AN ECONOMICAL CONSIDERATION OF FISH PARASITES.

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It is not the purpose of this paper to attempt more than a brief sketch of the subject. Before an exhaustive discussion of the economics of parasitism of fish could be profitably undertaken it would be necessary for us to know a great deal more than we do about the life-histories of the forms which infest fish. All that I shall attempt to do, therefore, will be to gather together in brief space such points as have come under my notice which seem to me to bear on the general thesis of parasites of fish economically considered.

The literature of parasitism as affecting fish, mainly systematic or morphological, is widely scattered through a great variety of publications and in many languages; and on account of the great amount of pioneer work which needs to be done—for only a comparatively small number of species of the fishes of North America have been examined for parasites with care—no compilation is yet possible for the parasites of fishes which could be of such permanent utility as the excellent ones which are being prepared for the Department of Agriculture by Dr. C. W. Stiles relating to the parasites of the domestic animals.

I think it must be acknowledged also, for the present at least, that by far the greater number of species of parasites infesting fishes are of interest to the zoologist alone and do not concern the practical fish-culturist, except as he may be interested in questions which have not yet emerged from the comparatively limited field of scientific investigation into the broader field of practical application. And yet even here it may not be wise to despise the day of small things. Under conditions incident to the work of fish-culture the natural interworking of bionomic relations may be so far disturbed as to give an otherwise insignificant parasite all the importance which attaches to the efficient cause of an epidemic. It is quite within the bounds of possibility for damaging cases of parasitism to arise among the fish of a given fish pond which owe their origin to the casual visit or brief sojourn of a fish-eating bird.

An unusual, though altogether natural, condition of this kind exists in Yellowstone Lake, which has been much written about. It is sufficient to say here that the lake when first discovered contained but a single species of fish—the Rocky Mountain trout—which, it is thought, made its way across the great continental divide by way of a bifurcating stream on Two-Ocean Pass. A considerable percentage of the trout of the lake were found to be infested with a parasitic flesh-worm. Upon a careful examination it was found that this worm, although more commonly occurring in cysts in the body cavity, very frequently left the cyst, and, migrating into the flesh of its host, there developed until it was, in extreme cases, a foot or more in length. This worm was plainly a serious drain on the vitality of its host and doubtless caused the death of large numbers of the trout. The very probable source of infection in this case was shown (No. 12) to be the pelican, which in 1890 frequented the lake in large

numbers and had at least one breeding-place on some small islands in the southeastern arm of the lake.

The case is of interest here because the unusual conditions at Yellowstone Lake are, in great degree, parallel to those which exist in an artificial pond; that is to say, the natural enemies are diminished in number and the geographical range of individuals is limited. In the case of the fish of Yellowstone Lake the effects of parasitism were more marked and the instances more numerous than they were in Heart Lake, where usual conditions of food, enemies, and geographical range prevail. So, in any confined area, such as a fish pond or even lake, if conditions favorable to parasitism exist, the cases of parasitism will, in all probability, be more numerous and more serious than they will be in an ordinary stream. A knowledge of the life-history of the parasite in question will be of the greatest value. This will help us to understand the importance of what we usually call purely scientific work.

As fish-culture becomes more extensive, there will naturally develop a condition of things in a degree paralleled by what we see in the case of the domestic animals. As civilization advances, the carnivorous enemies of the domesticated animals are exterminated, or at least driven out, and are no longer a source of loss to the sum total of herbivorous animals. Further, a link in the chain of an important group of animal parasites is thereby broken, and occasional cases of infection, to a degree which might prove fatal to the herbivorous host while the carnivores were ranging the country, would be impossible under the conditions imposed by civilization.

So the cultivation of useful food-fish should lead naturally to the extermination of such enemies as fish-eating birds, mammals, and fish which are not of economic value. Thus one source of parasitism would be destroyed.

In those cases, however, where the food-fish is the final host, the intermediate host being an invertebrate which is a necessary source of food for the fish, no link in the chain of parasitic existence is broken, and the extermination of such parasites seems to be altogether impossible. Something can be done, possibly, by instructing fishermen to burn or bury fish which are not in good condition and the viscera of fish, and not to throw them back into the water. Especially should this be insisted on where the fishing is done in the smaller lakes. It should be remembered that the destruction of a single adult cestode worm destroys immediately many thousands and even millions of eggs and prevents many thousands more from developing for each month which the worm might continue to live.

