STUDIES ON PARASITIC COPEPODS OF THE GENUS SALMINCOLA[1]

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THE parasitic copepods afford a very interesting group of animals for the biologist. Not only do these organisms offer many fascinating problems for the pure scientist, but from the commercial standpoint they are extremely important as parasites of our food and game fishes. There is every degree of parasitism amongst these crustacea, from those which spend a very small portion of their existence as parasites to those which are parasitic throughout almost their entire life. My own studies, covering a period of nearly ten years, have been confined to some of the most highly specialized members of the latter group, belonging to the genus *Salmincola* of the family *Lernæopodidæ*.

The *Salmincola* are parasitic on the *Salmonidæ*, which include such important fishes as salmon, trout, lake herring and whitefish. These copepods are all built on a similar plan and can be easily recognized. The adult females are the ones which are usually encountered, and these may be attached to the delicate membranes of the gills, gill chambers, fins and mouth of the host. Here they hang on and are supplied with a constant stream of fresh blood, which serves as their sole food.

These adult copepods can be readily seen with the naked eye. They are quite large, measuring a few millimeters in length, and are yellowish-white in color. Anteriorly they are fastened to the host by means of two second maxillæ and a chitinized bulla. This last named structure is imbedded in the tissues of the host. Posteriorly each female possesses a pair of slender freely

[1] Delivered before the Biological Club, Oregon Agricultural College.

dangling egg-sacs within which the embryos undergo complete development.

During the last few years our knowledge of the *Salmincola* has been increased largely through the efforts of Wilson and the present writer. Wilson, in 1915,[2] published a key to the various species of *Salmincola* found in North America, while the present writer (1912–1919)[3] has published a series of papers on the behavior, morphology, life-history and economic importance of two of these forms, namely *Salmincola edwardsii* (Olsson) Wilson, which parasitizes the brook trout of our middle-western and eastern states, and *Salmincola falculata* Wilson, which is parasitic on salmon and trout of our Pacific states. In speaking of the former species, Smallwood, in a recent paper,[4] says:

> These parasites are widespread in the United States in the native trout streams, and in Canada and Europe. The first scientific record of this particular parasite is by Linnæus in 1761. It seems strange that an animal could be known for so long and its habits not be understood until within the past five years.

The writer is at present engaged on other species of *Salmincola* which dwell on various salmon and trout of the northwest section of the United States. From all appearances the different stages in the life histories of the various species of *Salmincola* seem to be more or less similar and, therefore, will be briefly outlined.

As already mentioned above, the young larval copepods undergo development within the egg-sacs of the attached females. When these larvæ are mature, they rupture the egg-sacs and escape into the water as minute, freely-swimming organisms that closely resemble free-living pelagic copepods. Although they measure about one thirty-fifth of an inch in length, they are very active and

[2] *Proc. U. S. Nat. Mus.*, Vol. 47, pp. 565–729.

[3] *Report Wis. Fish. Com.*, 1911–12, pp. 12–22. *Jour. An. Beh.*, Vol. 3, pp. 36–60. *Biol. Bull.*, Vol. 27, pp. 115–127. *Biol. Bull.*, Vol. 31, pp. 407–419. *Pub. Puget Sound Biol. Sta.*, Vol. 2, pp. 73–77. *Pub. Puget Sound Biol. Sta.*, Vol. 2, pp. 153–181.

[4] AMER. NAT., Vol. 52, pp. 322–352.

swim about with a snappy spiral dart. They may thus swim about for nearly two days, constantly searching for a host to which to attach themselves. They dart here, there and everywhere: if not successful in meeting a host, they soon die, but if one is found they attach themselves and carry on their life-cycles to completion.

In *Salmincola edwardsii* it has been found that the larval copepods swim about near the surface of the water throughout the day, but at night they sink down to lower depths near the bottom of the stream. These migrations, although contrary to the general migrations of free-living copepods, are, nevertheless, of great benefit to these parasitic forms in that they are parallel with the migrations of the hosts. Brook trout generally feed near the upper surfaces of the streams during the day and at night they sink down to lower levels. This similar behavior on the part of the parasite and the host makes it much easier for the parasite to meet its host and thereby carry out its life-cycle.

