ZOOLOGICA

SCIENTIFIC CONTRIBUTIONS
OF THE
NEW YORK ZOOLOGICAL SOCIETY

1.

On *Sphyrion lumpi* (Krøyer), a Copepod Parasite on the Redfish, *Sebastes marinus* (Linnaeus), with Special Reference to the Host-Parasite Relationships.

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(Plates I-IV; Text-figures 1-3).

INTRODUCTION.

Many parasites of fishes have little or no appreciable effects on the host tissues. A few, however, are known to be deleterious; either they kill their hosts eventually or result in secondary infections of more virulent types of organisms. More often they weaken the fish so that they become easy victims for their predators. A large number of parasites, especially external forms, render the flesh, in the case of commercially valuable fishes, unmarketable.

Although many species of copepod parasites have been described from fishes, and although the general effects of these organisms on the hosts have been recognized, little is known about the histo-pathology of many such infections. It is the purpose of this paper, therefore, to describe the host-parasite relationships of a copepod infection occurring in the redfish, *Sebastes marinus* (Linnaeus). In recent years (since 1931), this species of fish has become important commercially, millions of pounds being caught annually and prepared for market. The copepod infecting the fish, referred to as *Sphyrion lumpi*, may be found attached to any part of the body, but usually it is buried in the region of the dorsal musculature.

DESCRIPTION OF THE PARASITE.

The copepod found on the redfish belongs to the family Sphyriidae Wilson, 1919. It was first described by Krøyer (1845) as *Lestes* and later

(1863) as *Lesteria.* It was Bassett-Smith (1899) who gave it the correct name *Sphyrion lumpi* (Krøyer). The parasite has been observed in limited numbers on the lump fish, *Cyclopterus lumpi,* from the Danish coast, by Krøyer (1845, 1863) and Steenstrup (1869); from the British seas by Bassett-Smith (1899), T. and A. Scott (1913) and Leigh-Sharpe (1933). Scott (1905) and Leigh-Sharpe (1933) have also reported the copepod on the wolf fish, *Anarrhichas lupus.* Wilson (1901) recorded *Sphyrion lumpi* from *Nematonurus goodei, Haloporhyrus viola* and a salted hake. Again Wilson (1919, 1931) was the first to report it from redfish of the North Atlantic coast of the United States.

The members of the genus *Sphyrion* are easily recognized by the presence of a cephalothorax, the anterior end of which, in females, is expanded transversely to form a process that has been referred to as the sphyra or "hammer" (Plate I, Figs. 1, 2). From the center of the anterior surface of this expanded structure projects the head with its modified appendages. The neck is elongated and smooth while the trunk broadens transversely and in most cases is depressed ventrally. These parasites have no abdomen, but there is a pair of knob-like caudal rami. The copepods are also characterized by the presence of multibranched processes extending from the trunk. The function of these structures is still uncertain. The ovisacs are long and smooth and extend beyond the trunk. In young females, the head appendages are discernible. There are two pairs of maxillae and a pair of maxillipeds which in the more matured parasites become transformed or replaced by simpler processes and in some cases may even be absent.

The male *Sphyrion* is comparatively minute, measuring a little more than 2 mm. in length and 1 mm. in width. The appendages present are the same as those seen in young females. The head is separated from the trunk and there is a small carapace present. The trunk is folded and lacks the arborescent appendage described above.

The present forms of *Sphyrion lumpi* were taken from the body of redfish caught by commercial fishermen off the coast of Maine. They agree in all essential details with the description given by Wilson (1919, 1931), although the measurements of the various parts of the body are slightly different. These are shown in Table I.

TABLE I.

	Hammer		Neck		Trunk			Post. Proc.	Ovisacs	
	Length	Width	Length	Width	Length	Width	Thickness	Length	Length	Width
Wilson[1]	13-16 mm.	10	35-15	2.5	16-12	12	6-5	8-16	20	2.5
Nigrelli & Firth	8-18	2-11	10-30	2-3	9-12.5	10-15	3-8	6-20	20-46	2-3

In young females, the body is more or less transparent, a condition which disappears as the copepod becomes more matured and the body structures thicken. During the growth process, the posterior arborescent structure becomes more and more branched. From the measurements given above, it can be readily noticed that there is quite a variation in the size of the different parts of the body. There are other differences not disclosed by these figures (Plate I, Fig. 2). Thus, the terminal parts of the "hammer" are usually swollen in bulb-like form. In some individuals the width of these ends is not much larger than the median parts of the "hammer," while in others they may be considerably enlarged, more or less

[1] Wilson's measurements based on two matured specimens. Our measurements based on 20 specimens showing ovisacs. In these measurements length of hammer is transverse to body axis.

round, slightly bifurcated or even multilobed. In some forms, the long tubular neck may have a comparatively even diameter throughout its entire length, while in others it may be thicker towards the "hammer" or towards the trunk end; sometimes it is long and thin; at other times it is long and thick and often it is short and thick. The trunk may likewise differ. In a few individuals it appears as a transparent structure, so much so that the internal structures are visible to the naked eye. In others, the ventral region of the trunk is more or less depressed, while in still other individuals this ventral depression is lacking, being for the most part slightly raised above the surface much as it is on the dorsal side.

Studies on the internal anatomy of *Sphyrion lumpi* from sectioned material agree with the description given by Wilson (1919). In the matured females the identity of the mouth appendages is entirely lost. The intestine is narrow in the neck region, dilating considerably in the trunk to form a widened rectum. The peculiar processes described by Wilson (1919) for this part of the intestine were also observed in our material. However, besides these processes, the striking feature of the intestine is the presence of a comparatively large number of secretory gland cells found in the epithelium. The large amount of corpuscles and digested blood in the lumen of the intestine shows that these matured parasites feed almost exclusively on the blood of the host.

The ovaries are two in number, more or less tubular, and situated in the anterior region of the trunk, one on each side of the intestine close to the body wall. The tubular cement glands are situated in the posterior half of the trunk, one below each ovary. The oviducts are coiled and surrounded by a thick layer of chitin. Each duct opens directly into the long chitinous ovisacs.

