STUDY ON FISH PARASITE OF LAKE MANITOU, MICHIGAN WITH SPECIAL REFERENCE TO INFESTATION OF SMALLMOUTH BASS BY THE BASS TAPEWORM, *PROTEOCEPHALUS AMBLOPLITIS* (LEIDY)

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ABSTRACT

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This is a report of an investigation of the degree of infestation of smallmouth bass of Lake Manitou, Michigan, by the bass tapeworm, *Proteocephalus ambloplitis*, and the extent of host tissue damage. A sample of 42 fishes was examined in this study which was represented by 36 smallmouth bass, five yellow perch, and one green sunfish. Altogether, nine different species of helminth parasites from the three phyla were recovered. The larval stage of the bass tapeworm (plerocercoids) were present in all the 42 fishes examined and were found to be most damaging. The extent of damage is greater in the females than in the males of the same age group. A study on larval lengths revealed that gonads, especially the ovaries, are better suited for the growth of these larvae. As the fish advance in age the larvae in the gonads also increase in length. The rate of growth of larvae is approximately three times greater in

the females than in the males.

Parasites recovered from all three species of fishes examined are listed separately. Life cycles of parasites are summarized in a different table with names of their first and second accessory hosts where they are known. Further work on the direct line of control is needed because of the damaging effects of this tapeworm.

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By

Prem Shankar Prasad

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INTRODUCTION

Animal parasites are organisms that live at the expense of other animals, usually without killing the host. Parasites, particularly internal parasites, may decrease the health, vigor, and reproductive potential of their host. These effects are accomplished by virtue of parasitic activities inside the host tissue. Some parasites act on fish by consuming body tissues and organs, while others produce various substances which may have a toxic effect on the fish, disrupting normal metabolic processes. Still other parasites inflict bodily, physical and biologic injuries which, in turn, give way to secondary bacterial infections.

For the past several years the general public has become increasingly aware of fish parasites. Fishermen are interested because some parasites cause ugly sores or ulcers in the flesh of the fish and render them unfit for fish markets. Federal and State fish and game agencies are interested in fish parasites because of the destruction of young fish in hatcheries and also by reason of their effects on the fecundity of game fish.

Lake Manitou on North Manitou Island, Michigan, has been producing a good catch of sport fishes for the past several years. The lake still retains its position for the smallmouth bass. However, during the last few years the fishes caught have been found to be heavily infected with parasites. The parasitic survey carried out by Alexander (1959) has revealed a generalized infection of fishes with various helminth parasites including the bass tapeworm, *Proteocephalus amblopIitis*. Increasing damage was observed in smallmouth bass with increasing age. The injuries, especially in the ovaries, were so severe that it was doubtful they could have spawned. It was indicated that these fish were prevented from spawning by the damage caused by plerocercoid larvae of the bass tapeworm. The primary objectives, therefore, of this investigation were to do a comparative study of the degree of damage inflicted by the larval stage of bass tapeworm in different age groups of smallmouth bass from Lake Manitou, Michigan; to determine species of helminth parasites present in the smallmouth bass other than the bass tapeworm; and to determine whether or not the bass tapeworm had any deleterious effect on the growth of the fish. Particular attention, however, was paid to the bass tapeworm, *Proteocephalus ambloplitis*, because of its high economic importance.

Numerous investigations dealing with the descriptions of fresh-water fish parasites have been conducted in the past. Recently, emphasis has changed from descriptive surveys to the studies of ecological and host-parasite relationship. These ecological surveys, therefore, have stressed the environmental relationships between parasites and their host, work that has in many cases been complicated by the fact that many parasites require several different hosts to complete their life cycle.

Also, for reasons unknown, some parasites show preference for a particular host-tissue over the others. The greatest difficulty encountered in these respects is that the life cycles of many of these parasites are still not completely known. It is fortunate, however, that the life cycle of bass tapeworm has already been worked out.

REVIEW OF THE LITERATURE

Proteocephalus ambloplitis was first described as Taenia ambloplitis by Leidy in 1887. The specimen was secured from the stomach of Ambloplites rupestris (Rafinesque) from Lake George, New York. La Rue (1914) suggested that this parasite was probably the plerocercoid stage of Proteocephalus ambloplitis described earlier by Leidy in 1887. Infection of the smallmouth bass, Micropterus dolomieui Lacépède, by this species was first identified by Benedict in 1900 in Ward's collection from Lake St. Clair, Michigan. Five years later, Marshall and Gilbert (1905) mentioned it in connection with a study of the food of fishes from lakes in the vicinity of Madison, Wisconsin.

In his monograph on the Proteocephalidae, La Rue (1914) examined critically all the materials available on this species. He carefully described the parasite and determined the synonomy of the forms described by Ribbenbach in 1896, Linton in 1897, and other workers.

Cooper (1915), while making a systematic study of fresh-water fishes of the Georgian Bay region, noted some plerocercoid larvae in the smallmouth bass (Micropterus dolomieui). By comparison of the adult characters with those of the larvae, he showed that the latter was *Proteocephalus amboplitis*. Recently, a new species, *Proteocephalus microcephalus* has been described from the intestine of *Micropterus dolomieui* from the northern California waters (Haderlie, 1953).

The effects of helminth infections on fish has been studied by several investigators. Davis (1953) described many helminth infections and the physical damage they do to their fish hosts. Rich (1924) was one of the first to report the heavy infection of gonads with the larval stage (plerocercoid) resulting in complete sterilization of the adult smallmouth bass.

Hunter and Hunter (1938) showed a statistically significant loss in weight of smallmouth bass heavily infected with the bass tapeworm larvae. This loss of weight was partially attributed to the disturbance of metabolic processes caused by the migrating larvae. Hubbs (1927) noted retardation of early growth and retention of the larval stages of fish apparently caused by heavy helminth infection. Moor (1926) described in some detail the invasion of the reproductive organs of fish by the larvae of bass tapeworm, *Proteocephalus ambloplitis*, and indicated that fish population could be eliminated by ensuing lack of reproduction. Hunter (1942) stated that it is not known exactly how the plerocercoid larvae of the bass tapeworm causes sterility; by mechanical damage, chemical change or by a combination of both. He also stated that heavily infected fish swim more slowly and are easier prey for fish-eating birds.

Sillman (1957) noted that fish having many metacercaria encysted in the liver suffered no inconvenience. Hunter (1937) demonstrated that if sufficient liver tissue is destroyed by the metacercaria of *Posthodiplostomum minimum*, the host will die.

Fischthal (1953) from his experiences in the examination of northwest Wisconsin fishes reported that the condition of most fishes was not handicapped by their parasitic burden. He believed that in the dynamics of an aquatic environment there are several factors (physical, chemical, biological) which can influence the condition of a fish or fish population. Unless rigid controls are maintained, it is extremely hazardous, even after statistical analysis of the data, to claim with certainty that parasitism is the cause of poor condition.

Hunter and Hunninen (1934) reported a marked difference in the position and numbers of the plerocercoid larvae of the bass tapewrom within the viscera of smallmouth bass. Their study of larval length in 90 bass of different age groups showed the mean length of plerocercoid larvae from the gonads to be always larger than the mean length of larvae from the rest of the organs.

Many surveys of fish parasites have been conducted by state and federal agencies in recent years in the United States because of the growing emphasis on fish management. One of the earliest and most complete surveys for fish parasites was conducted at Oneida Lake, New York by Van Cleave and Mueller (1934). Many similar investigations in different areas of the United States and Canada have been conducted by Bangham (1925, 1941, and 1951). More detailed work, dealing exclusively with the bass tapeworm, Proteocephalus amblopliti*s*, was conducted by Morrison (1957) in southern New Hampshire.

In Connecticut, Hunter (1942) found that fishes in three lakes were heavily infected with the bass tapeworm. He showed that the average number of worms per fish in smallmouth bass was 29 and slightly higher, 36.1, for largemouth bass. Although the latter were more heavily infected with the bass tapeworm, only 74 per cent of them were parasitized as compared with 95 per cent of the former group.

Fischthal (1953) carried a thorough survey of fish parasites in the northwest Wisconsin waters. Over a period of three years a total of 4,532 fishes, representing 61 different species and subspecies and collected from 124 different lakes and streams, were examined for parasites and 4,186 or 92.4 per cent of them were found to be infected with at least one species. This survey work included 27 smallmouth bass obtained from nine different waters in which all (100 per cent) were infected and a total of 28 different species of helminth parasites were recovered from them.

Sinderman (1953) found the concentration index for four heavily parasitized pond fishes in his survey area to be 53.7 worms per largemouth bass and 74.2 for smallmouth bass. Out of 20 smallmouth bass examined 95 per cent were found to be infected. This represented the highest percentage of infection of all species of fish examined by him.

In New Hampshire, Morrison (1957) found the smallmouth bass index to be 80.2 worms per fish, indicating a heavy infection. However, largemouth bass from the same body of water yielded very light infections. He examined a total of 192 smallmouth bass in which 80.2 per cent were infected.

Bangham (1925 and 1927), Hunter (1928), and Hunter and Hunter (1929 and 1930) have investigated the life cycle of Proteocephalus ambloplitis. Definitive hosts of this parasite thus far reported are the smallmouth bass (Micropterus dolomieui), largemouth bass (Micropterus salmoides), rock bass (Ambloplites rupestris), bowfin (Amin calva), burbot (Lota lota), and yellow perch (Perca flavescens).

The adult worms are located in the upper intestine of these definitive hosts. Gravid proglottids with the characteristic dumb-bell shaped eggs in tremendous numbers are passed out of the host in faeces. These eggs are not very viable and must be eaten by the first intermediate host within 24 to 36 hours (Hunter, 1928). The first intermediate host may be any of the following species of Crustacea: Hyalella knickerbockeri, Cyclops prasinus, Cyclops albidus, Cyclops leuckarti, Cyclops vulgaris and Cyclops serulatus (Hunter, 1928).

