THE INTERNAL FISH PARASITES OF LAKE MANITOU, NORTH MANITOU ISLAND, MICHIGAN

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THE INTERNAL FISH PARASITES OF LAKE MANITOU, NORTH MANITOU ISLAND, MICHIGAN

By

HOWARD C. ALEXANDER

A THESIS

Submitted to the College of Agriculture
of Michigan State University in
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The author, of course, assumes responsibility for any errors remaining in this thesis.

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ABSTRACT

This thesis reports a study on the internal parasites of five species of fish from Lake Manitou, North Manitou Island, Leelanau County, Michigan. Of the 67 fishes examined, all were found to be infected by at least one species of parasite. Flukes, tapeworms, and spiny-headed worms made up the majority of the parasites. Few nematodes were found in the fishes. Parasites of the following species are discussed: Smallmouth bass, *Micropterus dolomieu*; yellow perch, *Perca flavescens*; green sunfish, *Lepomis cyanellus*; common sucker, *Catostomus commersoni*; and northern sculpin, *Cottus bairdi*. A list of parasites giving the degree of infection is presented for each species of fish. Life cycles are given when they are known. Methods of parasite control are also discussed.

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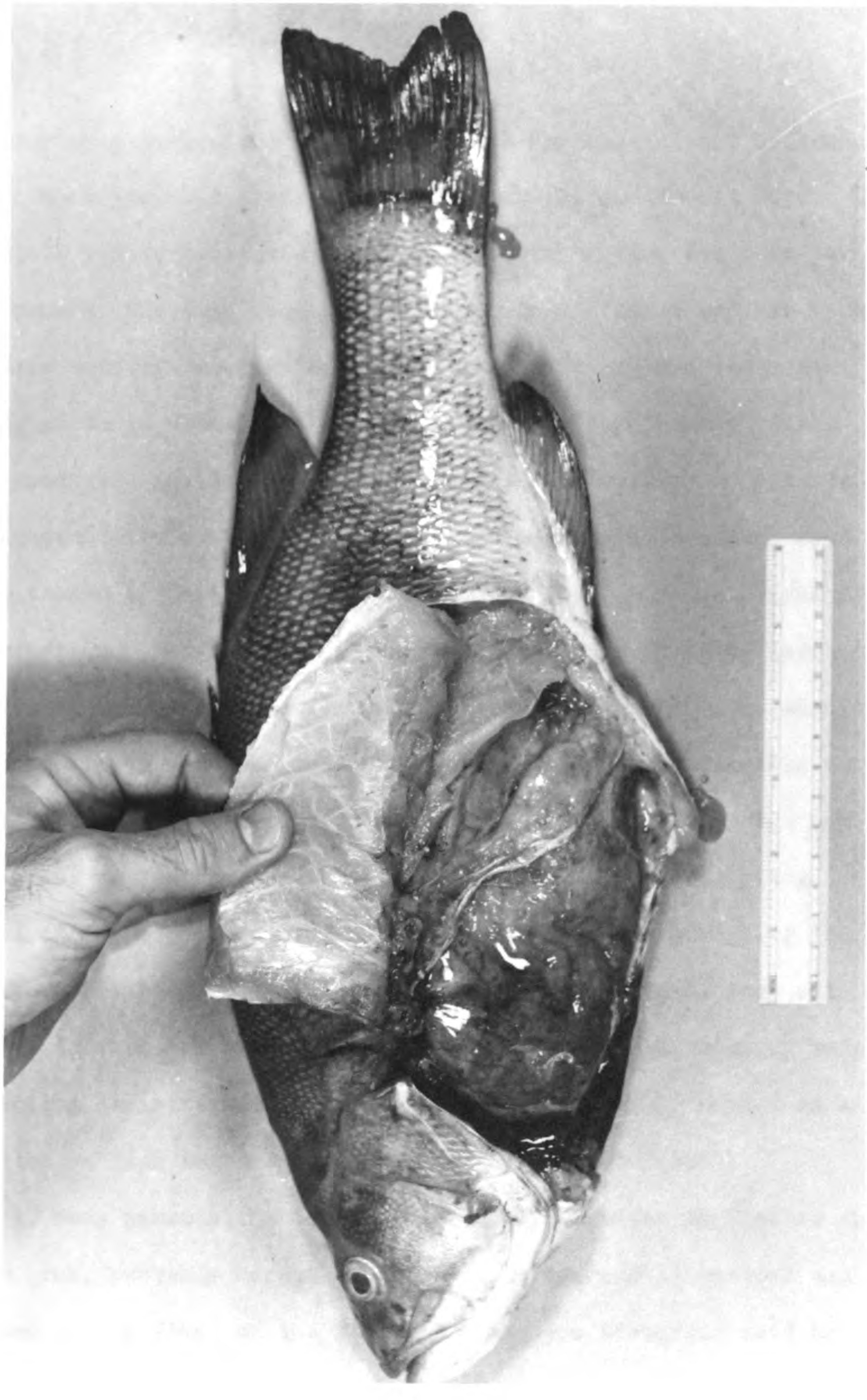