For some general considerations on this subject, as well as upon some phases of the economics of parasitism, reference is here made to an article prepared for the World's Fisheries Congress held in Chicago in 1893, and published in the Bulletin of the United States Fish Commission for 1893, pages 101–112; especially Sections III and IV of that article. In order, as far as possible, to avoid repetition, I shall continue the discussion under headings corresponding to the several natural orders or groups which furnish the majority of cases of parasitism among fish.

It does not come within the proposed scope of this paper to discuss vegetable parasitism among fishes. Reference may be made, however, to an article in the U. S. Fish Commission Bulletin for 1893, by G. P. Clinton: Observations and Experiments on Saprolegnia infesting Fish, pp. 163–172, with a bibliography.

A list of authorities, for the most part found in publications of the U. S. Fish Commission and National Museum, is appended, and will be referred to by number. More extended reference to the literature of the subject will be found in these publications.

PROTOZOA.

Parasitism occasioned by the presence of one-celled organisms has not been much studied in this country. Gurley's paper (No. 5) is an admirable compilation, and, it is to be hoped, will be followed by systematic work on the psorosperms of fishes inhabiting American waters. From an economic point of view, it is probable that parasitism which results from infection with protozoan parasites will, of all kinds, be found to be most important. Epidemics among European fish have been repeatedly traced to this source. The fatality which attends infection with psorosperms appears to be due to a secondary cause, however, namely, to bacilli which develop within the psorosperms (*Myxobolus*) tumors and give rise to ulceration. The discharge of these ulcers then disseminates the disease. For an account of an epidemic among barbels in the Meuse and other rivers of France and Germany, see Gurley's paper (No. 5), p. 231.

Brief mention of the remedies there proposed, pp. 233–234, may appropriately be repeated here. Mégnin sees no other method than to collect all the dead or sick fishes and destroy them by fire. Ludwig thinks that the waters should be kept pure and that the pollutions of the rivers by communities or industrial establishments should be interdicted. Further he says:

> That most dangerous contamination of the water by the *Myxosporidia* from the ulcers can not of course be stopped entirely, but it is evident that it will be less if all fishermen are impressed with the importance of destroying all diseased and dead fish instead of throwing them back into the water. Such destruction must be so effected as to prevent the reentry of the germs into the water.

Railliet says that it is expedient to collect the diseased fish and to bury them at a certain depth and at a great distance from the water-course. He further states that this was done on the Meuse with success, so that at the end of some years the disease appeared to have left no trace.

TREMATODA.[1]

Representatives of this order are numerous among the parasites of fishes, but, so far as I have observed, are not likely to occur in sufficient numbers to occasion serious loss. Their presence will be a tax, nevertheless, on the vitality of their host, which may be, in many contingencies, the determining factor in causing that host to fall an easier prey to its pursuer than its uninfected comrade will do.

In my paper on Trematodes, No. 17 of the appended list, are described 31 distinct species and one variety taken from 25 specifically distinct hosts. In the majority of cases these worms were found in small numbers in the intestines of their hosts, and presumably occasioned little inconvenience. In a few cases, however, I found them encapsuled in various positions in the body cavity, and occasionally in such numbers that they must have affected seriously the vitality of their hosts. For example, a species (which was referred to Diesing's *Diplostomum cuticola*) was found in great abundance on the viscera of three species of sunfish, *Lepomis auritus*, *Chænobryttus gulosus*, and, probably, *Lepomis pallidus*. The viscera consisted mainly of hearts and livers, and were sent to me by Mr. N. A. Harvey, of Kansas City, Mo., January, 1894. The serous coats of these organs were thickly studded with cysts. These were very numerous, and varied in size from minute specks to capsules measuring over 1 mm. in diameter. The largest larva, upon removal from its cyst, measured, in alcohol, a little over 1 mm. in length and about 0.4 mm. in breadth. On account of the immense numbers of these parasites they might very easily prove to be an economic factor of

[1] See List of Authorities: No. 6 and 13, pp. 553, 554, pl. 65, figs. 22–30; Nos. 17, 18, and 19.

considerable moment, and it is desirable that our knowledge of the life-history of the species should be extended. There is some reason for thinking that the final host is a fish-eating bird, although it may be some voracious fish, like the gar.