The onchosphere is liberated from its enclosing membrane, penetrates the intestinal wall of the copepod and develops in the body cavity of the crustacean as the first larval stage (procercoid). When an infected copepod is eaten by a suitable second intermediate host, which consists of 16 different species of fish including the smallmouth bass (Fischthal, 1953), the procercoid penetrates the stomach and intestinal wall of the fish and migrates to liver, spleen, kidneys, wall of the gut and gonads. In course of time, the larva looses its embryonic hooks, develops the primordial suckers with the fifth apical sucker, and is changed to the second larval stage (plerocercoid).

For the larva to become an adult, the second intermediate host must be eaten by a susceptible definitive host. In a fashion similar to that of the procercoid, the plerocercoid is digested out of the tissue of the intermediate host. It attaches itself to the intestinal wall of the final host with the suckers on its scolex and grows into an adult tapeworm.

Smallmouth bass, by virtue of their feeding habits, are exposed to mature and immature plerocercoids almost all through their life. As young fry and fingerlings, they ingest copepod members of zooplankton, some of which contain proceroid, and thus inadvertiently become the second intermediate host. When the fish attains a greater size, they start feeding on fry and fingerlings and may acquire the fresh infection of immature plerocercoids.

The life cycles of other parasites are equally as complicated as that of the bass tapeworm. In some cases the fish acts as an intermediate host, while in others as the definitive host.

MATERIALS AND METHODS

Obtaining fish sample:

A total of 42 fishes were examined for different parasites under this investigation. All these fishes were obtained from Lake Manitou, on north Manitou Island, Michigan. The fish were caught by hook and line during spring, 1963, quick frozen, and despatched immediately to the Michigan State University, East Lansing, Michigan. Five yellow perch, *Perca flavescens* (Mitchill), and one green sunfish, *Lepomis* cyanellus Rafinesque, were also obtained in the sample.

Handling of fish:

In the laboratory, fish were kept whole in deep freeze. They were thawed only at the time of examination. Fish were thawed individually as needed and their weight and lengths were recorded. A scale sample, from the region of the left pectoral fin, was also taken at this time. These were placed in a scale sample envelope bearing the same record number as the fish.

After these parameters were recorded, the fish was examined for evidence of external infection, or parasites, close to the surface of the skin. A mid-ventral incision was then made, fish eviscerated, and the sex and degree of maturity were noted. The head and body, including general musculature were then examined, and the parasites found placed in 0.7 per cent sodium bicarbonate solution. Viscera and gills were then separated in the following pieces: gills, stomach including pyloric caeca, small and large intestine, spleen, liver, kidneys, gonads, and the heart including big blood vessels. Each was opened up with fine scissors and placed along with its contents in petri dishes and covered with saline solution.

In searching the fish for the plerocercoid larvae of the bass tapeworm, Proteocephalus ambloplitis, each part of the viscera was exposed with the use of a fine scissors and a blunt probe. These parasites, which were all dead because of freezing, were counted separately and measured under a binocular dissecting microscope to the nearest tenth of a millimeter. More emphasis was placed on the determination of the presence of these larvae in the visceral organs. Smaller worms were handled with capillary pipettes, the larger with needles, forceps or wooden applicators. Helminths were listed by their host number and by their location inside the host. Stomach content of the fish, where found, were also examined and recorded.

Handling of Parasites:

Sodium bicarbonate solution (0.7 percent) was used for cleaning the worms as it simulates conditions in the intestine and tissues of the host and dissolves the mucus more effectively than the solutions of sodium chloride (Van Cleave and Mueller, 1934). Worms were washed in additional saline solution before being fixed. Larval forms of the bass tapeworm were fixed directly in a mixture of: commerical formalin five parts, 95 per cent ethyl alcohol 25 parts, glacial acetic acid one part, and distilled water 20 parts (FAA). The larger trematodes and tapeworms were placed between two glass slides, taking care the pressure was just sufficient to keep the worms straight, but not to squeeze them. The fixative was pipetted between the two pieces of glass slides. Worms were allowed to remain in this position for 24 hours when they were finally transferred to 70 per cent ethyl alcohol with 3 - 5 per cent of glycerine.

Acanthocephala, that were collected for identification, were placed in distilled water for the first 24 hours and kept under refrigeration. This caused the worms to swell up and the proboscis to be extruded. They were later fixed in FAA and preserved in 70 per cent alcohol.

Collecting and processing of parasites causing black spot required a somewhat more elaborate procedure. Both, the tissue digestion method as described by Hoffman (1955), as well as the fine dissection under a binocular dissecting microscope, were tried. Good results, however, were obtained by the later method after a little practice.

Tissue digestion method of freeing encysted nematode and trematode larvae has been in use by many workers and is particularly useful in Trichinella spiralis. The digestion solution, as used in this study consisted of 0.5 per cent pepsin in 0.25 per cent of hydrochloric acid made up in 0.65 per cent saline solution. Digestion consisted of teasing the tissue with fine needles in a petri dish and then digesting for 10-15 minutes. The parasites were allowed to settle and the solution decanted followed by three or four saline washings. This procedure released the strigeid cyst by digesting away the tissue of the host, leaving behind the metacercaria in their cyst.

Determination of the age of fish:

Scale samples obtained from individual fish were used to determine their age according to the methods described by Lagler (1956). Processing of the scales for counting the annuli consisted of pressing five or six scales between transparent cellulose acetate plates with a roller scale press. The impressions were examined under a microprojection apparatus and the scale annuli were counted and recorded as the approximate age of the fish.

Identification of helminths:

For positive identification, samples of parasites were stained and mounted on glass slides. All parasites were stained in para carmine, dehydrated, and permanent mounts were made using standard technics (Guyer, 1953). This stain yielded very good results. The mounted specimens were examined under compound microscope for final identification. The main source for cestode identification was by comparing the morphological characters described by Wardle and McLeod (1952), and Yamaguti (1959); while trematode identifications were centered around the work of Yamaguti (1958), and Van Cleave and Mueller (1934). For the identification and classification of Acanthocephala, works of Van Cleave (1919) and Van Cleave and Mueller (1934) were freely consulted.

During the course of investigation, several tissues of fish were also fixed and preserved in FAA solution for histopathological examination. These were later passed through usual histological techniques and sectioned at 8 microns. Sections were stained with Harris' hematoxylin and eosin stain.

Biometrics used:

Correlation coefficients and regression coefficients were used in this study to find the degree of correlation between the rate of growth of the parasite and the host. Data were further analysed to compare the rate of growth of the parasite within the visceral organs of the smallmouth bass. Analyses of data were carried out by standard statistical procedures (Snedecor, 1959), which express the average change in the dependent variable for each unit increase in the independent variable. To test the statistical significance of the regression coefficients the analysis of variance method was applied.

RESULTS AND DISCUSSIONS

A total of 42 fishes, representing three different species were examined. These included smallmouth bass (*Micropterus dolomieui*), yellow perch (*Perca flavescens*), and green sunfish (*Lepomis cyanellus*). Of these 42 fishes examined, all were found to be infected with at least one species of helminth parasite. Altogether a total of nine different species of parasites were recovered representing the three phyla of the helminth group. Tables 1, 2, and 3 give the host-parasite index in their phylogenic sequence recovered from the three species of fishes of the sample examined. As the fishes were very heavily infected, keeping records of the absolute parastie count of the individual species was rather difficult. This was especially so with the strigeid worms causing black spot, plerocercoid larvae of the bass tapeworm, *Proteocephalus amploplitis*, metacercaria of the yellow grub, *Clinostomum marginatum*, and the white grub of the liver, *Posthodiplostomum minimum*. Furthermore, in view of their generalized, heavy infection it was found unnecessary to do so. However, to determine the intensity, or degree of infection of fish with different species of helminth parasites, three categories were used

Table 1. Parasites Recovered from Smallmouth Bass, *Micropterus dolomieui* Lacépède, Taken from Lake Manitou, Michigan[1]

Parasite	Percentage of infected smallmouth bass[2]			
	Heavy	Mod-erate	Light	No in-fection
Phylum Platyhelmintheses				
Class Trematoda				
Order Digenea Van Beneden, 1858				
Suborder Prosostomata Odhner, 1905				
Family Clinostomidae Luhe, 1901				
Subfamily Clinostominae Pratt, 1902				
Genus *Clinostomum* Leidy, 1856				
C. marginatum (Rudolphi, 1819)	8.3	41.7	30.6	19.4
Family Diplostomidae Poirier, 1886				
Subfamily Diplostominae Monticelli, 1892				
Genus *Posthodiplostomum* Dubois, 1936				
P. (= *Neascus* sp., Hughes, 1927) Unidentified strigeid (black spot)	36.1	38.9	25.0	0
Class Cestoda				
Order Proteocephalidea Mola, 1928				
Family Proteocephalidae La Rue, 1911				
Subfamily Proteocephalinae Mola, 1929				
Genus *Proteocephalus* Weinland, 1858				
P. ambloplitis (Leidy, 1887)	0	8.3	5.6	86.1
P. ambloplitis[3] (Leidy, 1887)	86.1	13.9	0	0

(Table 1 continued)

