem to me to feed exclusively on the Entomostraca, although these unquestionably form by far the larger portion of its natural food.

The observations as to the food of the char were repeated several times, and always with the same results.

(The disappearance of the char from many lakes in Scotland, as for example, from the lake of Leven, may be connected with circumstances dependent on the natural history of the Entomostraca, which, no doubt, form its natural food.—*Added to the original MSS. April* 20, 1855.)

The Early Spring or Gray Trout of Loch Leven.

I had remarked many years ago that certain trout of Loch Leven come into season much earlier than others; that there were some, in fact, which were in the highest condition in the end of December, January, February and March, a period of the year in which all other descriptions of trout are worthless as food for man. I at first conjectured that this peculiarity might depend on a specific distinction, and I am still disposed to believe that in Loch Leven there are two distinct species of lake trout, an early fish and a late one, but anatomical investigation has not as yet borne out this view. But be this as it may, the facts remained simply as they were,—namely, that an admirable sort of trout comes into perfect condition in Loch Leven as early as December and January; and then came the question of its food.

In January, 1832 or 1833, I requested two friends* to be present at

* The late Mr. William Murray, of Henderland, and Mr. Graham, of Redgorton, nephew to Lord Lynddoch.

the examination of *four* specimens of very fine Loch Leven trout, purchased in the market that morning. On their stomachs being laid open and examined with a lens, they were found to be filled with Entomostraca; and these I have always found to constitute the food of the early spring trout of Loch Leven.

During the remainder of the year the ordinary Loch Leven trout live on the small Buccinum and the common food of trout, with which the lake abounds: they rise readily at an artificial fly, and may, no doubt, be taken with worms or minnows, or any of the ordinary bait for trout.

It has been asserted, since these discoveries were made, that the Entomostraca form the staple food of most of the finer sorts of lake trout. I believe the statement to be very probably correct, but I have not myself had an opportunity of verifying the fact. Those who doubted all these facts at first went soon afterwards, on finding they could not be refuted, into the opposite extreme, and asserted that the Entomostraca, of which, by-the-bye, they had no very clear idea, formed the most nourishing food of fishes. I lay no claim to such sweeping generalizations, being simply contented with what I can prove by demonstration.

The Herring.

Having thus cleared the way, as it were, of some of the obstacles to the successful prosecution of the inquiry, I next proceeded with that of the food of the herring. The difficulty was to obtain the herring from the deep sea, in fine order and as remote as possible from its spawning condition. When found near the coasts, the herring is either about to spawn or has already spawned: it is, to a certain extent more or less, a foul fish, and the food it may take at that time is not to be held to be its natural food; this can only be made out in the herring when in the finest order and in the deep sea, to which he seems annually to retire. This part of the inquiry was accompanied by a good deal of trouble and considerable expense: the herring had to be examined on both coasts of Scotland, and indeed under a variety of circumstances.

Of the hundreds and hundreds of herrings I have examined, with this view, I remember but a very few in whose stomachs anything was found excepting Entomostraca of various species. Of the specimens to which I allude as having been feeding on other prey, one had

been living on sand-eels; another on what appeared to be small herrings; and in the stomach of the third were the shells of about a dozen small Buccinums. These were the only specimens out of hundreds in which the Entomostraca did not form the sole food. I leave the negative and positive evidence to speak for themselves. The positive evidence I at last obtained on this curious point would fill a volume.

Throughout the inquiry, which was prolonged for several years, my great object was to obtain the herring at as great a distance from the shores as possible and in the best order. The British herring-fisheries are in reality shore-fisheries, or nearly so, and the herrings are most frequently taken on the spawning-ground, and in a condition when the fish do not feed. Notwithstanding these innumerable difficulties, it seems to me that I have succeeded in determining, beyond all doubt, the food of the herring to consist of various species of Entomostraca, with which it is known the seas and bays abound.