Dr. H. B. Ward has published some very interesting notes of his observations on the fish parasites of the Great Lakes (No. 18). From an examination of 20 species of lake fish, the total number of individuals examined being 102, 95 of which were infested with parasites, he obtained something over 4,000 Trematodes, 2,000 Acanthocephala, 200 Cestodes, and about 200 Nematodes. Trematodes were obtained from every species examined, and in enormous numbers from the dogfish (*Amia calva*). Cestodes were obtained from 14 of the 20 species, Acanthocephala from 13, and Nematodes from 7. Dr. Ward describes a new Distoma from *Amia calva* (No. 19,) encysted forms of which he finds in the crayfish (*Cambarus propinquus*), thus establishing its life-history. The adult form was found also in the channel catfish, *Ictalurus punctatus*, and the yellow perch, *Perca flavescens*.

I would conclude from the results of Dr. Ward's researches, as compared with what I have had the opportunity to observe, that Trematodes are relatively much more abundant in fresh-water fishes than in marine fishes.

CESTODA.[1]

My investigations have been mainly on marine fishes, in which I have found the members of this order very abundant, largely, perhaps, because of the predilection which the adult forms appear to have for the spiral valve of the Elasmobranchii. The individual shark or skate is not only an engine of destruction, but a source of infection from which innumerable ova of a variety of cestode parasites issue to become encysted in various animals which serve them for food. There can be little doubt that if the sharks and skates were to be exterminated, or sensibly diminished in number, the aggregate of intermediate parasitism among the teleosts, squids, crustacea, and other food of sharks and skates would be materially lessened. The destruction of the Elasmobranchii, while probably not practicable, would be a disturbance of the balance of nature wholly in favor of the food-fishes.

I find larval forms of two genera (*Rhynchobothrium* and *Tetrarhynchus*), in which the adult forms are peculiar to sharks and skates, very commonly encysted in many species of marine food-fish, such, for example, as the squeteague (*Cynoscion regale*). Of adult forms, while the genus *Dibothrium* is somewhat abundant in cods (*Gadidæ*) and flounders (*Pleuronectidæ*), and tapeworms not unusual in the eel and some fresh-water fish, the vast preponderance is to be found infesting the *Elasmobranchii*. The case of the *Dibothrium* of the Rocky Mountain trout has already been mentioned.

It is very desirable that our knowledge of this important group of parasites be extended, both in the direction of ascertaining what forms are to be found in the fish of our waters and in working out the life-histories of forms already known. It should be remarked that one species of human tapeworm (*Bothriocephalus latus*) is believed to be got from eating the flesh of the European tench.

I take this opportunity of calling attention to a paper by Dr. F. S. Monticelli (Boll. d. Soc. d. Nat. Napoli, Serie I, vol. VIII, Anno VIII, Fasc. I, 1894) *Si Mangiano le Ligule in Italia?* In this paper the author affirms that Leuckart is in error in stating (*Die Parasiten des Menschen*) that in Italy the ligula—a larval form of a cestode worm which develops in the abdominal cavity of certain fresh-water fish and there

[1] See List of Authorities: Nos. 7, 8, and 10 to 16.

attains considerable dimensions—is "eaten as living macaroni." This statement of Leuckart's has been taken without question and repeated in various forms by different writers. Donnadieu (Contribution à l'histoire de la Ligule, Journal d'Anatomie et de la Physiologie 1877) repeats the assertion and adds that many people in Lyons have the same habit. Doubtless the truth is that ligulæ have been eaten along with the fish which harbored them, much as roe is eaten, by persons who did not know the real nature of the tidbit, which no doubt, in the blissful ignorance of the eater, pleased his palate quite as well as did the flesh which was a part of the fish.

ACANTHOCEPHALA.[1]

The members of this order, so far as my observation goes, are not found in large numbers in many species of fish, although they are likely to occur in great number in occasional individual hosts, particularly among the flounders (*Pleuronectidæ*). The most persistently occurring cases of parasitism which I have observed, however, have been in this order. I have examined the striped bass (*Roccus lineatus*) repeatedly in successive summers at Woods Hole, Massachusetts, and have rarely found an individual which was not infested with a thorn-head worm (*Echinorhynchus proteus*). Sometimes it occurs in considerable numbers, and almost always penetrates with its thorny proboscis the coats of the intestine of its host, thus causing more or less local irritation, followed by a waxy degeneration of the tissues.

There is probably no practical way of counteracting the bad influences of worms of this order, since their larval state is passed, in some cases certainly, and in most cases probably, in small crustacea, which constitute a constant and necessary source of food for the fish. The same remark which was made in another connection with regard to the disposal of the viscera of fish applies here. In no case should the viscera of fish be thrown back into the water. In this order the sexes are distinct, and the females become at last veritable sacs for the shelter and nourishment of enormous numbers of embryos. The importance, therefore, of arresting the development of as many embryos as possible is at once apparent.