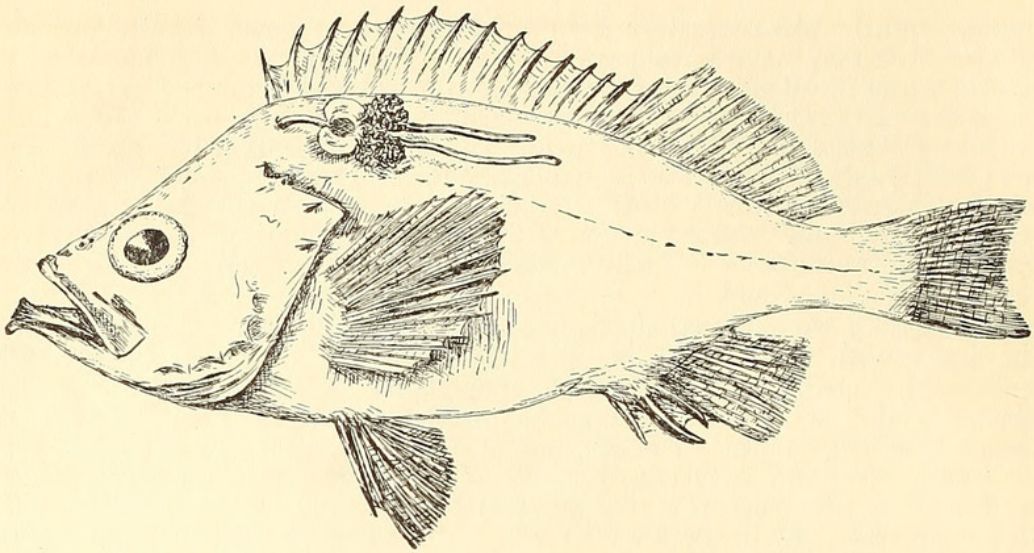
The internal anatomy of the male was not studied.

Although the complete life-history was not followed, due to a lack of living material, from studies of extremely young stages of female *Sphyrion lumpi* and from what we know of the life-cycle of closely related forms, the larvae (copepodid stage?) are the only forms in the cycle that can infect other parts of the body of the fish or other fish. Extremely small forms (2 mm.) found buried beneath the epidermis, beside being highly transparent, show well developed mouth parts, such as maxillae and maxillipeds. It is by means of these structures that the copepod moves about on the body of the host and burrows deeply into the skin and muscle. In such forms the sphyra is not well developed or only slightly so. The neck and trunk are distinct while what will be the arborescent appendage appears as two knob-like outgrowths.

It is of interest to mention here that a large number of redfish examined for *Sphyrion lumpi* were also found infected with a gill species referred to as *Chondracanthopsis nodosus* (see Wilson, 1931).

Distribution of the Parasite on the Host.

In the majority of the redfish examined, the parasites were found buried deep in the skin and musculature in the region dorsal to the lateral line, usually at the base of the dorsal fin. (Text-fig 1). As in the Lernaeidae (see Wilson, 1919), the parasites attempt to reach the dorsal blood vessel for their nourishment. Occasionally, however, parasites were found attached in the body wall in the region ventral to the lateral line. These invariably had penetrated the body cavity. Several specimens were found attached to the eye, anchoring in the anterior chamber. Quite a number of fish were found with the copepod attached to the bony plates of the pre-operculum and the operculum proper. Here, in the majority of instances, the soft bone was perforated so that the cephalothorax passed



Text-figure 1.

Redfish, *Sebastes marinus*, showing typical infection with the copepod parasite, *Sphyrion lumpi*.

into the branchial cavity and became attached to the gill arches, often destroying parts of the gill filaments. On a few occasions parasites were found pendant from the rim of the anal opening, anchoring between the rectum and the body wall of the host.

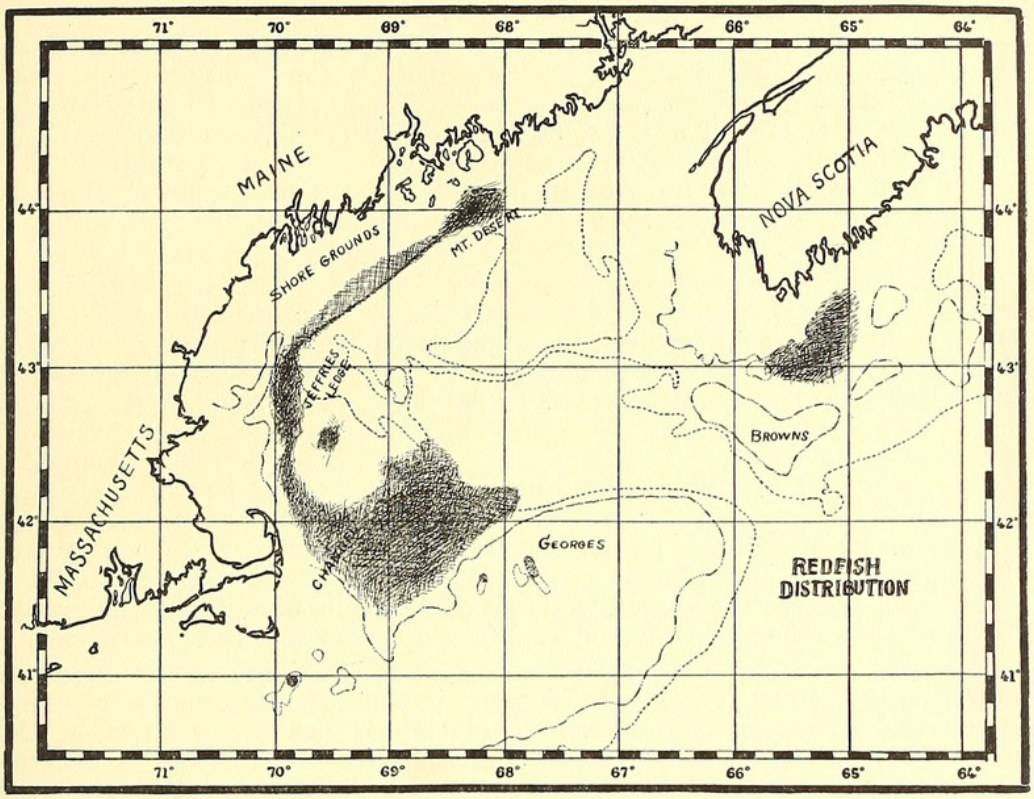
The process involved in this penetration is not exactly known. It is assumed, since the young forms have well developed mouth parts, that they eat their way through the host tissues, for long before they reach any blood vessel there is quite a cavity formed. It is interesting to point out that these copepods have well developed digestive and secretory glands, and it is altogether possible that the secretion given off by these glands may aid the parasite in the penetration.