Parasite	Percentage of infected smallmouth bass[2]			
	Heavy	Moderate	Light	No infection
Phylum Acanthocephala				
Class Metacanthocephala				
Order Palaecanthocephala				
Family Echinorhynchidae Hamann, 1892				
Genus Leptorhynchoides (Zoega, 1776)				
L. thecatus (Linton, 1891)	16.7	52.8	30.6	0
Genus Pomphorhynchus Monticelli, 1905				
P. bulbocolli Linkins, 1919	0	0	16.7	83.3
Phylum Nemathelminthes				
Class Nematoda				
Order Spiruridea Diesing, 1861				
Family Cucullanidae Cobbold, 1864				
Subfamily Dacnitoidinae York et Maplestone, 1926				
Genus Dacnitoides Ward et Magath, 1917				
D. cotylophora Ward et Magath, 1917	0	0	2.9	97.2

[1] A total of 36 smallmouth bass were examined
[2] Heavy, a parasite count of 50 or more
Moderate, a parasite count of 10-49
Light, a parasite count of 1-9
[3] Larval stage of the worm

Table 2. Parasites Recovered from Yellow Perch, *Perca flavescens* (Mitchill), Taken from Lake Manitou, Michigan[1]

Parasites	Percentage of infected yellow perch[2]			
	Heavy	Moderate	Light	No infection
Phylum Platyhelminthes				
Class Trematoda				
Order Digenea Van Beneden, 1858				
Suborder Prosostomata Odhner, 1905				
Family Clinostomidae Luhe, 1901				
Subfamily Clinostominae Pratt, 1902				
Genus *Clinostomum* Leidy, 1856				
C. marginatum (Rudolphi, 1819)	20	40	40	0
Family Diplostomidae Poerier, 1886				
Subfamily Diplostominae Monticelli, 1892				
Genus *Posthodiplostomum* Dubois, 1936				
P. (= *Neascus* sp., Hughes, 1927)				
Unidentified strigeid (black spot)	80	20	0	0
Class Cestoda				
Order Proteocephalidea Mola, 1928				
Family Proteocephalidae La Rue, 1911				
Subfamily Proteocephalinae Mola, 1929				
Genus *Proteocephalus* Weinland, 1858				
P. amblopitis[3] (Leidy, 1887)	40	40	20	0

(Table 2 continued)

Parasites	Percentage of infected yellow perch[2]			
	Heavy	Mod-erate	Light	No in-fection
Phylum Acanthocephala				
Class Metacanthocephala				
Order Palaeacanthocephala				
Family Echinorhynchidae Hamann, 1892				
Genus Leptorhynchoides (Zoega, 1776)				
L. thecatus (Linton, 1891)	0	0	20	80
Phylum Nemathelminthes				
Class Nematoda				
Order Spiruridea Diesing, 1861				
Family Cucullanidae Cobbold, 1864				
Subfamily Dacnitoidinae York et Maplestone, 1926				
Genus Dacnitodes Ward et Magath, 1917				
D. cotylophora Ward et Magath, 1917	0	0	60	40

[1]A total of 5 yellow perch were examined
[2]Heavy, a parasite count of 50 or more
Moderate, a parasite count of 10-49
Light, a parasite count of 1-9
[3]Larval stage of the worm

Table 3. Parasites Recovered from Green Sunfish, Lepomis cyanellus Rafinesque, Taken from Lake Manitou, Michigan[1]

Parasites	Infection[2]		
	Heavy	Moderate	Light
Phylum Platyhelminthes			
Class Trematoda			
Order Digenea Van Beneden, 1858			
Suborder Prosostomata Odhner, 1905			
Family Clinostomidae Luhe, 1901			
Subfamily Clinostominae Pratt, 1902			
Genus Clinostomum Leidy, 1856			
C. marginatum (Rudolphi, 1819)			1
Family Diplostomidae Poirier, 1886			
Subfamily Diplostominae Monticelli, 1892			
Genus Posthodiplostomum Dubois, 1936			
P. (= Neascus sp., Hughes, 1927)[3]	1		
Unidentified strigeid (black spot)[3]			
Posthodiplostomum minimum (MacCallum, 1921)[4]	1		
Class Cestoda			
Order Proteocephalidea Mola, 1928			
Family Proteocephalidae La Rue, 1911			
Subfamily Proteocephalinae Mola, 1929			
Genus Proteocephalus, Weinland, 1858			
P. amblopliti̇s (Leidy, 1887)[5]			1

[1]Only one green sunfish was represented in the sample
[2]Light infection, a parasite count of 1-9; moderate infection, a parasite count of 10-49; heavy infection, a parasite count of 50 and above
[3]From integument
[4]From liver
[5]Larval stage of the worm

which indicate whether the fish was lightly, moderately, or heavily infected. A light infection was represented by 1-9, a moderate infection by 10-49, and a heavy one by 50 and more parasites of a given species. No further counts were made beyond fifty with the exceptions of the spiny-headed and the roundworms whose numbers were comparatively low. For this reason, hunter's (1942) method for determining the parasite concentration index is not applicable in this study for all the species of parasites recovered. The fish parasites of Lake Manitou, Michigan, and their relations with the host will be discussed separately.

Order: Proteocephalidea Mola, 1928
Family: Proteocephalidae La' Rue, 1911
Subfamily: Proteocephalinae Mola, 1929
Genus Proteocephalus Weinland, 1858
Proteocephalus amblopltitis (Leidy, 1887)

Hosts: Micropterus dolomieui, Perea flavescens, and Lepomis cyamellus

A total of 36 smallmouth bass were examined. Of these 36 fish examined, all were found to harbor at least two kinds of worms--the plerocercoid larvae of the bass tapeworm, Proteocephalus ambloplitis, and the mature stages of the spiny-headed worm, Leptorhyncoides thecatus.

The sexually mature stage of the bass tapeworm, Proteocephalus ambloplitis, was recovered from the pyloric caeca and the small intestine of smallmouth bass. As many as 50 adult worms were recovered from five of the bass examined. Adults of the genus are recognized by the following characters: Scolex unarmed, with four large, round or oval typical suckers directed outward and anteriad (Figure 1). A fifth or apical organ may or may not be present. Excretary stems are situated slightly medial to the outer edge of medulla. Testes, 70-100 in number, are situated between vitellaria in one contineous layer dorsal to uterus. Ovary is bilobed, extending transversally at posterior end of proglottids. Vitellaria are in lateral fields of medulla outside of excretary stems. Segments of the proglottids are jointed to each other with rounded ends (Figure 2).

The life cycle of the bass tapeworm is discussed earlier in this paper (page 9). Identification of the plerocercoid larva is based on the presence of the fifth sucker. Even after the scolex is evaginated, the vestigial fifth sucker is in evidence where it may be seen embedded in the scolex near its distal extremity (Figure 3). The plerocercoid larvae recovered from the lumen of the gut retained the

Figure 1. Unarmed scolex of *Proteocephalus ambloplitis* (adult). 125 X.

Figure 2. Mature proglottid of bass tapeworm, *Proteocephalus amblopliti*s showing the position of uterus, testes, and vitelline glands. 135 X.

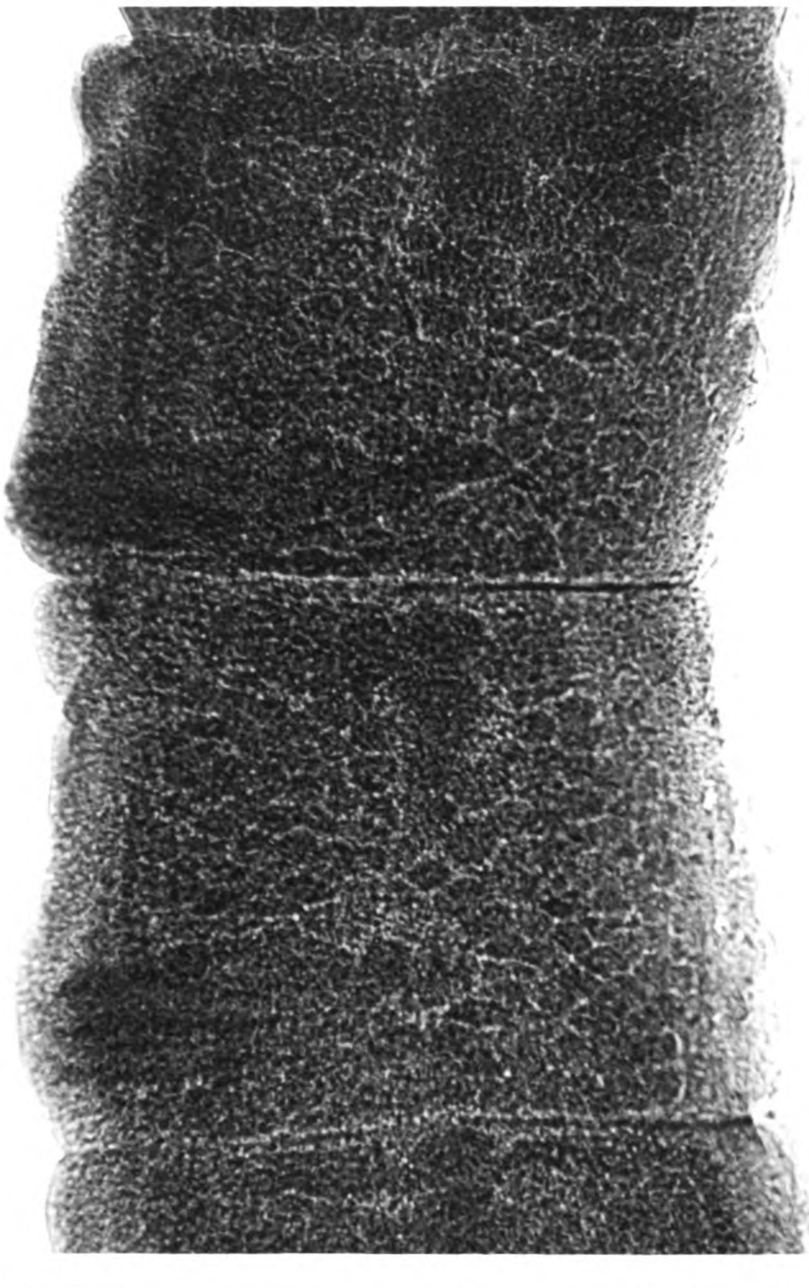


Figure 3. Larva of Proteocephalus ambloplitis (Plerocercoid) with characteristic vestigial fifth sucker embedded distally in the evaginated scolex. 6.5 X.

everted scolex (Figure 4). The fifth sucker of the plerocercoid larvae may even persist for a time in the adult worms.