NEMATODA.[2]

The round worms are very abundant, especially in immature stages, in marine fishes. In fresh-water fishes they are probably not so abundant.

I have lately gone over a large collection of nematode parasites of fishes, made in part by myself at Woods Hole, Massachusetts, and in part belonging to the United States National Museum, having been collected in various localities. In this collection there are nematodes from over 60 species of fish. I have noted some 80 distinct kinds, 14 of which have to be recorded as "*Ascaris* species," they being immature, although free in the intestines of their hosts. They plainly belong to the genus *Ascaris*, but do not have distinct characters which will enable one to refer them to species already established or to make it advisable to give them new specific names. At least 40 kinds, from as many specifically different hosts, I have been obliged to refer to a section headed "Immature nematodes, encapsuled, and for the most part belonging to the genus *Ascaris*." It would not be profitable to give names to these immature forms, since many of them are doubtless different stages in the development of the same

[1] See list of authorities: No. 7, pp. 490–498, pl. v, vi; No. 9; No. 13, pp. 555–556, pl. 65–67.
[2] See list of authorities: No. 13, pp. 557–561, pl. 67; No. 14, pp. 111–112.

species. Often in a lot of encapsuled forms, collected at the same time from the same host, individuals are obtained which differ very considerably one from another.

One viviparous species belonging to the genus *Ichthyonema* (which I have referred, with some hesitation, to the species *Ichthyonema globiceps* Rudolphi) on account of the enormous number of young which the adult specimens contain, might, under favorable conditions, become of serious import. I shall speak of it somewhat in detail. The several lots of worms which I refer to this species come from the following hosts:

1. Bluefish (*Pomatomus saltatrix*), ovaries, Woods Hole, August, 1884.
2. Spanish mackerel (*Scomberomorus maculatus*), ovary, New Jersey coast, S. E. Meek, collector, October, 1886.
3. Black grouper (*Lobotes surinamensis*), peritoneum, Woods Hole, August 3, 1887.
4. Black grouper (*Lobotes surinamensis*), viscera, Woods Hole, August 6, 1887.
5. Tarpum (*Tarpon atlanticus*), U. S. Nat. Mus. collection, locality and date of capture not given.

The specimens are all females, and, with the exception of lots 2 and 5, have the uterus, at least its lower portion, filled with embryos. They are all very long and of nearly uniform diameter throughout, and rather bluntly rounded or conical at the extremities. In lot 1 the embryos, which occur in myriads, appear to have escaped by rupture of the uterus into the body cavity. Lot 3 consists of two specimens obtained from the body cavity of their host. They measured living 510 and 580 mm. in length, respectively, and 1.48 mm. in diameter; color, brownish. The intestine appeared as a dark-brown line for more than two-thirds of the entire length and as a white line for the remainder of its length. The intestine ends blindly at its posterior extremity. My notes, made at the time of collecting, state that the external opening of the uterus is at a point about 1 mm. from the anterior end, where it was observed that the young were being discharged in vast numbers. Under slight pressure, however, two tubes were seen protruding for a short distance, from each of which young were escaping. This would appear to indicate that the uterus had been broken, and what was taken to be an external opening may have been a break in the body wall.

The embryos measured about 0.4 mm. in length, 8 μ in diameter at the posterior end, and 13 μ in greatest diameter. The anterior end was very slender, appearing as a mere line, even when highly magnified. These embryos are characterized by having a few, about four, dark-brown granular masses scattered along the middle region of the body. A slight notch was noticed at the posterior end of some. A favorite position of these embryos is with the posterior end bent rather sharply, often so much so as to point forward. The anterior end is also often bent so that the two ends point toward each other. Where they occur in the greatest abundance in the parent worm they impart to the latter a plump and even distended appearance. After the discharge of the embryos the worm is transparent, much contracted, quite irregular in outline, and in places flattened and shriveled. I do not know what the history of this worm is between the embryos as seen in these specimens and the adult. The embryos are eminently well fitted for making their way by means of their attenuated and filiform anterior ends through the tissues of their host, whatever that host may be. If they have a history anything like that of *Trichina spiralis*, then the animal which would make a meal off of a fish harboring one or more adult *Ichthyonemæ* has trouble ahead.