The manner in which the larval copepod attaches itself to the host is extremely interesting. Each larva possesses powerful mouth parts and a peculiar attachment filament which aid in the attachment of the organism. On coming in contact with a desirable portion of the host, the parasite first rasps a hole in the tissues by means of its mouth parts. Then the attachment filament is brought in contact with this cavity and by means of the contraction of numerous thin head muscles which are attached to the proximal end of the attachment filament, the bulb-like distal end of the filament is driven into the cavity. The glue-like secretion of the attachment filament as well as the regenerating tissue of the host soon attach the copepod quite securely.

The copepod now undergoes degeneration. It loses its segmentation as well as its plumose swimming feet. The abdomen rounds out, becomes larger and more bag-like in outline. The mouth parts also change their appearance. The mouth itself grows into a prominent tube-like

piercing organ, which is capable of puncturing the tissues of the host for purposes of sucking blood. This is the exact method by means of which the attached parasite feeds itself.

About a week after attachment to the host, the modification of the parasite has been so complete that one can hardly recognize any resemblance between it and the free-living larva from which it was derived. In another week and a half, that is, about two and a half weeks after attachment, the copepods have reached sexual maturity and are ready to undergo fertilization. The males can now be easily distinguished from the females. This was not possible previously. The females are veritable giants as compared with the males, being about three or four times the size of the latter.

The only male ever discovered in the genus *Salmincola* is that of *Salmincola edwardsii,* which has been described and figured in the *Biological Bulletin* for 1914. The writer has just completed the study of another male of a different species of *Salmincola,* namely, *Salmincola beani* Wilson which he recently discovered on the gills of the chinook salmon.[5] This new male shows the same size difference when compared with the female as does the male first mentioned.

Prior to fertilization, the males and females hang side by side on the tissues of the host. In order to accomplish fertilization, the male undergoes a rather peculiar behavior. He begins circling movements and somewhere in his vicinity he comes in contact with a female. As soon as this occurs, the male clasps the female with his maxillipeds and at the same time he releases his hold on the tissues of the host. The male then creeps towards the posterior region of the female's body, in the neighborhood of the genital pores, and here he attaches himself in position for fertilization. The male next bends his abdomen upward toward the genital openings and soon extrudes two pear-shaped pouches known as spermato-

[5] In press, *Biol. Bull.*

phores. These are manipulated by the free maxillæ of the male and are ultimately attached near the genital pores of the female. The spermatophores contain a cement-like material which aids in their attachment. They are also filled with large numbers of mature spermatozoa which wander through the genital pores and become stored within the spermatheca of the female. Here these male gametes remain dormant until the ova of the female are ripe for fertilization. When the wandering of all the spermatozoa has been completed the spermatophores collapse and soon come to resemble transparent, shell-like, yellowish spheres. The female may be fertilized more than once. Oftentimes as many as six spermatophores may be found clinging to the genital pores of some of the females, showing that these have been fertilized three times.

After fertilization, the male drops off the body of the female and soon dies. The female, however, lives on and completes the life-cycle. She now undergoes extreme degeneration, increases enormously in size, and develops a large number of eggs which become clearly visible within her abdomen. At the same time two slender membranous egg-sacs make their appearance at the posterior margin of the female's body. When the ova are ripe they are passed down through the oviducts and as they migrate past the spermatheca they are fertilized by the stored spermatozoa. The embryos are then transferred to the egg-sacs where they carry on their complete development. In about a month the young are liberated as free-swimming larvæ ready to begin the cycle again. In *Salmincola edwardsii* two batches of young are produced, each numbering about one hundred and twenty individuals. After all the young have been liberated, the adult females die and soon deteriorate on the tissues of the host.