The 36 smallmouth bass examined in this study ranged from 7.3 to 19.5 inches in length. Smallmouth bass measuring from 10-12 inches were most heavily infected with the plerocercoid larvae, whereas the younger specimens yielded fewer numbers of parasites. As expected, the larger bass heavily infected with the plerocercoid larvae contained an abnormal quantity of connective tissue in their coelom, which made it difficult in most of the cases to recognize or to separate the visceral organs. Most of the larvae were found encysted in the mesenteries or embedded in the heavy network of proliferated connective tissue. This proliferation of connective tissue was apparently associated with the damage caused by the internal migration of these parasites. Also, in such locations, a heavy fibrous cyst was found thrown closely around the developing plerocercoids. Larvae located in the liver, spleen, and gonads, however, were found loosely encased in thin, membranous cysts (Table 4).

Hunter and Hunninen (1934), based on their previous experimental findings, indicated that the mesenteries and omenta constitute, beyond doubt, the first location

Figure 4. Larval stage of bass tapeworm, *Proteocephalus amblopl itis* (plerocercoid) with everted scolex. The fifth vestigial sucker is situated in the center. 6.5 X.

Table 4. Descriptive Summary of Helminth Parasites with Relation to the Fish Host Taken from Lake Manitou, Michigan

Parasite	Fish host	Location in fish	Descriptive features	Importance
Proteocephalus ambloplitis *	Smallmouth bass, yellow perch, and green sunfish	In mesenteries, spleen, liver, gut wall, ovaries and testes	Thin white worm up to 4 cm. long, characterized by 4 suckers and a fifth vestigial sucker on the apex of the scolex, no proglottids	Causes sterility in smallmouth bass (Hunter, 1942)
Proteocephalus ambloplitis	Smallmouth bass	Caeca and upper portion of the small intestine	Thin white worm reaching up to 12 cm. long and 0.1 to 0.2 cm. broad, segments well marked with scolex loosely attached to the mucous membrane	Exact pathology not known, may cause depletion of important nutrients in host. In heavy infection, may interfere with digestion and absorption by mechanical obstruction
Posthodiplostomum minimum	Green sunfish	Liver, mesenteries, and spleen	Thin-walled white transparent cyst with the posterior end of parasite folded inside the cyst, cysts mostly located on the surface of the organs	Destroys liver and other tissues, may kill the fish in cases of severe infection (Sillman, 1957)

(Table 4 continued)

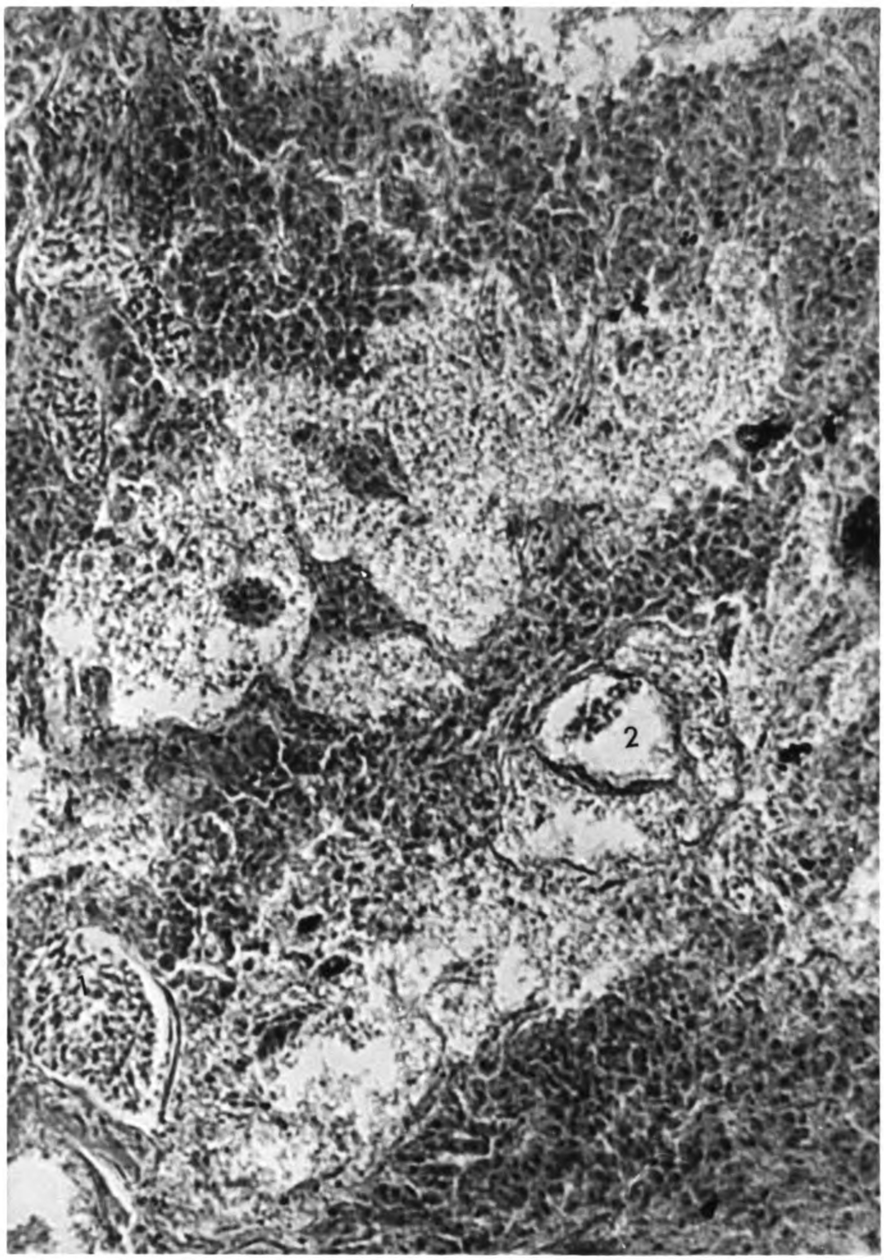
Parasite	Fish host	Location in fish	Descriptive features	Importance
Lepto-rhynchoides thecatus	Smallmouth bass	Stomach, caeca, and anterior portion of small intestine	Thin and white worm, reaching up to 0.5 cm. long, firmly attached to the mucous layer of gut wall	Injure the mucous lining of the gut wall, may interfere with food absorption
Pompho-rhynchus bulbocolli	Smallmouth bass	Upper portion of small intestine	Thin white pyriform worm strongly at-tached to the intestinal wall with bulb of the probos-cis embedded deeply into the mucous and submucous layer	Similar to that described for Leptorhyncoides thecatus

*Larval stage of the parasite

normally assumed by the young, migrating larvae of the bass tapeworm. With the growing age of the bass, the larvae tend to migrate and occupy the more favorable and better developed sites like ovary, testes, liver and spleen. This observation was further exemplified when the younger bass of the Lake Manitou, Michigan, were found to harbor either fewer numbers or no parasites in their spleen and gonads, although their mesenteries and omenta were beaded with several small larval cysts. It is presumed, therefore, that the initial invasion of these larval forms elicit a severe host reaction resulting in a heavy fibrotic cyst in the first instance as compared with the later thin, membranous cysts in the liver, spleen, and gonada mentioned earlier.

As can be seen from the forthcoming, Proteocephalus ambloplitis affects the various species differently. This is true not only for the type of infection but also the degree of infection. The plerocercoid larvae in smallmouth bass and green sunfish were generally located near the surface of the organ. In heavily infected fish they were found throughout the visceral tissues. Extensive degeneration of the liver tissue caused by the migrating larvae of the bass tapeworm may be seen in Figure 5. Similar degenerative changes were also noticed in the

Figure 5. Section of liver of smallmouth bass showing extensive degeneration of the Liver Tissue. Numbers 1 and 2, on the photograph, show the cross section of the parasite. Hematoxylin-eosin. 370 X.


2

ovaries of the smallmouth bass permeated with large numbers of the plerocercoid larvae. Eggs in this organ were degenerating and the whole organ was wrapped around a thick fibrotic mass of connective tissue. Apparently, the fish were rendered sterile by the combined effect of the mechanical injury caused by the parasite and the response of the host fish to this infestation.