When near the coast the herring is frequently not feeding. Thus, in the Forth, in January and February, 1836, I examined the stomachs and intestines of a very great number of fresh herrings, taken in the Frith of Forth, and found them empty. The roes and milts were large, but not remarkably so. On the other hand, after spawning, and whilst close to the shores, they seem to take to other food, as sand-eels and shrimps. I find in June, 1831, that herrings taken off Dunbar were in this state; the stomach and intestines loaded with putrescence; the fish worthless and insipid. My journals of observations, made by my brother and myself, at every season of the year and on both coasts, are now before me: they confirm the facts, already well-established by practical men, that shore-fisheries of fish whose habitat is the deep sea seldom produce fish in their prime condition. The deep sea cod and haddock, as compared with the same fish caught high in estuaries, furnish a good example of this truth; the herring another. Thus, in the Frith of Forth fishings of the 20th of July, 1834, five male herrings, taken at random from a large number, were found to have the milts small; they had been feeding on the Entomostraca alone: these herrings proved of good flavour and were excellent to eat: thirty others of the same take were found to be insipid and worthless. Of these some had been living on sand-eels as well as Entomostraca; their stomachs and intestines were full of putrescent remains. Thus food, as well as their approach to

the spawning or recently spawned state, exercises a striking influence on the quality of certain fishes as food for man.

In August some fine herrings were examined in Glasgow (west coast of Scotland); the food appeared to be the ova of some testaceous animal, as the shrimp, but after all, was probably merely Entomostraca, exceedingly minute: nevertheless, a few even of these herrings had been eating the sand-eel. On this coast also, as the herrings get out of order, they take to other food and become insipid and worthless. These observations were repeated on September 27th and October 13th, 1834, at Anstruther, in Fife, and close to the mouth of the Frith of Forth. Of fifteen herrings taken on July 6th, 1838, of three different sizes, the stomachs were filled with Entomostraca: the first were in good order as food. But in winter, in friths, they do not seem to feed; as on February 6th, 1836, of many fresh herrings caught in the Frith of Forth, the stomachs and intestines were found to be empty.

Of fifty herrings examined on the 13th of February, 1836, caught in the Frith of Forth, forty-two had the stomachs and intestines empty; four had been feeding on the ova of small fishes, and four on a peculiar red substance: in twenty-two others nothing was found. Thus, when caught in bays and friths, the stomach is often quite empty; like the salmon, they are then off their feeding-ground, which is the deep sea. The sexes are usually in equal numbers. On the 30th of November, 1834, my brother remarks, in his journal, that it has been invariably in herrings caught off the Isle of May that he has found the Entomostraca: further up the frith, their stomachs are very generally empty. The Isle of May is close to the German Ocean. On the 4th of December, some herrings taken even now are good; and this, my brother remarks, is invariably the case with the first taken—even in winter.

Continuing the examination of these original journals, I find the following entries:—

"July 6, 1838. Fifteen herrings, taken off Anstruther and dissected, gave the following results; the date of capture as above.

Largest size.—From snout to centre of tail	. . .	$10\frac{3}{8}$ inches.
Length to dorsal fin	. . . . .	$5\frac{1}{8}$ „
„ to extreme margin of gills	. .	$2\frac{1}{8}$ „
Greatest depth	. . . . .	$2\frac{3}{8}$ „
Weight	. . . . .	8 oz.

Middle size.—Measured as above	. . . . .	$8\frac{5}{8}$ inches.
Ditto	„	$4\frac{1}{8}$ „
Ditto	„	$1\frac{3}{4}$ „
Ditto	„	$1\frac{7}{8}$ „
Smallest size.—Measured as above	. . . . .	$7\frac{1}{4}$ „
Ditto	„	$3\frac{5}{8}$ „
Ditto	„	$1\frac{1}{2}$ „
Ditto	„	$1\frac{5}{8}$ „

"The results of the dissection of these three sorts were as follows:—

"1st examined, was in good order, fat; a male: milt small; 3 inches long by $\frac{1}{4}$ inch broad: food Entomostraca.

"2nd, a male; in most respects as preceding: food Entomostraca.

"3rd, a male; as above: stomach empty; intestines clean and quite empty.

"4th, in fine order, as above; a male: food Entomostraca.

"5th, a female; in all other respects as those already examined: food, 1st, Entomostraca, abundant, minute; 2nd, two small prawns.

"6th, a female; in other respects as above: food Entomostraca, of two kinds; one extremely minute.

"7th, a female; the fish in the highest order: food Entomostraca.

"8th, a male, $9\frac{1}{2}$ inches long: milt longer than in those described; 4 inches long by $\frac{1}{2}$ inch broad: food Entomostraca.

"9th, a male; as in the first seven: food Entomostraca.

"10th, a female; in the best order: food Entomostraca.

"11th, ditto; ditto: food Entomostraca, of a large species and greenish colour.