The number of visible parasites found on each fish may vary somewhat. The largest number of matured parasites recovered from a single fish was 6. Actually, the damage done was considerable, for each copepod would eat and digest away tissue from 1 to 1.5 cm. in depth and about 1 cm. in width, some parasites even penetrating the entire width of the dorsal musculature. However, the parasite population may be greater than that mentioned above, for any fish may harbor many minute copepods underneath the skin. Thus, one fish examined in the laboratory showed three external parasites and two sores. Microscopic examination of the skin revealed as many as twelve immature forms.

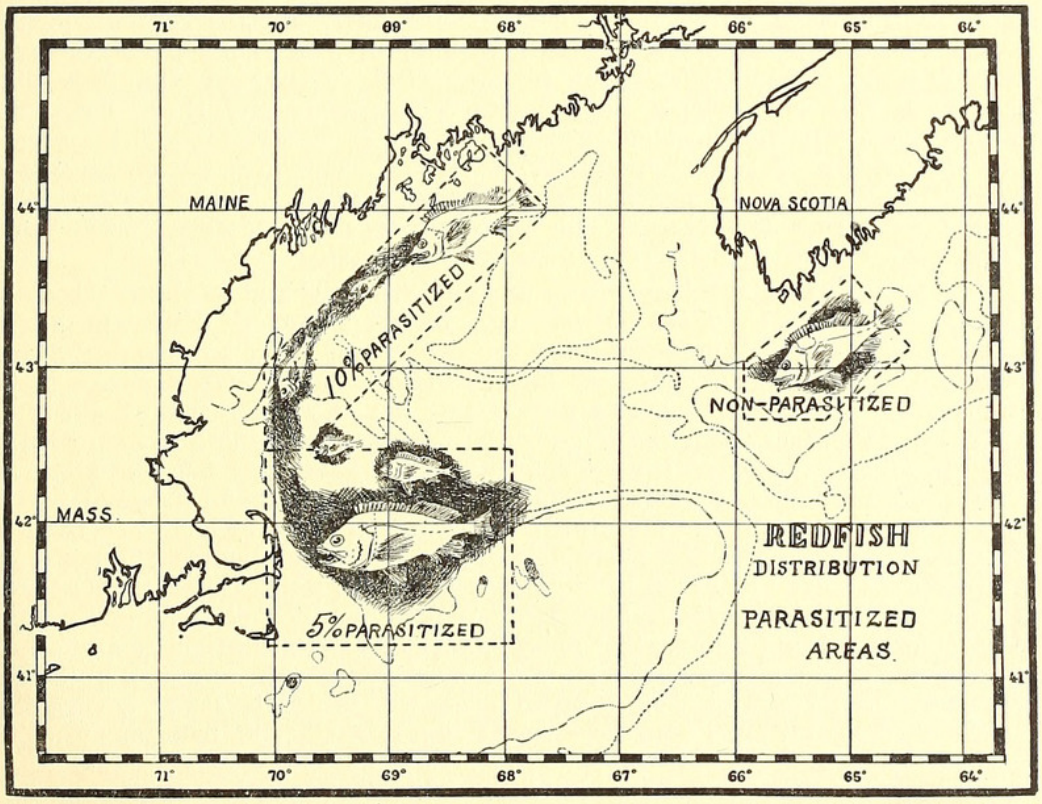
Although the samplings for examination of parasites were taken at random and at various times of the year, there appears to be no definite correlation between temperature (time of year) and the number of visible parasites or the number of infected fish. It has been determined, however, that young parasites are present during the late summer and early fall. It is assumed that these grow and become visible by spring, reaching maturity by summer. It is during the latter periods that the parasites superficially appear to be more numerous.

Geographical Distribution of Parasitized Redfish.

In the North Atlantic coast of America the normal redfish population is distributed off the coast of Maine, Massachusetts and Nova Scotia. (See



Text-figure 2.
Distribution of the redfish, *Sebastes marinus*.



Text-figure 3.
Distribution of the redfish, *Sebastes marinus*, showing parasitized areas.

Text-figs. 2 & 3).[2] Practically every area in 80 to 150 fathoms on or near the fishing banks supports a redfish population, with the exception of the southern rim and NE peak of George's Bank. About 90% of the commercial catch ranges in size between 24 to 32 cm. from snout to fork of caudal fin in length, and it is among such fish that the copepods were recovered. No redfish under 22-24 cm. were ever seen with parasites, while those under 16-20 mm. do not appear in the catches because most of them pass through the trawl meshes and the balance are culled out at the docks.

Redfish are caught almost exclusively in the daytime, for fishing at night invariably yields only comparatively small catches. Why this should be is as yet not known. It was assumed that the fish might rise off the bottom and therefore not be caught by the deep set trawls of the fishermen, or that they might scatter widely at night and congregate again during the day. The redfish appear to disperse also after spawning, and again in October and November. The spawning period seems to be concentrated between May 15 and July 15, but the season may extend from early May to August. It is probably during these periods and at the times when the fish are concentrated that the majority of infections occur. The incidence of infection should be higher at such times. That this is not demonstrable is not surprising for the reason that the presence of parasites is not recognized until they appear on the body surface or when sores are developed.

One definite item that can be determined, however, is the fact that fishes from the banks off the southern tip of Nova Scotia appear free from the parasite, although the redfish population is nearly as large in this region, comparatively, as it is in the infective areas. Although a seasonal study of the distribution of the infections was made, there was no correlation. It definitely showed that fish from south of Nova Scotia, referred to as Brown's Bank, are free of *Sphyrion lumpi*. Ecologically, this area appears to be characteristically different from the regions where parasitized fish occur, influenced chiefly by cold water currents. In this region the fish are on the average smaller than those found off the coasts of Maine and Massachusetts (Cape Cod). This is supported further by the fact that the growth rate of Brown's Bank haddock is slower and these fish have a different scale pattern. Also, insofar as could be determined, there seems to be no mixing of redfish populations, for if they did, parasites would most certainly show up on fish from Brown's area. The presence of a cold current from the NE is one factor that may possibly divide and separate the Canadian fish from those off our coast.