Comparison of the plerocercoid larvae in young and adult smallmouth bass:

The sample of 36 smallmouth bass examined ranged from two to ten years in age and was composed of 20 males and 16 females. The 20 females ranged from 2 to 10 years, while the 16 males represented the age group of 3 to 9 years. Table 5 shows the distribution of the calculated mean length and the standard error of the plerocercoid larvae in the visceral organs of the smallmouth bass. Figures in parenthesis represent the total number of parasites examined in each case. There were 414 plerocercoid larvae measured from ovaries and testes and 885 from the rest of the visceral organs. The overall average length of plerocercoids in the visceral organs of the smallmouth bass, regardless of the age group of the fish, are shown in Table 6. The

Table 5. Average Length of Plerocercoid Larvae of Proteocephalus ambloplitis in the Visceral Organs of Smallmouth Bass of Various Age Groups

Age group	Number of fish examined	Length of larvae in different organs (mm.)				
		Ovary	Liver	Spleen	Mesentery	Testes
II	3	4.03 ± .30* (16)	2.34 ± .23 (12)	2.24 ± .25 (11)	1.26 ± .13 (54)	
III	14	5.54 ± 1.12 (106)	3.35 ± .16 (102)	3.42 ± .22 (46)	1.82 ± .07 (179)	2.91 ± .34 (15)
IV	9	7.01 ± .53 (64)	3.27 ± .18 (66)	3.25 ± .26 (22)	1.53 ± .30 (133)	3.37 ± .21 (50)
V	4		2.67 ± .23 (20)	4.05 ± 1.15 (10)	1.93 ± .12 (47)	3.46 ± .29 (31)
VI	1	9.09 ± .70 (22)	4.33 ± .47 (17)	6.00 ± 1.64 (5)	2.29 ± .29 (12)	
VII	1	8.83 ± .19 (30)	2.50 ± .29 (3)	3.33 ± .17 (3)	1.77 ± .21 (11)	
VIII	1	12.00 ± .107 (20)	4.34 ± 1.00 (8)	6.70 ± 1.56 (5)	2.11 ± .21 (18)	
IX	2	16.43 ± 1.44 (36)	6.51 ± 1.99 (14)	6.01 ± 1.38 (14)	2.48 ± .17 (32)	6.17 ± .70 (11)
X	1	17.19 ± 2.97 (13)	4.65 ± .42 (8)	6.45 ± .54 (14)	2.34 ± .33 (19)	

*Mean + S.E., figures in parentheses represent the total number of parasites examined

Table 6. Comparison of the Plerocercoid Larvae of *Proteocephalus ambloplitis* in the Visceral Organs of the Smallmouth Bass Taken from Lake Manitou, Michigan, Irrespective of Their Age Group

Organs	Total number of parasites examined	Average length of parasite (mm.)
A - Ovary	307	8.44 ± .36
B - Liver	250	3.53 ± .15
C - Spleen	130	4.17 ± .25
D - Mesentery	505	1.83 ± .04
E - Testes	107	3.62 ± .18

*Calculated probability of comparisons between ovary and other visceral organs:

A vs. B: $P < 0.001$ A vs. D: $P < 0.001$

A vs. C: $P < 0.001$ A vs. E: $P < 0.001$

contrast is striking and the comparison of the average length of plerocercoids in ovary is statistically significantly greater than the average length of plerocercoids in the rest of the organs.

The consistent increase in the mean length of plerocercoids in the ovary and the testes with the gradual increase in the age of the fish is again striking. A correlation of .96 was obtained between the average length of plerocercoids in the ovary and the increase in the age of the fish by one year. This is statistically highly significant. Similarly, correlation between the mean length of larva in the testes and the increase in the age of the fish by one year is .94 which again is highly significant statistically (Table 7).

In order to compare the growth rate of plerocercoids in the ovary with those growing in the testes, separate regression coefficients were obtained for each of these organs. The regression coefficients of lengths of plerocercoids in ovaries and testes are 1.60 and 0.55 respectively. By F test, each of these regression coefficients were found to be significantly different from that of a simple chance occurence. The average length of plerocercoid

Table 7. Correlation and Regression Coefficients Between the Lengths of Plerocercoid Larvae of the Bass Tapeworm Growing in Ovary and Testes and the Annual Increment in the Age of the Smallmouth Bass

Organ	D.F.	Sum of squares and products			r	b
		$S\ x^2$	$S\ xy$	$S\ y^2$		
Ovary	6	58.87	94.10	163.71	.958[1]	1.60[1]
Testes	2	20.75	11.51	6.58	.941[2]	.55[2]

[1]Significant at the 1 per cent level

[2]Significant at the 5 per cent level

larvae for a given age of fish can be calculated from this regression coefficient. Figures 6 and 7 show the equation of regression coefficient ($Y = a + bX$) and the calculated lengths of plerocercoid larvae in ovaries and testes. The vertical lines represent the distribution of standard errors for each of the larval lengths calculated.

From the above statistical analysis of the data it is evident that as the fish increases in age the gonad larvae also increase. The rate of growth of larvae, however, differ in male and female gonads. The average annual increment in the length of larvae of testes is .55 mm. as compared to 1.60 mm. of the larvae growing in the ovary. This increase is approximately three times greater than the other. Since the growth of the larvae in the gonads is directly associated with the degree of damage done to these organs, it is apparent that extensive damage would be expected earlier in the female than in the male bass.

Hunter and Hunninen (1934) did a similar type of work in smallmouth bass obtained from rivers and lakes of New York. Their study on 116 smallmouth bass revealed the number of plerocercoid larvae to be always greater in gonads than in any of the visceral organs. Also, they found the mean length of plerocercoids in gonads as 10.7 mm. and

Figure 6. The relationship between the age of the fish and the length of plerocercoid larvae of *Proteocephalus ambloplitis* growing in the ovaries of smallmouth bass. Vertical lines represent the distribution of standard error.

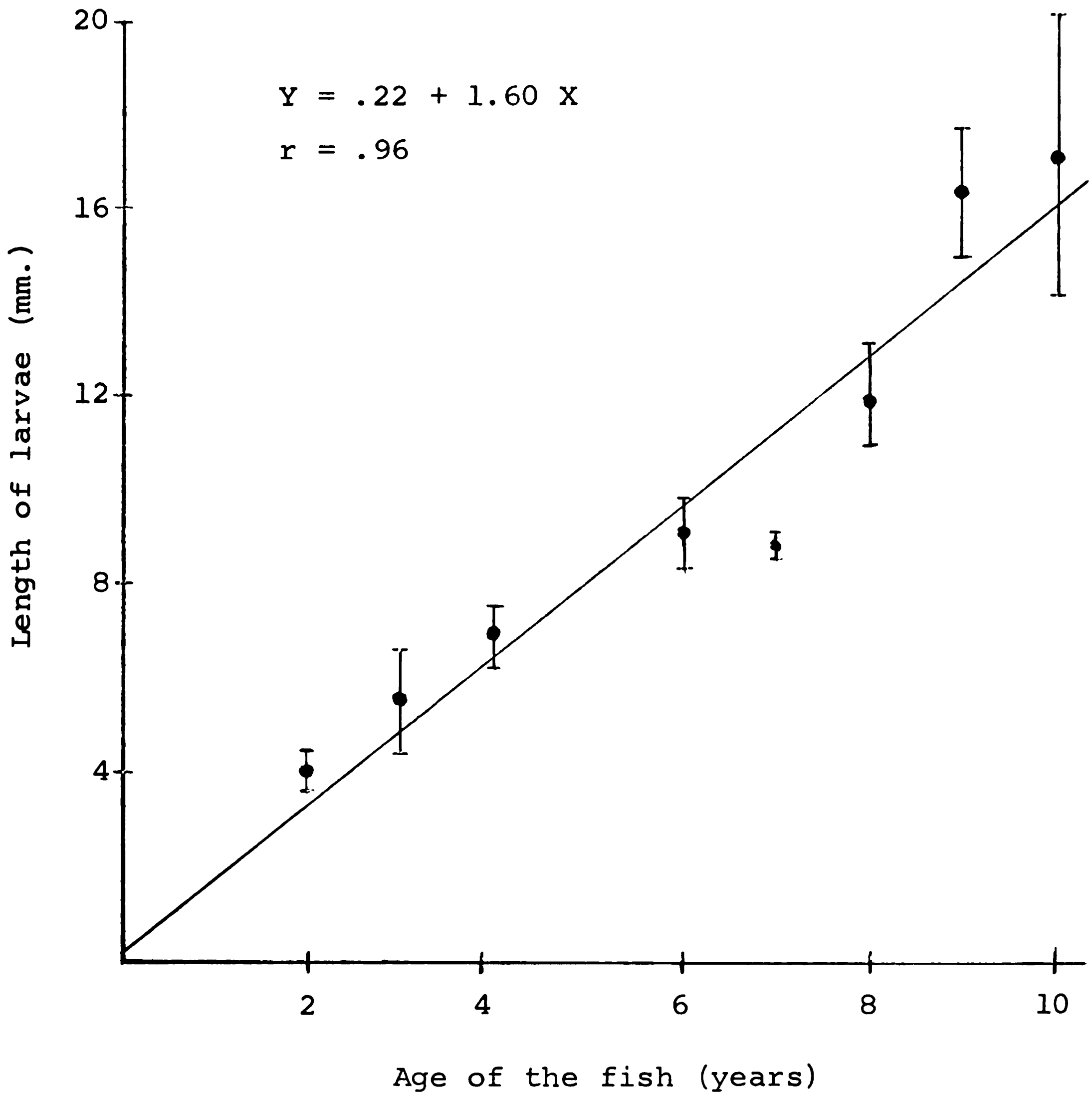
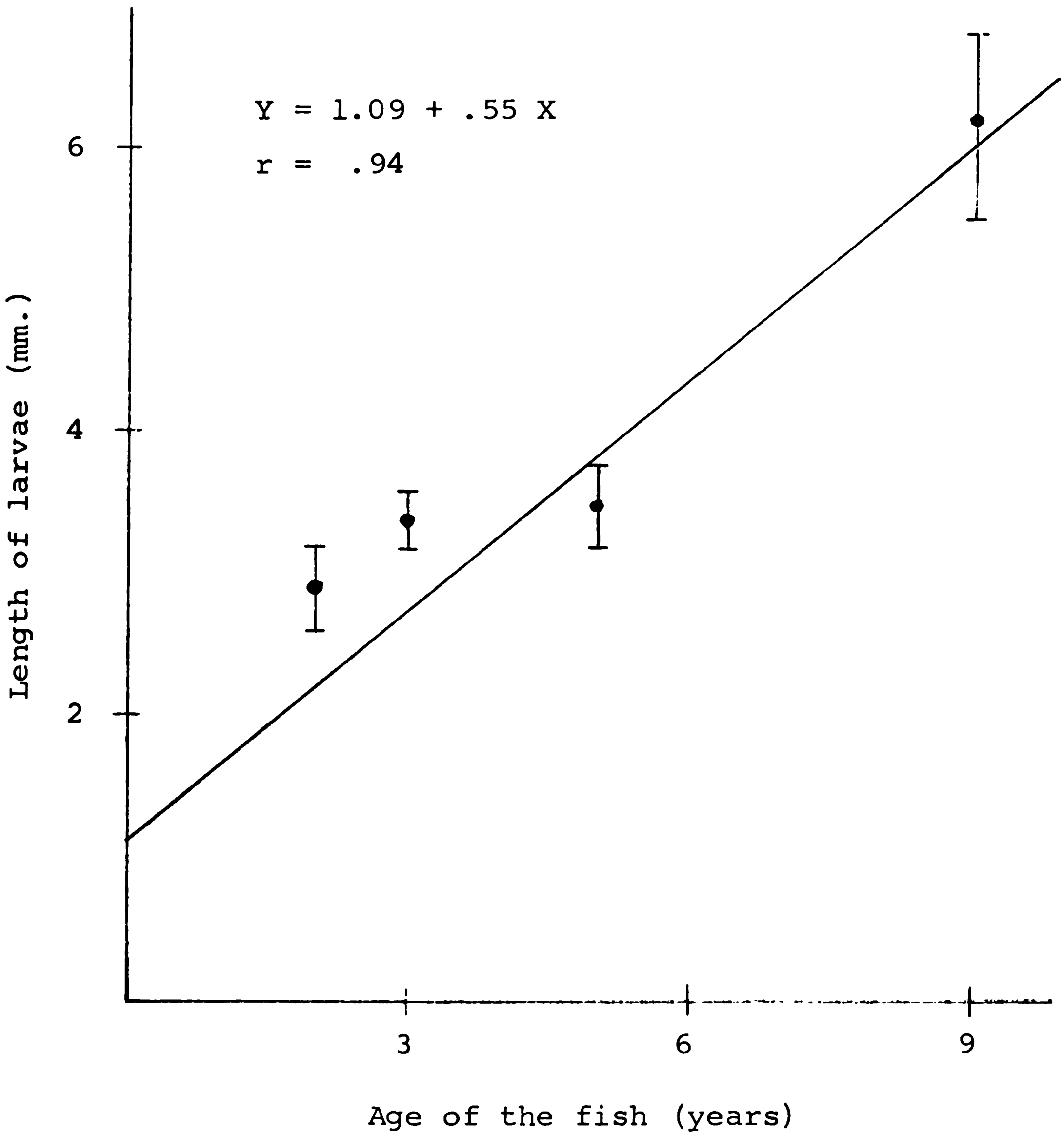