"12th, length 7 inches; of very inferior quality, soft; seemingly a young fish, yet tolerably fleshy; a female: food Entomostraca.

"The 13th, 14th and 15th specimens were in as good condition seemingly as those described, but although taken early this morning the viscera by 5 P.M. were found to be putrescent: food Entomostraca.

"Thus, the quality as to food of the natural family of the Clupea depends—1st, on species; 2nd, on their food; 3rd, on their condition as to the state of the milt and roe. Their natural habitat is the deep sea, where they find their natural food—the Entomostraca."

Lastly, I availed myself of the assistance of my much esteemed friend and former student Mr. Henry D. Goodsir, now, alas! with Sir John Franklin. This gentleman with his more celebrated brother, Mr. John Goodsir, were my favourite students and assistants in my comparative anatomical pursuits, in consequence of their fondness for such

studies. Their family resided at Anstruther, a great fishing station on the Frith of Forth, and I wrote to Mr. Henry D. Goodsir to push the inquiry for me to the utmost: this he did by embarking in the fishing-boats himself on the stormy frith, and proceeding with the fishermen to the fishing-ground, not far from the Isle of May, and in the open sea. He wrote me two letters in answer to my inquiries, one of which, I fear, has been lost; I transcribe a copy of the second; of its value I need say nothing:—

Copy of Mr. Goodsir's Letter respecting the Food of the Herring.

"Anstruther, June 15, 1843.

"My dear Sir,—I have put off thus long in answering your letter of the 29th ult. for the purpose of making further observations on the herring and its food, and find that my previous observations are quite correct in regard to the matter. I will now, then, answer your queries separately.

"1st. The Entomostraca are at certain seasons the almost exclusive food of the herring: there can be no doubt, either, that they follow shoals of these Crustacea to prey upon them, for it is only when the latter make their appearance on this coast that the former are seen; and when their food is most plentiful the herring are in best condition. It is during the summer months also that we find the larvæ of the more common species of Decapoda, along with those of Balani, and occasionally a minute shell-fish, amongst the contents of the stomach.

"2nd. It appears to be chiefly during the winter and spring months that the herring take other kinds of food than the Entomostraca; during these months, however, we find the stomach oftener empty, and only occasionally filled with the larger Crustacea, such as the shrimps, &c.; in other cases with Entomostraca.

"3rd. As to Entomostraca being the partial or exclusive food of other fish besides the herring, there can be no doubt that during the summer months, when the shoals of Entomostraca, or what our fishermen term *maidre*, are in great abundance, they form the food of a great number of other animals besides the herring. The common coal fish is perhaps the species which, next to the herring, preys on the *maidre* in greatest number, and is consequently often caught in large quantities in the nets during the early part of the season.

"It appears to me also that the shoals of Cetacea which make their appearance in the frith during the herring season are in pursuit of the *maidre*, and not of the herring, as is most generally thought to be the case.

"If you are aware of any other points which would require observation, be so good as let me know.

"Believe me most sincerely yours,

(Signed) "H. D. Goodsir.

"To Dr. Knox."

Thus, after the lapse of nearly twenty years, a student of my own, favoured by his position, confirms, to an extent I had scarcely hoped for, my original observations on the food of the herring. I call the attention of naturalists, and especially of my esteemed friend M. Valenciennes, to these *facts*. As regards man, they are the most important which, next to the capture of the herring, can be brought forward in respect of the natural history of the herring; and they explain certain economic statistics bearing on the great fisheries of Holland, which otherwise were wholly unintelligible. The naval power of the ancient republic of Holland was created and based on a deep-sea herring fishery; the modern herring fisheries of France, England and the Scandinavian States are shore and boat fisheries, of little value as a food-producing employment, and of no value whatever in a naval point of view.