The fish-parasite relationship is most interesting and is summarized as follows: from 4,971 individual redfish, or 52 samples from the same number of individual trips, examined for the copepod, the average infection for the inshore redfish grounds off Maine and Massachusetts, appears to be roughly 10%, while the average number of parasites per fish is approximately 1½. The fish from the offshore or Channel grounds had an average of roughly 5% infection, with the number of parasites per fish the same as inshore. The redfish population off Nova Scotia was found to be consistently free of the infection. The striking feature of the data collected to date is the gradual reduction in the percentage infection as one leaves the coast of the United States. It must be realized, however, that these percentages refer only to those parasites visible to the naked eye. There is no doubt that the percentage would be greater under laboratory examination at any time, and very probably disproportionately greater in the late summer and fall, when more young are present than at other times. This study covers the first 11 months of 1938 and represents samples of 100 fish per trip in practically all cases.

[2] Other areas, not shown on the map, where redfish are occasionally taken and from which no parasitized fish have been found, include Sable Island, Roseway, Liscombs and Banquero Banks.

The writers wish to thank Mr. Henry M. Bearse of the U. S. Bureau of Fisheries for some of the data presented in the above paragraph, and Mr. B. O. Knake for the drawings. The Bureau of Fisheries is now carrying on research into the further details of the life history of the redfish and relationships between host and parasite.

Pathological Effects of *Sphyrion lumpi* Infection.

The majority of the parasites protrude from the body through a small opening in the skin of the host. The minute forms are indicated by small, dark, lumpy growths on the skin, the external openings of which are hardly visible. As the parasites increase in size, these openings become larger and larger until, in some cases, the skin and muscle are turned out, forming large flaps. (Plate II, Fig. 4). In such instances, the overlying epidermis and scales are lost.

The striking feature of the histo-pathology of these infections is the tissue response of the host to the parasite. The buried part of the cephalothorax is encapsulated by a well defined wall composed of host connective tissue. (Plate III, Fig. 5; Plate IV, Fig. 8). In older infections, where the healing process is more or less completed, this connective tissue is further developed and entirely surrounds the cephalothorax of the parasite. (Plate II, Fig. 3). The general host response, however, is a typical inflammatory reaction. The muscle bundles become interposed with blood elements and most conspicuous of all, by an extreme dilation of vessels. (Plate III, Fig. 6). In certain regions the tissue is oedematous, showing an exudate of leucocytes, erythrocytes, monocytes and plasma cells in a network of fibrin. (Plate IV, Fig. 7). The cellular elements between the muscle fibers are mostly leucocytes, chiefly small lymphocytes and neutrophiles. Occasionally, however, granulocytes, some distinctly eosinophiles, have been encountered. In certain regions many red blood cells are found free in the host tissue. The activity of the leucocytes is evident by foreign body inclusions in the cytoplasm of these cells.

A similar type of host reaction is present wherever the parasite is attached. Those found around the anal opening cause an intense inflammation of the rectum and surrounding tissues. When the eye becomes the point of attachment, the anterior chamber is the place of anchorage. The cornea is split and stretched, resulting in a distortion of vision. A slight amount of fibrous connective tissue is developed and surrounds the anterior end of the parasite. Here again, a dilation of blood vessels has occurred and numerous leucocytes infiltrate the surrounding tissues.

In two instances, small tumors were found in the region of the dorsal fins. These were more or less round in appearance and about .5 cm. in diameter. Although these fish are red in color, the tumors were black with some red pigmented cells intermingled. Microscopically, however, the melanophores and erythrophores are limited to the surface, while the remainder of the tumor was composed of dense fibrous tissues, infiltrated with all sorts of wandering cells, especially lymphocytes.

The many sores encountered in these redfish are almost invariably the remains of what was previously the anchoring place for the copepods. A few are the sites in which immature parasites are implanted. The larger of these sores consistently contain a slightly viscid exudate. Microscopic examination of this fluid revealed the presence of many algae-like microorganisms, singly or in chains. These were round, ovate, elongated or rod-shaped. The elongated forms measured 18 x 12 μ. All such organisms contained round greenish plastids, many of which were found free in the exudate. Beside these, many flagellates were present which also contained the greenish coccus-like bodies. Whether there is any

relation between the algae-like forms and the flagellates was not determined. Very little bacteria were present in these sores, although the usual host cellular elements were evident. These were leucocytes with ingested particles in the cytoplasm, débris composed of dead cells and partly digested muscle fibers.

Discussion.

The pathological effects resulting from copepod infestations are not well known. Wilson (1917) reported that the female members of the family Lernaeidae become anchored in the flesh of the host by special organs of attachment. The irritation set up during the burrowing process results in the development of "a tough membrane or skin immediately around them, which adds considerably to the security of prehension. This tough membrane also envelops the free thorax or neck of the parasite and reaches as far as the real skin of the host." In the case of fishes parasitized with *Pennella* these cysts may be found anywhere in the body, including the stomach, intestinal wall, the mesentery, liver and even the heart wall. "When the copepod dies the cyst simply shrivels and hardens still more, and such lumps, nearly as hard as bone, may be cut out of the liver or elsewhere alongside of the living ones!" Wilson further stated that the parasites of the family Lernaeidae and even those of the Sphyriidae (Wilson, 1919) feed upon the blood of their host. He reported (1917), "The simple fact that they burrow through the flesh until their head and mouth are brought into close proximity with some large blood vessel, and sometimes penetrate into the heart itself, leaves us no choice but to conclude that the parasite is making sure of a copious food supply."