20
16
12
8
4
Y = .22 + 1.60 X
r = .96
Length of larvae (mm.)
2
4
6
8
10
Age of the fish (years)

Figure 7. The relationship between the age of the fish and the length of plerocercoid larvae of *Proteocephalus amblopliti*s growing in the testes of smallmouth bass. Vertical lines represent the distribution of standard error.


Y = 1.09 + .55 X
r = .94
Length of larvae (mm.)
6
4
2
3
6
9
Age of the fish (years)

from the rest of the visceral organs as 6.2 mm. They, however, did not find any correlation between the age of the fish and the growth of larvae in male gonads.

One of the original proposals, besides the one discussed thus far, in this investigation was to know whether or not infection of bass tapeworm had any effect on the growth of the smallmouth bass of Lake Manitou, Michigan. This consideration had to be abandoned when every fish of the sample was found to be infected with the plerocercoid larvae of the bass tapeworm. There are several variables in the dynamics of aquatic environment which affect the condition of fish (Fischthal, 1953). Under the circumstances, comparisons, as evidenced by lengths and weights of a non-parasitized fish from different body of water will not be directly comparable.

It is surprising, however, to note that, even under such heavy infestations, the growth rates of the smallmouth bass from Lake Manitou, Michigan, compared favorably with growth rates of smallmouth bass taken during a survey of 400 Michigan lakes (Beckman, 1946). Damage in these fish, based on gross and histopathological examinations, seems to be very extensive to the vital organs. However for the anglers, these fish do not show any apparent effects of parasitism. They faught well on hook and line. Every fish of the sample examined had good deposit of peritoneal fat.

Yellow perch of Lake Manitou, Michigan were not found as one of the final hosts of the bass tapeworm, *Proteocephalus amboplitis*. The larval stage of the worm, however, were recovered from all five yellow perch examined. As indicated earlier, infection of plerocercoid larvae of *Proteocephalus amboplitis* presented altogether a different picture in this species of fish. The larvae, unlike those found in smallmouth bass, were enclosed in round, yellowish-white cyst with a heavy cyst wall. These cysts were of varying size and were distributed in liver, spleen, mesenteries, and omenta. In no case cysts containing plerocercoid larvae were found inside the ovary. Out of the five fish examined, only one had heavy infection. Bangham (1941) reported that the heavy cyst wall in case of yellow perch appears to retard the growth of the larva.

Order: Digenea van Beneden, 1858
Suborder: Prosostomata Odhner, 1905
Family: Clinostomidae Luhe, 1901
Subfamily: Clinostominae Pratt, 1902
Clinostomum marginatum (Rudolphi, 1819)

Hosts: *Micropterus dolomieui*, *Perca flavescens*, and *Lepomis cyanellus*.

Immature stage of Clinostomum marginatum (metacercaria) commonly known as yellow grub were found distributed in the general musculature, gill, gill cover, and operculum of the smallmouth bass (Figure 8). Of the 36 smallmouth bass examined, 26 or 72.3 per cent had light to moderate infections. Infection with metacercarial stage of Clinostomum marginatum has practically been reported from all species of fresh-water fishes except trout (Hunter, 1942). Perca flavescens is, by far, the most common host reported by Van Cleave and Mueller (1934). In the yellow perch this parasite had a congregation along the head, throat, gills, gill covers, and opercular regions. In the smallmouth bass and the green sunfish the cyst of Clinostomum marginatum were more common in general body musculature and not concentrated in any particular region. However, there appears to be very little damage done to the host fish by yellow grub. According to Fischthal (1953), heavy infection of Clinostomum marginatum may increase the oxygen requirement of the fish.

Life cycle of Clinostomum marginatum, along with the life cycles of other parasites recovered in this study are summarized in Table 8.

Figure 8. Metacercaria of Clinostomum marginatum from the musculature of smallmouth bass. 2 X.

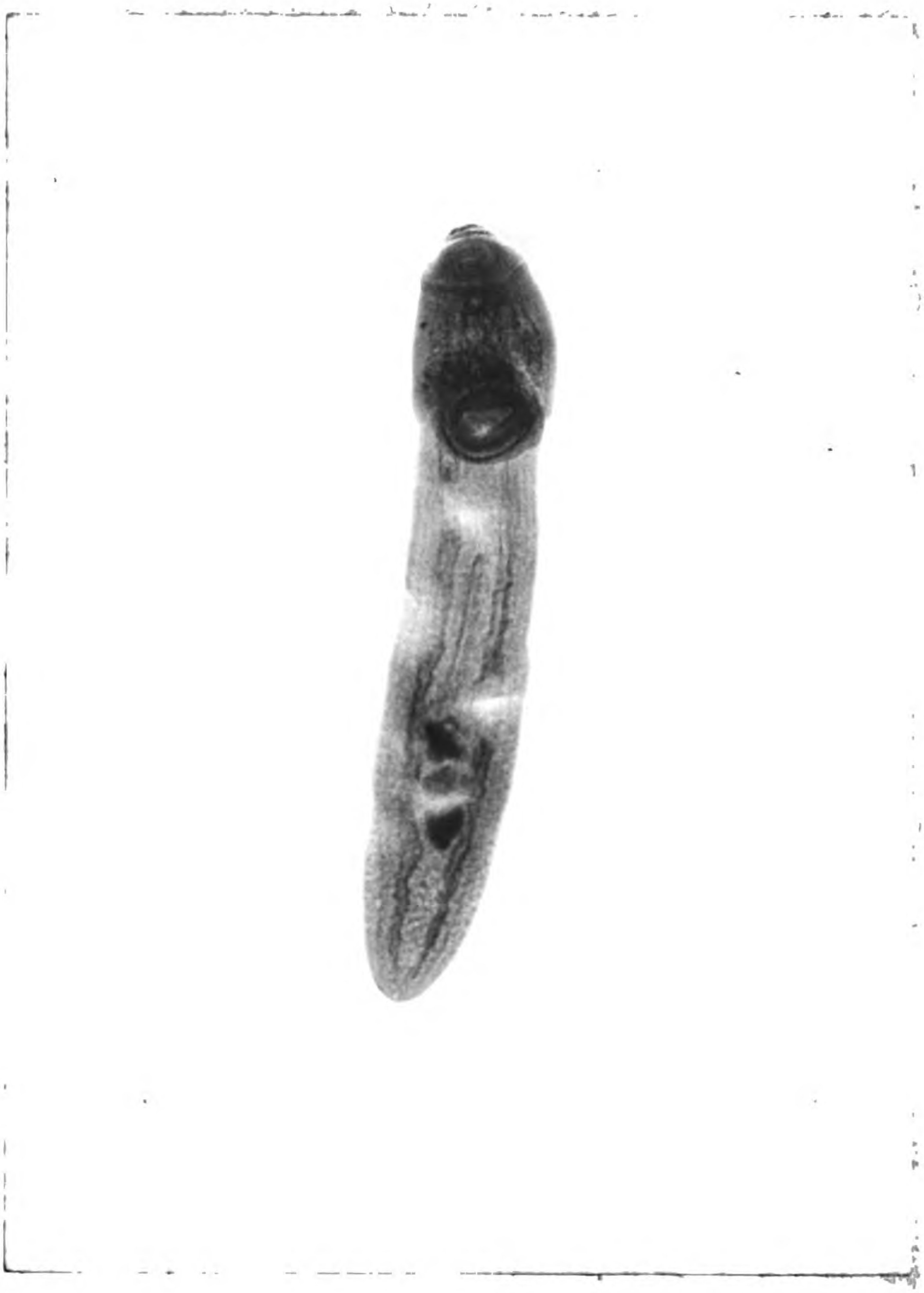


Table 8. Life Cycles of Helminth Parasites Obtained from the Fishes of Lake Manitou, Michigan