Prior to these researches the difficulty of discovering the food of the herring was proverbial, and had been declared such by all. Soon after my discovery of the food of the vendace, I spoke with that true patriot and most amiable and talented man, the late Sir John Sinclair, on the subject, and he informed me that he had often turned the matter over in his mind, but without coming to any definite conclusions: he put into my hand a pamphlet, by the late Sir Gilbert Blane, entitled 'Reflections on the Present Crisis of Public Affairs,' dated 1831, pointing out to me the following passage:—"There are few problems of Nature in the solution of which naturalists are more at fault than the disposal and *nutrition* of the finny family. It is proverbially true that they prey upon each other; but it is so much even beyond conjecture to ascertain what is the ultimate food of fish, that it is the tenet and belief of some of the most respectable inquirers into this department of Nature, that the last fishes which those next above them make their food have no sustenance but water. The phenomenon of the immense shoals of herrings, and the fact of gold and silver fishes living without any visible food, are some of the grounds upon which they found their doctrine." When I removed from the stomachs of the herring, the vendace, the char and the Loch Leven trout, hundreds of Entomostraca, in the presence of this excellent nobleman, and, placing them under a microscope, convinced him that the popular belief that all or any of these

admirable fishes lived by or on suction, or on water merely, or on nothing, as some would have us believe, was unfounded, he was greatly surprised and pleased. Thus was this most difficult problem solved at last. I am aware that there are some, but still, I hope, for the honour of my countrymen, few, who say that the solving such a problem as this is a perfectly simple matter—of no value in science, and scarcely meriting notice; yet strange to say that, in respect of all the fishes enumerated, amongst which we may include the salmon, the problem had avowedly remained unsolved from the earliest recorded period until that of my own investigations. It would seem also that Dr. M'Cullagh gave an early attention to this matter, and conjectured that the herring preyed on the Medusæ; but he made no inquiries into the subject. Lastly, it has been asserted that Leuwenhock had detected Entomostraca in the stomach of the herring. There is not a single passage in the Memoirs of this celebrated observer furnishing the smallest hint for the belief that he ever detected the Entomostraca in the stomach of the herring, and his remarks are as follow:—"After much turning this matter in my thoughts, I had a fancy to know what is the food of this fish (the herring); and for that purpose I inquired of many men used to this fishing, what food they generally found in the stomachs of herrings when first caught, but the constant answer I got from them was that they never found any. At length I met with a merchant who fits out ships for the herring fishery, and from him I learned that in a certain tract of sea near the coast of Scotland herrings are caught, in the stomachs of which are found some kinds of small fishes, but that those herrings will not keep long." "Not content with this," continues Leuwenhock, "I determined to wait for the season when certain herrings are brought to our town, which, as I have heard, are caught in great numbers not far from Amsterdam."

Thus it would appear that to practical men, fishermen, merchants, Dutchmen, who turned over millions of florins and guilders annually from this great staple, the food of that fish by which they lived and throve was itself as unknown *as it is at this day* to the same class of men in Britain; that is, fishermen, who deny that it lives on anything; fishermen who say that it lives upon suction, but without attaching the smallest meaning to the word suction. But Leuwenhock says that he "was not content" with the answers of fishermen and merchants, so he commenced opening the stomachs of some fresh herrings caught in the Zuyder Zee. Failing in all attempts to ascertain the real food of the herring, he came to the conclusion that herrings not only "feed on small fishes and even on their own eggs, but that when urged by

hunger they will swallow anything they meet with." This illustrious man, for he truly was so, adopted other theories and hypotheses in regard to the herring: he thought that all herrings were of one year's growth, and that when they once abandoned the coasts they never more returned to them; and, lastly, he concluded that the small fishes on which herrings feed (which, by-the-bye, he admits he could not discover), besides being inconceivably small, "are used but sparingly by the herring."

The Food of the Salmon.

From about midsummer, but more especially with the autumnal floods, salmon and sea trout of various sizes begin to rush up the fresh water streams and rivers: their object in this annual migration is clearly enough made out—they are proceeding to the place of their birth, the original streams in which they first saw the light, there to perform the act of the propagation of their species. As the roe and milt grow the fish get more and more out of condition: from the time it enters the fresh-water rivers it ceases to feed, properly speaking. True, it may be tempted to spring at an artificial fly, or to attack a worm or minnow, in accordance seemingly with its original habits and nature; for whilst it lived as a smolt in the fresh waters the ordinary food of trout was also its food; but from the time it first descends to the ocean as a smolt and tastes its marine food, it never again resorts to its infantile food as a constant mode of nourishment. This great fact, well understood by fishermen and true anglers, Mr. Young, of Invershin, has placed, by direct experiment, beyond all doubt.

But what is the food of the true salmon in the ocean?—that food which he cannot do without?—that food on which relatively all his good qualities depend?