From our observations on *Sphyrion lumpi*, however, *the parasites very seldom reach a large vessel, and in no cases did they reach as far as the dorsal aorta.* On the other hand, what does happen in every instance, a strong irritation is set up, both mechanically and by means of secretions given off by the parasite, which result in an inflammatory reaction. There is a considerable dilation of blood vessels in this reaction, so much so that the fine capillaries, usually of microscopic size, become enlarged to such an extent that they are visible to the naked eye in killed and fixed material, and in many cases can be dissected out. Thus, the vessels widen and pour their fluid and cellular contents into the surrounding tissue until it becomes oedematous and infiltrated with leucocytes and scattered erythrocytes. This, in the writers' opinion, is the source of nutriment for these parasites and not any particular blood-vessel as it is supposed. The source of irritation is constant in so long as the parasite keeps growing and moving about. Once the growth process is completed, the parasite becomes an inert object which finally becomes surrounded by repaired host tissue, forming the so-called cysts observed in many cases. It is obvious, however, that in the early stages of growth, the young parasites must feed on muscle and other tissues beside blood.

The allocation of parasitized redfish to a definite area off the coast of Maine and Massachusetts is the striking thing in the present studies. Why this should be we have as yet no definite explanation. That the fish do disperse at certain intervals has been more or less definitely established by investigators in the field. Yet nearby areas and especially those off the coast of Canada have yielded very few parasitized redfish and none in the samples investigated. The fish in the non-infective areas are apparently separated ecologically by a cold current, and on the average are smaller in size than those caught off the coast of Maine. This would indicate possibly that the redfish population in both these areas are distinct and for some reason or other (temperature, current, etc.) the parasites are not present.

SUMMARY.

1. *Sphyrion lumpi* (Krøyer), a parasitic copepod found on the redfish (*Sebastes marinus*) is redescribed.

2. The host-parasite relationships are discussed and the pathological effects of the copepod infestation is described.

3. The geographical distribution of parasitized redfish is indicated.

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EXPLANATION OF THE PLATES.

PLATE I.

Fig. 1. Typical female *Sphyrion lumpi*, about 3× natural size showing collapsed ovisacs. All photographs by S. C. Dunton, N. Y. Aquarium.

Fig. 2. Female copepods without ovisacs. Note variability in form and size of cephalothorax. The smaller and younger specimens are transparent. About 2×.

PLATE II.

Fig. 3. An old female. One ovisac missing. The "hammer" part of the cephalothorax is entirely surrounded with a thick fibrous covering.

Fig. 4. Area just in front of the dorsal fin showing skin and muscle turned out. About 3×.

PLATE III.

Fig. 5. Extreme low power photomicrograph of section through region of infection, showing encapsulated parasite.

Fig. 6. Low power photomicrograph showing inflammatory reaction to the copepod parasite infection. This reaction is indicated by the extreme dilation of blood vessels.

PLATE IV.

Fig. 7. High power photomicrograph of one of the dilated vessels and surrounding region filled with an exudate of lymphocytes, monocytes, plasma cells and enythrocytes.

Fig. 8. Photomicrograph of same magnification as in Fig. 7, showing the development of fibrous connective tissue.

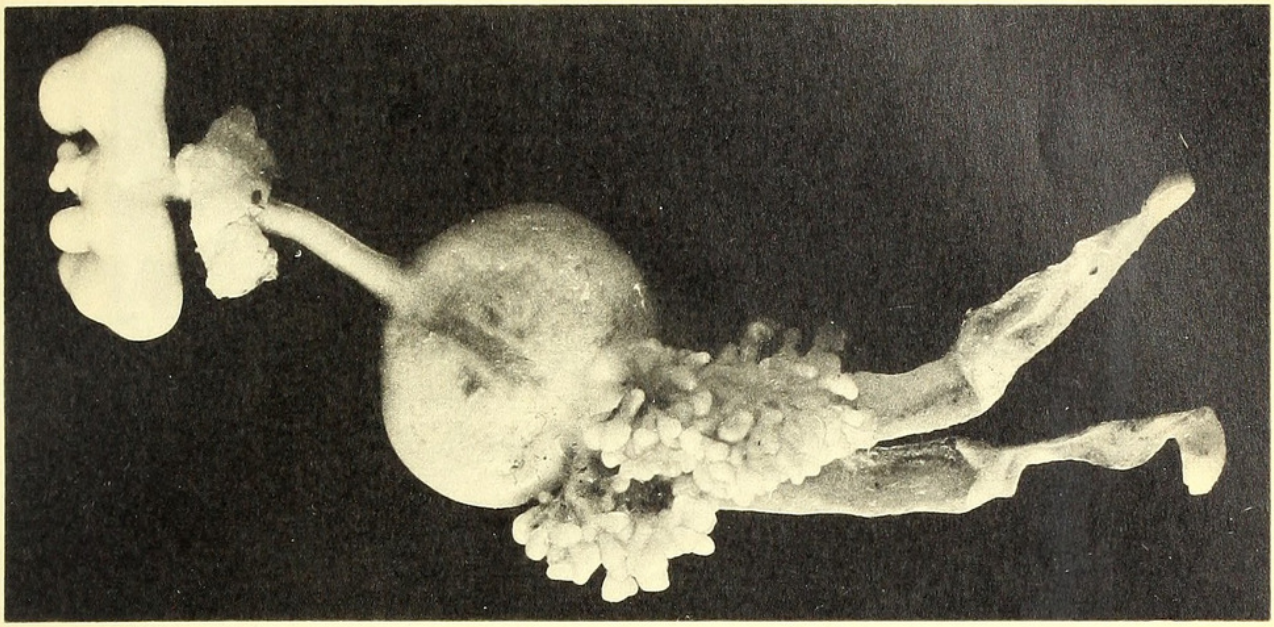

FIG. 1.