INTRODUCTION

For many years Lake Manitou on North Manitou Island, Leelanau County, Michigan, has produced good fishing for smallmouth bass. The lake still yields good catches of fish. However, for the past few years many of the fish caught have been released after capture because they were heavily infected with parasites. The anglers refer to certain of these diseased fish as being "wormy" or "grubby" fish. The wormy condition is the result of infection of a variety of parasites. The acceptability of the fish as food is apparently dependent upon the damage caused by certain types of parasites found and the degree of the infection. For example, black spot, caused by the tiny larva of a parasitic worm which incepts itself in the skin of the fish, when present in small numbers goes unnoticed or is not objectionable to most fishermen. However, when black spot is present in large numbers, the fish is no longer considered palatable although the angling qualities of the species of fish are unaffected. Some anglers indicate that they believe their health may be endangered if they eat parasitized fish. There is no danger of human beings becoming infected from eating parasitized fish that have been thoroughly cooked as all parasites of fish are destroyed by cooking, Allison (1950).

To many persons the most objectionable parasite in fish is the yellow grub, probably because this parasite is readily noticed and is imbedded in the flesh of the fish. One Manitou fisherman said he

didn't mind the black spot or yellow grub, but he couldn't stand the thought of eating fish that had long worms crawling out of their mouths. The long worms referred to by the angler were bass tapeworms which commonly crawl out of the fish's mouth when kept a few hours before cleaning. Black spot is less readily recognized as a parasite by most anglers. In many specimens this parasite principally infects the skin. Thus skinning the fish will remove the majority of the parasites and the angler's objections to them. Visible tapeworm infections of the intestine and body cavity are removed upon cleaning the fish. The remaining parasites generally go unnoticed by fishermen and are, therefore, not objectionable.

METHODS

A total of 67 fishes, representing five species, were examined for parasites. The smallmouth bass, Micropterus dolomieu Lacepede; yellow perch, Perca flavescens (Mitchill); green sunfish, Lepomis cyanellus Rafinesque; and common sucker, Catostomus commersoni (Lacepede); were the major species collected. The fishes were collected by gill nets and angling. One northern sculpin, Cottus bairdi Girard, was also collected.

Waterfowl commonly harbor the sexually mature stages of many animals which parasitize fish. In an effort to find adult stages of parasites waterfowl were collected for examination. The importance of certain species of waterfowl and their connection in the life cycles of various fish parasites will be discussed later in this text.

Two species of snails, Physa gyrina and Goniobiasis livescens, were collected because of their importance in the life cycles of trematode parasites. They were collected by wading along the shore and picking them from the lake bottom and from sunken material. Snails were placed in damp moss and taken to the laboratory at Michigan State University. The snails were segregated in small jars half filled with water containing a small piece of Chara. The jars were checked daily for cercaria over a period of two weeks with a dissecting microscope.

A temporary field laboratory on the island was set up for the examination of the fishes and birds. Examinations for parasites were performed as soon as the fishes and birds were brought in from the lake. Fish were first examined for external evidence of infection, or parasites close to the surface of the skin. Next the viscera and the gills were

removed and placed in 0.65 percent saline solution. The head and body were then examined and the parasites found placed in a saline solution. The viscera and gills were then cut in the following pieces: Gills, stomach and pyloric caeca and intestine. Each was opened up with scissors and placed along with its contents in petri dishes and covered with saline solution. Then each dish was searched for parasites with the aid of a dissecting microscope. Tissues and cysts that were suspected of harboring protozoa were crushed on a slide and a smear made of the residue.

Each species of parasite was counted and recorded in the following manner: Over 50, heavy infection; from 10 to 49, moderate infection; and from 1 to 9, light infection.

Acanthocephala that were collected for identification were placed in distilled water and refrigerated for about 24 hours. This hypotonic solution causes the body to swell and the proboscis to be extruded. They were then killed and fixed in A.F.A. (alcohol, formalin and acetic acid).