As nothing is ever to be found in the stomach and intestines of the fresh-run salmon but a little reddish substance, I placed a microscope over this substance. After much difficulty I came to the conclusion that it was composed of the ova of some species of the Echinodermata. With salmon, whilst in the sea, this is the constant and sole food: sea trout and hirling also live on it, but they readily take to other food, even in the sea, such as the sand-eel, herring-fry, &c. In fresh-water streams the true salmon does not feed; the sea trout feeds, but does not thrive. The absence of this peculiar food forms an insurmountable obstacle to the localization of the salmon, and even of some kinds of the sea trout in fresh-water lakes.

M. Valenciennes remarks, in his great work on Fishes, that the salmon is "vorace; sa nourriture consiste en poissons; (annodytus tobianis.") There exists not a single fact in the history of British salmon in support of this opinion.

In the absence of positive evidence in respect of the marine food of the salmon various theories have been invented by ingenious men, fishermen, closet naturalists, amateurs, and others, to explain the well-known fact of the seeming emptiness of the stomach and intestines in the high-conditioned fresh-run salmon. These theories require no refutation. Some imagined that the salmon refrained from eating in order to prepare himself for his ascent up the river; we owe this singular fancy to Sir Humphrey Davy. Others imagined that the digestive powers of the salmon resembled a furnace, consuming in an incredibly short space of time all the little fishes they swallow; as the intestines are empty as well as the stomach, they were obliged to assign to the salmon's stomach a power equal to the digestion of indigestible parts, such as the skeleton, lens of the eye, &c. Lastly, some conjectured that the salmon discharges, on being taken, the contents of his stomach; but daily on the Tay at Invershin, and elsewhere, salmon are taken *in large numbers* at a single haul of the seine; I have often seen them so taken. Could such a fact, if true, escape observation? I leave the hypothesis in the hands of the practical fishermen.

In spring, as the spawned fish are descending with the smolts towards the ocean, they may occasionally be tempted with an artificial fly or lob-worm; but as to their *feeding* regularly in rivers, Mr. Young's experiments prove, beyond all doubt, that if they feed they profit nothing by it, losing weight and strength daily during their sojourn in the fresh waters.

*Of the Entomostraca themselves.**

The object of this memoir being simply to establish the fact that many valuable gregarious fishes live, some exclusively, others partly, on the Entomostraca, it is not my intention to say much respecting the minute shell-fish serving as their food. They were first admirably described by Müller and Jurine, and their natural history is tolerably well known. They must be exceedingly prolific, and breed no doubt many times a year: they are abundant in the sea as well as in fresh-water

* Engravings of the specimens of the Entomostraca first discovered in the vendace and herring will be found in my Memoir presented to the Royal Society of Edinburgh.

lakes; and it is easy to see, by their numerous remains in the limestone of Birdiehouse, and in the limestone of other quarters, that they played an important, perhaps the same, part in the economy of the ancient world that they do in this, namely, serving as food to countless shoals of gregarious fishes, which abounded then as now in fresh and marine waters.

The Entomostraca of the Southern hemisphere differ seemingly from those of the northern; there also they serve as the food of gregarious fishes. This was proved by my brother many years ago, in respect of the so-called herring of the Bay of Islands, a gregarious fish abounding in these seas, and living on Entomostraca.

To the minuteness, and, indeed, microscopic character of the Entomostraca, must be ascribed the fact of their having so long escaped the notice of naturalists and others, and causing even distinguished observers to consider their occasional presence in the stomachs of fishes to be merely accidental.

The largest of the gregarious fishes I have as yet observed which lives, or may live, exclusively on the Entomostraca, is the early gray trout of Loch Leven and the char; but I have no doubt that on the American continent there are many admirable fishes of the natural families of Salmonidæ, Corregoni, Clupeadæ, and even others, whose food, when discovered, will be found to be Entomostraca of various species. They vary considerably in size, and seem to extend from pole to pole, consuming the organic remains which but for them might speedily infect the ocean itself.

To the geologist the facts stated in this memoir must, I think, prove of deep interest. Certain of the most productive of the gregarious fishes of past and present times depend for their existence on a class of animals exposed to destruction by chemical or other changes in the waters they inhabit: their destruction would probably involve the fish which prey on them. As regards the herring, these facts may some day explain the capriciousness in the movements of the vast shoals which visit the coasts of Scotland and other northern countries—their appearance and disappearance at various times; for the question of food must be with herrings, as with men, the all important question.

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