Although these copepods are not, ordinarily, very dangerous to fish in their natural haunts, yet from the standpoint of fish-culture they are of considerable eco-

nomic importance. When once they make their appearance in our hatcheries they cause a great deal of damage and loss amongst the fish. Here conditions are ideal for parasitism. The ponds are small and large numbers of fish are crowded into them. Because of this situation the parasitic larvæ have very little trouble in finding their hosts. At the same time the current of water which circulates through the hatchery ponds is not swift enough to interfere with the movements of the parasitic organisms. It is therefore a matter of a short time before most of the fish become heavily infested with copepods.

While the young fish as well as the adults are attacked in the hatchery ponds, nevertheless it is mainly the adult fish which are most heavily parasitized. These are attacked by so many of the copepods that they are ultimately killed. It is by no means uncommon to find as many as two hundred and fifty copepods on one trout. Recently I found around five hundred copepods on the gills of a single chinook salmon. In such cases of parasitism the injury to the host is considerable. In the first place, the parasites suck enormous quantities of blood, thereby depriving the host of a large amount of nourishment. Secondly, when the copepods attach themselves, they injure the tissues of the host, thereby making it possible for injurious spores and bacteria to enter and set up secondary infections of a serious nature. And lastly, the injured tissues swell and develop into so-called "scar tissues," which interfere with the normal functions of the host. Taking all these facts into consideration, there is little wonder that fish succumb under the attacks of these parasites, particularly in hatchery ponds where conditions are just right for parasitism. In one Wisconsin hatchery the author found that in a single year about twelve thousand adult trout out of fourteen thousand kept in outdoor ponds died from the attacks of these copepods.

Many states have had this trouble for years, with very serious losses. The writer has devoted considerable

attention to the control of these parasites, and has recommended the following remedies in the state of Wisconsin. These have also been found useful in other states where the same type of parasitism has made its appearance.

1. When the water supply is polluted, sand filters should be installed at the mouth of the water stream as it makes its way into the hatchery ponds. The sand catches most of the free copepods before they enter the hatchery, thereby preventing them from attacking the fish.

2. The young fry should be given salt baths quite often. The salt solution kills the copepods during the early stages of attachment. At the same time this solution makes the fish more resistant to the attacks of the parasites.

3. Since the adult fish are the ones most heavily parasitized, it is better to do away with these as soon as possible and to keep only the younger fish for spawning purposes.

4. Inasmuch as the free-swimming stages of the copepods are strongly attracted by intense light, powerful arc lights should be erected at various points over the fish ponds. By means of fine gauze bags towed over the illuminated regions, a large number of the copepods can be gathered and removed.

5. The introduction of certain types of minnows into the hatchery ponds tends to keep the parasites down. These minnows feed on the free-living larvæ of the copepods, thereby destroying many of them before they have the opportunity of coming in contact with the proper host.

Another means of overcoming this sort of parasitism which has often suggested itself to the writer is, through breeding, to develop a strain amongst the hosts which would be practically immune to the attacks of the parasites. This appears to be possible when one considers the fact that under similar conditions the hosts show varying degrees of resistance to the parasitic organisms. Some

are attacked very lightly, while others become heavily parasitized. Doesn't it seem logical to speculate that through intelligent selection and breeding, one could develop resistant strains of fish, which would be attacked by so few of the parasitic copepods that the parasites would be almost a negligible quantity?

These remedies, of course, are not absolute, but they may help a great deal in reducing the loss of the fish. In cases of such parasitism there is no absolute cure known. A most desirable remedy would be one which would destroy the adult copepods while they are attached to the structures of the fish, without in any way harming the latter; but all attempts in this direction have thus far been without success. The hosts are so delicately constituted that they can withstand only a very slight change in their environmental medium. The adult copepods, on the other hand, can resist powerful chemical solutions by virtue of their resistant body walls. It is obvious that the weak link in the chain of the life-history of these parasites is the free-living period, and in view of this, the real solution seems to be quite clear. One must catch the organisms as they break out of the egg-sacs of the mother and kill them before they come in contact with their hosts. As with a good many of our modern diseases, "prevention before parasitism occurs" should be our motto, rather than "cure after parasitism."