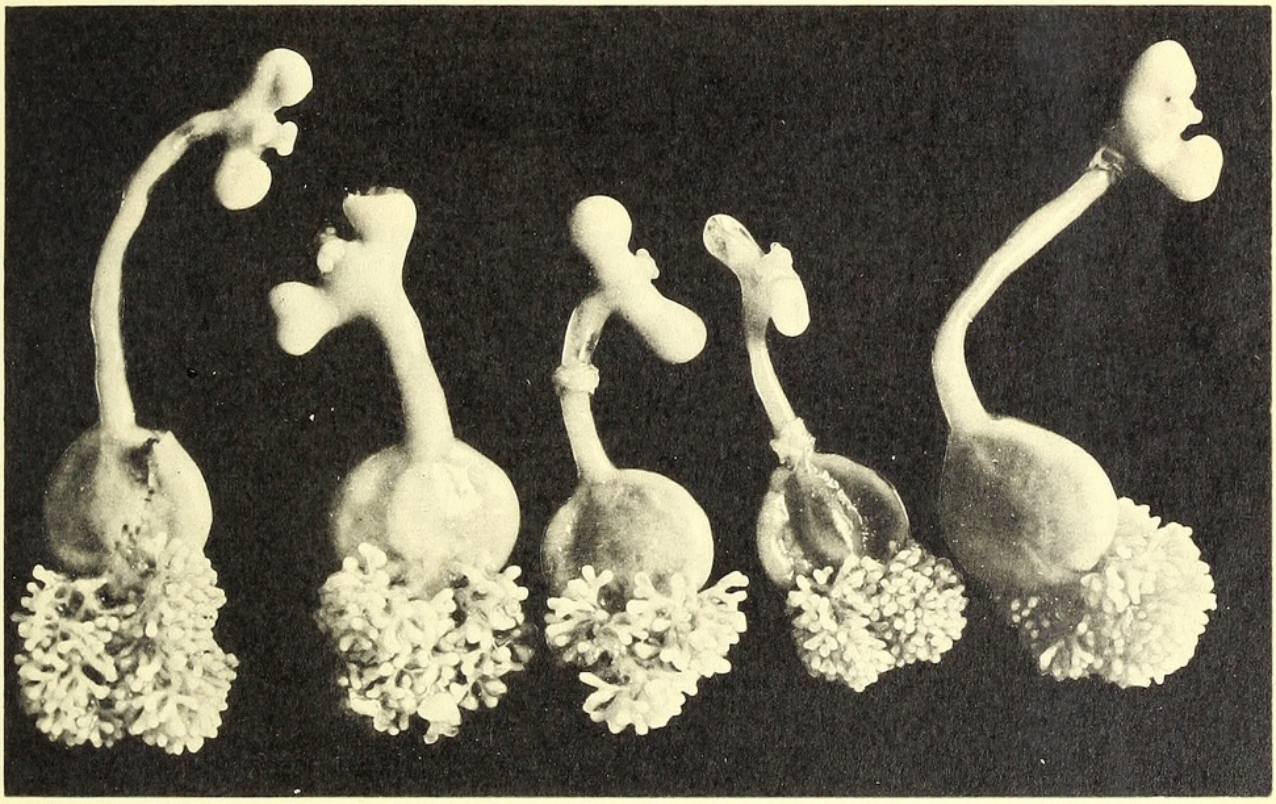

FIG. 2.

ON SPHYRION LUMPI (KROYER), A COPEPOD PARASITE ON THE REDFISH, SEBASTES MARINUS (LINNAEUS), WITH SPECIAL REFERENCE TO THE HOST-PARASITE RELATIONSHIPS.

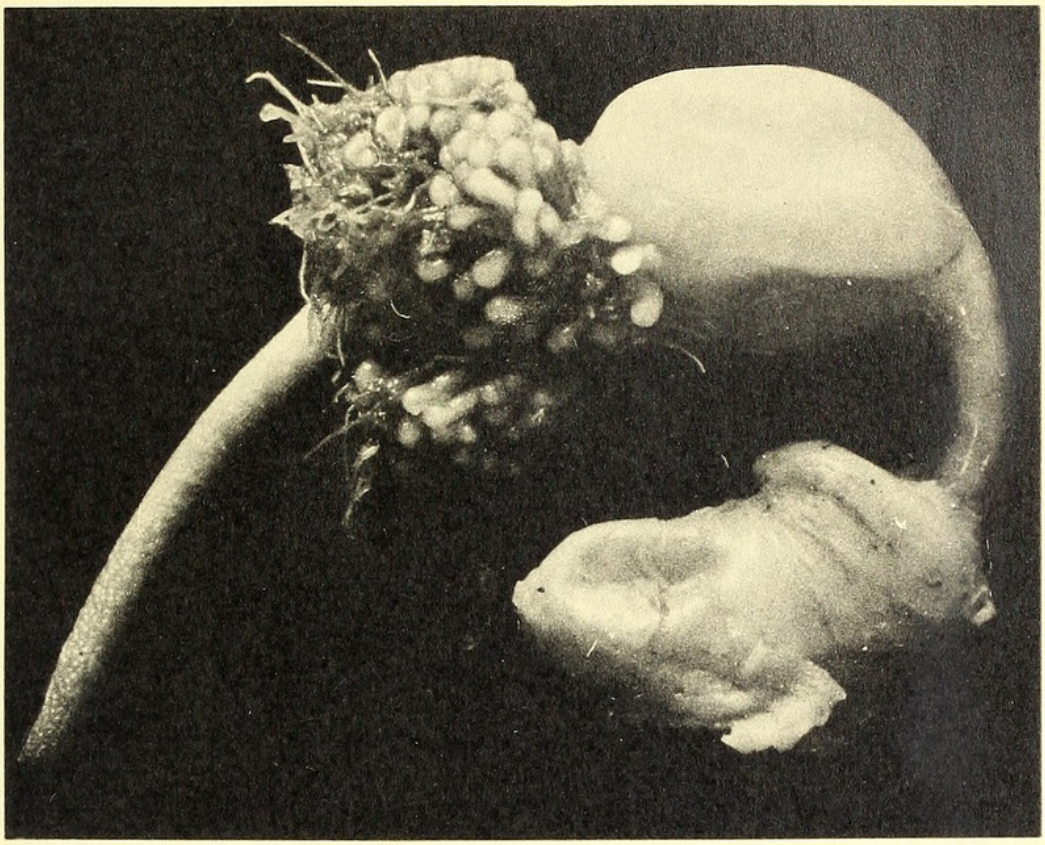

FIG. 3.