Parasite	Host			Reference
	First accessory	Second accessory	Final	
(Trematoda: Fish were the intermediate host in all cases)				
Clinostomum marginatum	*Lymaea palustris*	Larvae encyst in 27 species of fish, frog (*Rana pipiens*), salamanders, and also in land snails (*Sublina octona*)	Buccal cavity and esophagus of fish-eating birds	Hunter & Hunter (1935)
Posthodiplostomum minimum	*Physa gyrina*	Metacercaria encyst in 25 different species of fish, including rock bass, large and smallmouth bass, yellow perch, bowfin, and various others	Intestine of Halcyones--the fish-eating birds	Hunter (1937) & Hoffman (1956)

(Table 8 continued)

Parasite	Host			Reference
	First accessory	Second accessory	Final	
Strigeid worms *Posthodiplostomulum* (= *Neascus* sp.)	*Helisoma trivolvis*, *H. campanulatum* and *H. anceps*	Encystment of metacercaria in most species of sunfish, rock bass, large and smallmouth bass and various others	Fish-eating birds	Hunter & Hunter (1935); Lanchance (1947), & Yamaguti (1958)
(Cestoda: Fish were both the intermediate as well as the final host)				
Proteocephalus ambloplitis	*Hyalella knickerbockeri*, *Cyclops parsinus*, *Cyclops albidus*, *Cyclops leuckarti*, *Cyclops vulgaris*, and *Cyclops serrulatus*	Second accessory host includes 16 different species of fishes including smallmouth bass	Small and largemouth bass, rock bass, bowfin, burbot, and yellow perch	Bangham (1925 & 1927); Hunter (1928), Hunter & Hunter (1929 & 1930)

(Table 8 continued)

Parasite	Host			Reference
	First accessory	Second accessory	Final	
		(Acanthocephala)		
<u>Leptorhynchoides thecetus</u>	Amphipod	Not separated from the final host	Several species of fishes are involved; Fischthal reported 37 species of fish; according to Lincicome and Van Cleave, 79 species are involved	Fischthal (1953); Lincicome & Van Cleave (1949); & Van Cleave (1947)
<u>Pomporhynchus bulbocolli</u>	Amphipod	Not separated from the final host	31 different species are involved	Fischthal (1953)

Order: Digenea Van Beneden, 1858
Family: Diplostomidae Poirier, 1886
Subfamily: Diplostominae Monticelli, 1892
Genus *Posthodiplostomum* Dubois, 1936
P. (= *Neascus* sp. Hughes, 1927)

Hosts: *Micropterus dolomieui*, *Perca flavescens*, and *Lepomis cyanellus*

Black spot disease results from infestation of the fish by various metacercariae of the digenetic trematode group called strigeids. Adults of this group reach maturity chiefly in fish-eating birds and mammals and are strikingly unlike the metacercaria.

One member of the group Posthodiplostomulum (= *Neascus* sp. Hughes, 1927) was identified from the musculature of the smallmouth bass. Hughes (1927) described the following morphological characters for recognizing the members of the group:

"Strigeid metacercariae with both fore- and hindbodies well developed and distinctly set apart by a constriction; no lateral sucking cups; forebody leaf-like; holdfast organ well developed; reserve bladder highly developed, the smaller branches of which are usually anastomoses; calcareous granules mostly free in the circumambient fluid; encysted."

Black spot cysts were located under the scales, near the base of the fins, between the reys of the fins, around the eye, in the mouth cavity, operculum, and the flesh of the host. The encysted larvae are surrounded by double protective walls or the cyst membranes. The thinner membrane lies next to the worm and is laid by the parasite (Figure 9). The outer membrane with the black pigment in between the space is the product of interaction between the host tissue and the parasite. There appears to be little damage done to the host by black spots other than the aesthetic value. Dogiel and Bykhovski, however, reported mass destruction of young fish caused by black spot disease in the Aral Sea (Petrushevski and Shulman, 1961).

Out of 42 fishes examined in this study, green sunfish had the severest infection. Next in order ranked the yellow perch and the smallmouth bass.

One species of the strigeid producing black spot disease in the fishes of Lake Manitou, Michigan remained unidentified. The photographs of the larva escaping out and completely free from the cyst may be seen in Figures 10 and 11.

Order: Digenea Van Beneden, 1858
Family: Diplostomidae Poirier, 1886
Subfamily: Diplostominae Monticelli, 1892
Genus: *Posthodiplostomum* Dubois, 1936
P. minimum (MacCallum, 1921)

Host: *Lepomis cyanellus* Rafinesque

Figure 9. Strigeid metacercaria of the black spot in the cyst; outer membrane and the black pigment in between the space is removed. 175 X.

Figure 10. Unidentified strigeid escaping from the cyst. 175 X.

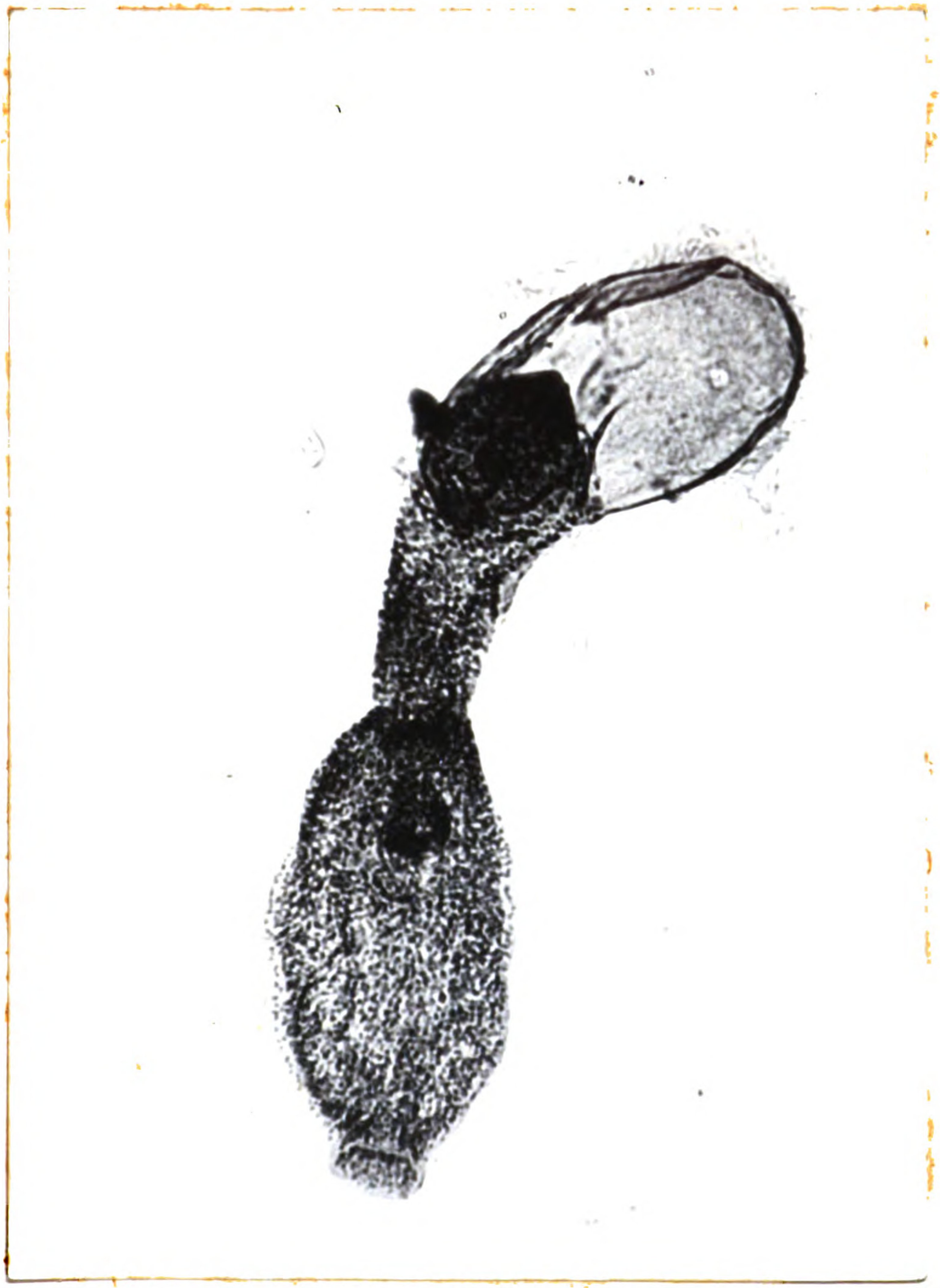


Figure 11. Unidentified strigeid of black spot completely free from cyst. 175 X.