While encapsuled nematodes were found in a large number of the species of fish examined, and in considerable abundance in some, they were almost always confined to the body cavity, where they lay in flat coils for the most part on and among the viscera. They were very seldom seen in the flesh. The adults in the alimentary canal

in most cases occurred in comparatively small numbers in the several hosts. The only fish in which I found numerous adult nematodes was the swordfish (*Xiphias gladius*). These worms were referred to the species *Ascaris incurva* Rudolphi. They were found in the stomach and were of different sizes, from immature, filiform specimens up to large, plump individuals 250 mm. in length. The largest of which I have any record was 267 mm. in length and 3 mm. in diameter.

I pass over cases of external parasites of fishes, leeches, lerneans (fish lice), etc., as not coming within the proposed scope of this paper.

WASHINGTON, PENNSYLVANIA.

Partial list of American authorities on fish parasites, especially such as have been published by the U. S. Fish Commission and the U. S. National Museum.

PROTOZOA.

1. On certain wart-like excrescences occurring on the short minnow, *Cyprinodon variegatus*, due to psorosperms. Edwin Linton. Bulletin U. S. Fish Commission for 1889, pp. 99–102, pl. XXXV.
2. Notice of the occurrence of protozoan parasites (Psorosperms) on cyprinoid fishes in Ohio. Edwin Linton. Bulletin U. S. Fish Commission for 1889, pp. 359–361, pl. CXX.
3. On the classification of the Myxosporidia, a group of protozoan parasites infesting fishes (issued July 15, 1893). R. R. Gurley. Bulletin U. S. Fish Commission for 1891, pp. 407–420.
4. Report on a parasitic protozoan observed on fish in the Aquarium. C. W. Stiles. Bulletin U. S. Fish Commission for 1893, pp. 173–190, pl. 11, 12.
5. The Myxosporidia, or psorosperms of fishes, and the epidemics produced by them. R. R. Gurley. Report U. S. Fish Commission for 1892, pp. 65–304, pl. 1–47.

HELMINTHA.

6. On a skin parasite of the cunner (*Ctenolabrus adspersus*). John A. Ryder. Bulletin U. S. Fish Commission for 1884, pp. 37–42.
7. Notes on entozoa of marine fishes of New England. Edwin Linton. Report U. S. Fish Commission for 1886, pp. 453–511, pl. I–VI.
8. Notes on entozoa of marine fishes of New England, Part II. Edwin Linton. Report U. S. Fish Commission for 1887, pp. 719–899, pl. I–XV.
9. Notes on entozoa of marine fishes, Part III. Edwin Linton. Report U. S. Fish Commission for 1888, pp. 523–542, pl. LIII–LVIII.
10. The anatomy of *Thysanocephalum crispum*, a parasite of the tiger shark. Edwin Linton. Report U. S. Fish Commission for 1888, pp. 543–556, pl. LXI–LXVII.
11. On two species of larval dibothria from the Yellowstone National Park. Edwin Linton. Bulletin U. S. Fish Commission for 1889, pp. 65–79, pl. XXIII–XXVII.
12. A contribution to the life-history of *Dibothrium cordiceps*, a parasite infesting the trout of Yellowstone Lake. Edwin Linton. Bull. U. S. Fish Commission for 1889, pp. 337–358, pl. CXVII–CXIX.
13. On fish entozoa from Yellowstone National Park. Edwin Linton. Report U. S. Fish Commission for 1889–1891, pp. 545–564, pl. 63–67.
14. Some observations concerning fish parasites. Edwin Linton. Bulletin U. S. Fish Commission for 1893, pp. 101–112.
15. Notes on larval cestode parasites of fishes. Edwin Linton. Proc. U. S. National Museum, vol. XIX (1897), pp. 787–824, pl. LXI–LXVIII.
16. Notes on cestode parasites of fishes. Edwin Linton. Proc. U. S. National Museum, vol. XX (1897), pp. 423–456; pl. XXVII–XXXIV.
17. Notes on trematode parasites of fishes. Edwin Linton. Proc. U. S. National Museum, vol. XX (1897), pp. 507–518; pl. XL–LIV.
18. Some notes on the biological relations of the fish parasites of the Great Lakes. (Abstract.) H. B. Ward. Proceedings of Nebraska Academy of Science, IV, pp. 8–11. 1894.
19. Notes on the structure and life-history of *Distoma opacum*, new species. H. B. Ward. Proceedings of American Microscopical Society, vol. XV, pp. 173–182, with plate.