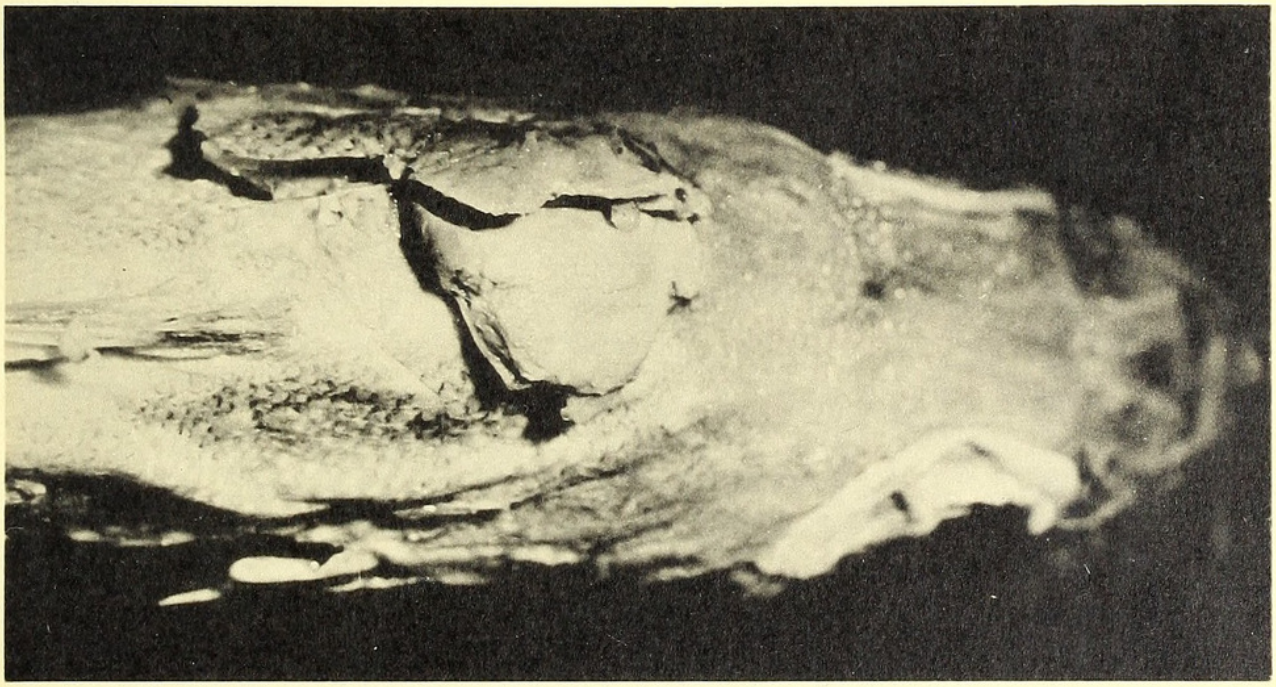

FIG. 4.

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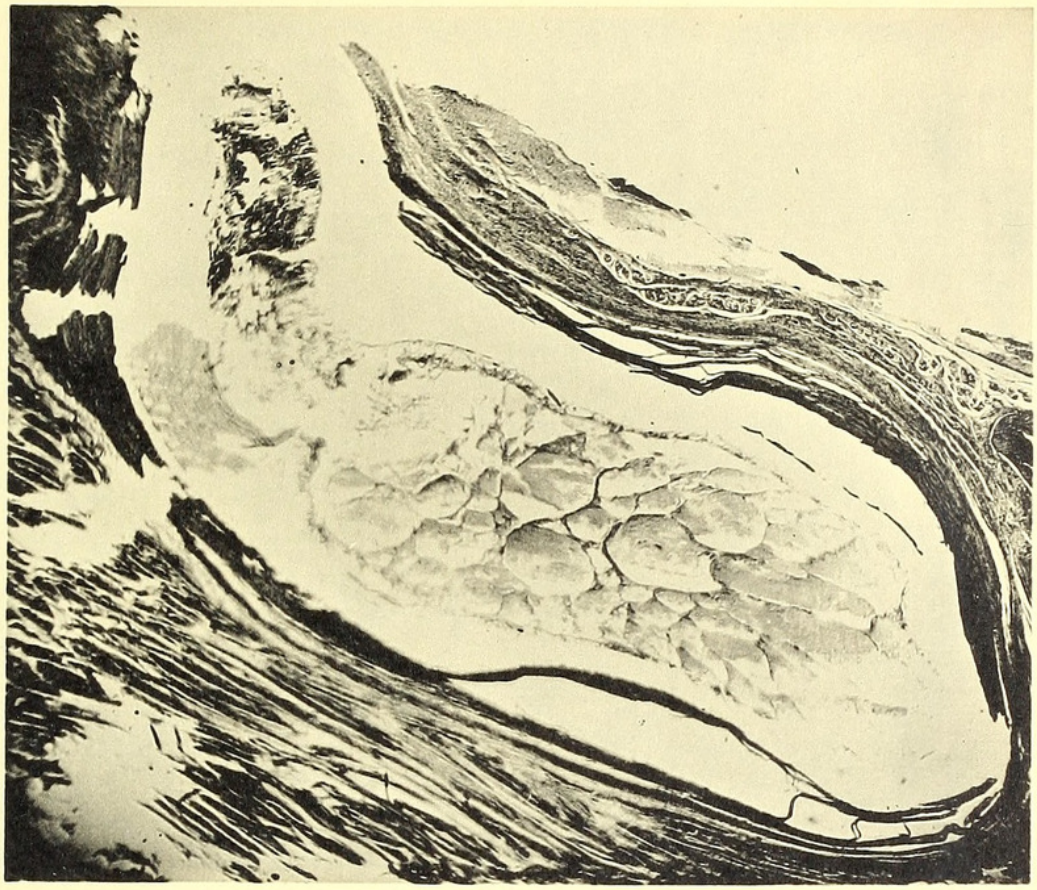

FIG. 5.

FIG. 6.