Fortunately, this parasite was not particularly prevalent in fishes of Lake Manitou, Michigan. The only green sunfish, Lepomis cyanellus, was found to harbor the metacercarial stage of this fluke. Alexander (1959) examined a total of 67 fishes from this lake, which included 18 smallmouth bass, 35 yellow perch, and six green sunfish. Out of these fishes examined, 66.7 per cent of the smallmouth bass were infected with this parasite including one with a heavy infection. In the green sunfish, on the other hand, every fish of the sample showed moderate to light infections. It is surprising, however, that none of the smallmouth bass examined in this study were found to harbor this parasite.

The visceral organs, especially liver and spleen of the green sunfish, were heavily infected with the cysts containing metacercaria of Posthodiplostomum minimum (Figure 12). Liver is considered to be the normal site of this parasite which, in cases of heavy infection, is badly destroyed. It is however surprising to note that a fish so heavily infected with this worm do not show apparent detrimental effects. It is believed that adverse environmental conditions may cause such fish to be less resistant than normal fish.

Figure 12. Metacercaria of *Posthodiplostomum minimum*, obtained from the green sunfish, *Lepomis cyanellus*. 130 X.

The life cycle of Posthodiplostomum minimum is summarised in Table 8 (page 55).

Order: Palaeacanthocephala
Family: Echinorhynchoides Hamann, 1892
Genus Leptorhynchoides (Zoega, 1776)
Leptorhynchoides thecatus (Linton, 1891)

Hosts: Micropterus dolomieui, Perca flavescens, and Lepomis cyanellus

Next in order to the bass tapeworm (P. amploplitis), spiny-headed worm (L. thecatus) was the most abundant of the fish parasites of Lake Manitou, Michigan. Of the 42 fishes examined, all had this worm in common with the bass tapeworm. A total of 1,125 parasites were recovered from the pyloric caeca, stomach, and intestine of the 36 small-mouth bass examined. This means that, on an average, every fish had 31.4 of this worm.

The spiny-headed worm are elongate, cylindrical worm provided anteriorly with a specialized organ of attachment called the proboscis. This proboscis is capable of inversion and retraction within the front end of the body. The sexes are separate and, like tapeworms, they have no trace of digestive system. The food is absorbed directly through the body surface of the worm. The surface of proboscis bears numerous recurved hooks which grapple into the host tissue and thereby provide secure attachment for the parasite (Figure 13).

Majority of the worms recovered were secured from the pyloric caeca or the small intestine. These worms were found with their proboscis firmly attached to the mucosa of the intestine, with a characteristic patch of inflammed area surrounding the place of attachment. Very few of them were found free in the lumen of the gut. In some instances adult worms were about to bore through the wall of the digestive tract. In cases of heavy infestations, ulcer-like lesions with conspicuous areas of laceration and inflammation in the intestinal wall of the host were observed. These were apparently caused by the armed proboscis of the parasite.

Van Cleave and Mueller (1934) reported that *Micropterus dolomieui* seems to be the most significant host of this species. Infection in yellow perch (*Perca flavescens*) and green sunfish (*Lepomis cyanellus*) were comparatively low than in smallmouth bass. It is surprising however that inspite of such heavy infestations, fishes seem to have suffered no inconvenience.

During the entire life span of acanthocephalans there seems no time when the individual leads a free life, even

Figure 13. A mature male of Leptorhynchoides thecatus showing the internal organs and spines on the proboscis. 2 X.

for a brief interval. The entire life cycle is intimately tied up with and conditioned by food chains and feeding habits. If the amphipod containing acanthellas or cystacanths are eaten by unsuitable host, they become secondarily encysted and are known as juveniles. When the fish containing the juvenile is eaten by the proper final host, the worm attains sexual maturity.

Order: Palaeacanthocephala
Family: Echinorhynchidae Hamann, 1892
Genus *Pomphorhynchus* Monticelli, 1905
Pomphorhynchus bulbocolli Linkins, 1919

Host: *Micropterus dolomieui* Lacépède

Adults of this species were recovered from the upper intestine of six of the 36 smallmouth bass examined. Maximum number of parasite recovered from individual fish was two. The parasite, therefore, was not a common parasite of fishes of Lake Manitou, Michigan. The members of the genus are distinguishable from all the other fish parasites by the presence of a long cylindrical neck. At the end of this neck there was usually a large spherical enlargement (Figure 14). This bulb serves as an accessory attachment organ, for though it lacks hooks or spines, the tissues of the host intestine grow around it and serve as an effective

Figure 14: Pomphorhynchus bulbocolli, entire female showing the characteristic bulbous enlargement on the proboscis. 1.5 X.

anchor to prevent dislodgement of the worm. Particular care was taken to avoid breaking this worm, and the best results were obtained by fixing the worm and the attached piece of intestine and then dissecting away the host tissue.

The life history and the pathology of the worm is almost the same as those of Leptorhynchoides thecatus.

Order: Spiruridea Diesing, 1861
Family: Cucullanidae Cobbold, 1864
Subfamily: Dacnitoidinae York et Maplestone, 1926
Genus Dacnitoides Ward et Magath, 1917
Dacnitoides cotylophora Ward et Magath, 1917

Hosts: Micropterus dolomieui and Perca flavescens

Males of Dacnitoides cotylophora were recovered from the intestine of two smallmouth bass and three yellow perch. The total worms recovered from these fishes were 13 which indicate that the parasite was not very common in Lake Manitou, Michigan.

Males are slightly less than 5 mm. with the tail end recurved ventrally into a hook. Spicules are equal and the presence of a preanal sucker is characteristic. Females are said to be slightly bigger than the males and they have only one ovary. No apparent pathological change associated with the presence of this roundworm was noticed. The life cycle of the worm is not yet known.

SUMMARY AND CONCLUSIONS

A comparative study was made to the extent of damage done by the larval stage of the bass tapeworm in the different age groups of the smallmouth bass. For this, a total of 42 fishes were collected from Lake Manitou, on the north Manitou Island, Michigan. Of the 42 fishes in the sample, 36 were smallmouth bass representing a good proportion of males and females. Their age group ranged from 2 to 10 years. The remaining fishes of the sample were represented by five yellow perch and one green sunfish. Of all the fishes examined, not a single fish was found to be free of parasites.

A total of nine different species of helminth parasites, representing all the three phyla were recovered. Of all these parasites, bass tapeworm, Proteocephalus ambloplitis, was found to be the most damaging one. The larval stage of the bass tapeworm (plerocercoid) was present in all the 42 fishes examined and produced considerable damage to the body tissues and organs. Migration of these larvae cause inflammation and subsequent proliferation of connective tissue in and around the visceral organs, thus the reproductive organs are not able to function properly and the fish are rendered sterile. The extent of damage is greater in the females than in the males of the same age group. A study of larval lengths in the smallmouth bass ranging from 2 to 10 years in age revealed that gonads, especially the ovaries, are better adapted for the growth of the plerocercoid larvae. As the female fish increases in age the gonadal larvae also increase. The rate of growth of larvae is approximately three times greater in the ovaries than in the testes.

The adult bass tapeworm was found in five of the smallmouth bass and a total of over fifty worms were recovered. Yellow perch of Lake Manitou, Michigan, were not found to be serving as one of the definitive hosts for this parasite.

Plerocercoid infections in the yellow perch were quite different from those observed in the smallmouth bass and the green sunfish. The larvae of _P. amblopLitis_ were enclosed in tough, yellowish-white cysts. The heavy fibrotic cyst apparently retards the growth of the parasite and the subsequent damage is comparatively low in the yellow perch than in the smallmouth bass.

The next most abundant fish parasite in Lake Manitou, Michigan, is the spiny-headed worm (_L. thecatus_). They were present in almost every fish of the sample in common with the plerocercoids of the bass tapeworm. The proboscis of these worms were, in most cases, embedded deep in the mucosa of caeca and small intestine with a characteristic patch of inflammation surrounding the place of attachment. In few instances worms were about to bore through the lumen of the gut wall. It is, however, amazing that in spite of such a heavy infestation the fish appears to have experienced no inconvenience.

Parasites causing yellow grub and black spot, although quite abundant in the fishes, did not seem to have much effect. The metacercaria of the yellow grub were encysted just beneath the skin, especially in the region of throat. In very heavy infestations they are quite easily noticed and the acceptability of the fish for table use is greatly reduced. Though it is realized that cooking destroys the parasite and man in no case can be infected, I, myself would hesitate eating fish from Lake Manitou, Michigan, as heavily parasitized with yellow grub as they were.

The remaining fish parasites of lake Manitou, Michigan, were not of much importance. Either they were present in very small numbers in only a small percentage of the fish, or they did not seem to affect the host in any way.

Elimination of bass tapeworm from natural water would indeed be a difficult undertaking. The first approach that comes to mind would be to do away with the copepods, one of the accessory hosts of the bass tapeworm. Various workers have suggested several methods for the destruction of copepods without, at the same time, damaging the host fish. The greatest difficulty encountered in this respect would be to get rid of all the species of copepods which have thus far been proved as the first intermediate host. Since copepods are one of the important segments of a biotic environment and play an important role in the food chain of aquatic organisms, their removal may upset the entire natural balance of the ecosystem. The result may be quite disastrous. These consequences, therefore, must be considered before tampering with nature's balance.

The other drastic method suggested for the control of bass tapeworm at the present time is the complete reclamation of the lake. The method no doubt may prove successful but will certainly involve considerable time and money.

As we know, the eggs of the bass tapeworm are not very viable and unless they are eaten by the right species of the copepod within 24 to 36 hours they start degenerating and die. This weak point in the life history of the bass tapeworm may be advantageous in breaking its life cycle. Various antiseptic dyes or chlorinated compounds may be tried to sterilize the eggs *in vitro* or *in vivo*. The eggs in this way may be rendered sterile before they are made available to the copepods and further propagation of the bass tapeworm may be stopped.

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