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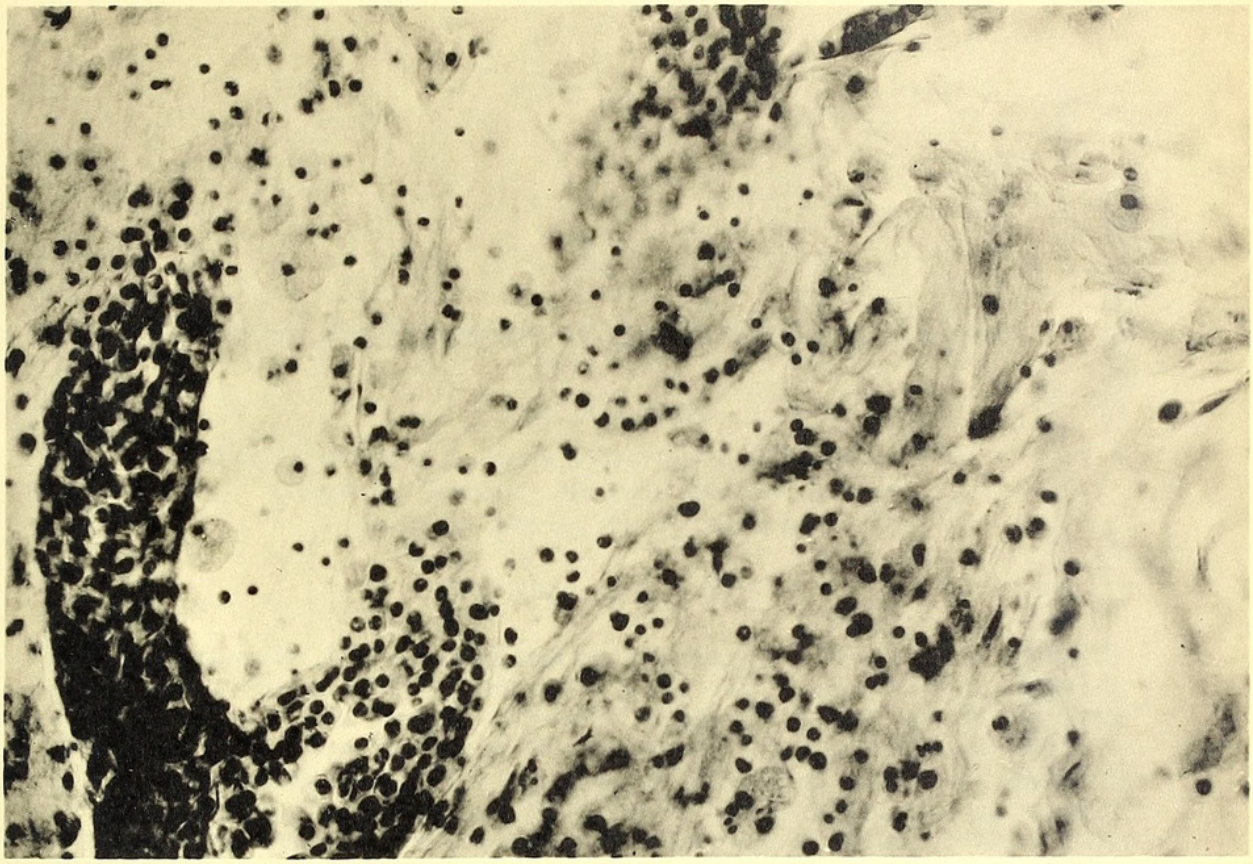

FIG. 7.

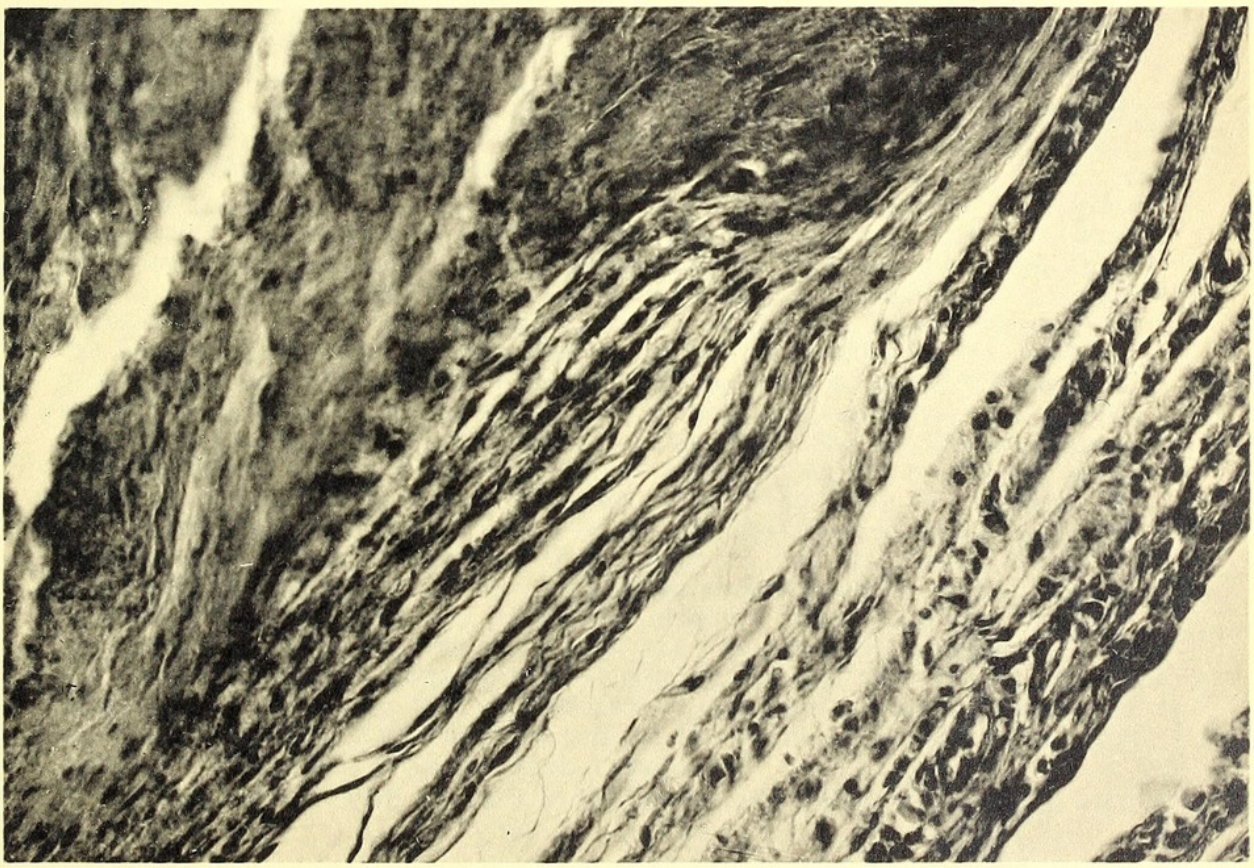

FIG. 8.

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