Collecting the parasites which cause black spot and white spot required a somewhat more complex procedure. The artificial digestion method described by Hoffman (1955) was used. First, tissue containing cysts was macerated in a Waring blendor for one minute followed by digestion for 10 to 15 minutes in a solution of 0.5 percent pepsin in 0.25 percent HCl made up in 0.65 percent saline solution. After digestion, the remaining material was washed with saline, placed in petri dishes and examined with the aid of a dissecting microscope. This method releases the strigeid cyst by digesting away the tissue of the fish, leaving mostly the metacercarae in their cyst. Some of these cysts rupture, freeing a few of the larvae. Free larvae and cysts were placed directly in A.F.A.

Other small trematodes found during the routine dissection were placed directly in A.F.A. The larger trematodes were first flattened between slides and fixed by adding A.F.A. around the edges of the slide. Adult cestodes were placed in distilled water and kept under refrigeration for about 48 hours until they were completely relaxed. They were then fixed with A.F.A. Plerocercoid larva were placed directly in A.F.A.

To make positive identification the parasites were stained and mounted on slides. Whole mounts were stained with Semichon's acetic acid carmine stain. Several pieces of tissue were also fixed in A.F.A. for sectioning. These tissues were impregnated with paraffin and then sectioned at 10 microns. Sections were double stained with Harris' hematoxylin and eosin. Protozoan smears were stained with Giemsa's stain.

INTERNAL FISH PARASITES

A list of the parasites found in the fishes of Lake Manitou can be seen in Tables 1, 2, 3, 4 and 5. It should be noted that all the fishes examined were found to be parasitized by at least one parasite. In the majority of the fishes examined it was not necessary to make an exact count of the parasites because they were present in such great numbers, especially black spot, white grub of the liver, yellow grub and tapeworm larvae. The fish parasites of Lake Manitou will be discussed by parasite species rather than by host species.

Phylum Platyhelminthes
Class Trematoda
Order Digenea
Family Clinostomidae
Clinostomum marginatum (Rudolphi, 1819)

Hosts - *Micropterus dolomieu*, *Perca flavescens*, *Lepomis cyanellus* and *Catostomus commersoni*.

The larval stage (metacercaria) of *Clinostomum marginatum* is commonly called yellow grub (Figure 1). Cysts of yellow grub about one-eighth inch in diameter were found in the flesh of the above hosts. According to Van Cleave and Mueller (1934), the infection of perch with this parasite is much heavier and more frequent than that of any other species of fish. Heaviest infections were also noted in the perch of Lake Manitou. The perch from deep water when infected with yellow grub had light infections, whereas those from shallow water had the heavier infections. It is believed that the fish in shallow water are more subject to infection by the cercariae than the fish in deeper water because

TABLE 2. **Parasites found in *Perca flavescens* (Mitchill) (Yellow Perch) taken from Lake Manitou, Fall 1958 and Spring 1959.**

35 examined — 35 infected	Infection			Total No. Infected Fish
Parasite	Heavy Over 50	Moderate 11-50	Light 1-10	
PHYLUM PLATYHELMINTHES				
Class Trematoda (Flukes)				
Order Digenea				
**Clinostomum marginatum* (Yellow Grub)	2	9	11	22
*Unknown Strigeid (Black Spot)	4	8	3	15
**Posthodiplostomum minimum* (White Grub of Liver)		4		4
Class Cestoidea (Tapeworms)				
Order Proteocephala				
**Proteocephalus amblopl`itis* (Bass Tapeworm)	11	6	9	26
PHYLUM ACANTHOCEPHALA (Spiny-Headed Worms)				
Class Metacanthocephala				
Order Palaeacanthocephala				
Leptorhynchoides thecatus		4	28	32
PHYLUM NEMATHELMINTHES (Round Worms)				
Class Nematoda				
Order Camallanidea				
Dichelyne cotylophora			1	1
Order Dracunculoidea				
Philometra cylindracea			1	1
PHYLUM PROTOZOA				
Class Sporozoa				
Order Microsporidia	1			1
Order Myxosporidia	2			2

*Larval Stage

Figure 1. *Clinostomum marginatum* (metacercaria) from yellow perch, (natural size about 6 mm. long).

the snails, which are intermediate hosts in the life cycle, inhabit shallow water.

In the perch the yellowish cysts occur most frequently in the region of the gills and operculum and occasionally under the skin, particularly at the base of the dorsal fin (Meyer, 1954). Clinostomum marginatum in smallmouth bass and green sunfish was more common in the flesh and not concentrated in any particular body region. There appears to be little damage done to the fish by yellow grub. The heavily infected fish seem to thrive as well as the non-infected fish. Fischthal (1953) points out that Clinostomum marginatum may increase the oxygen demand of fishes thus making them more susceptible to oxygen deficiencies under ice cover.

The complete life cycle of Clinostomum marginatum is given in Plate II.

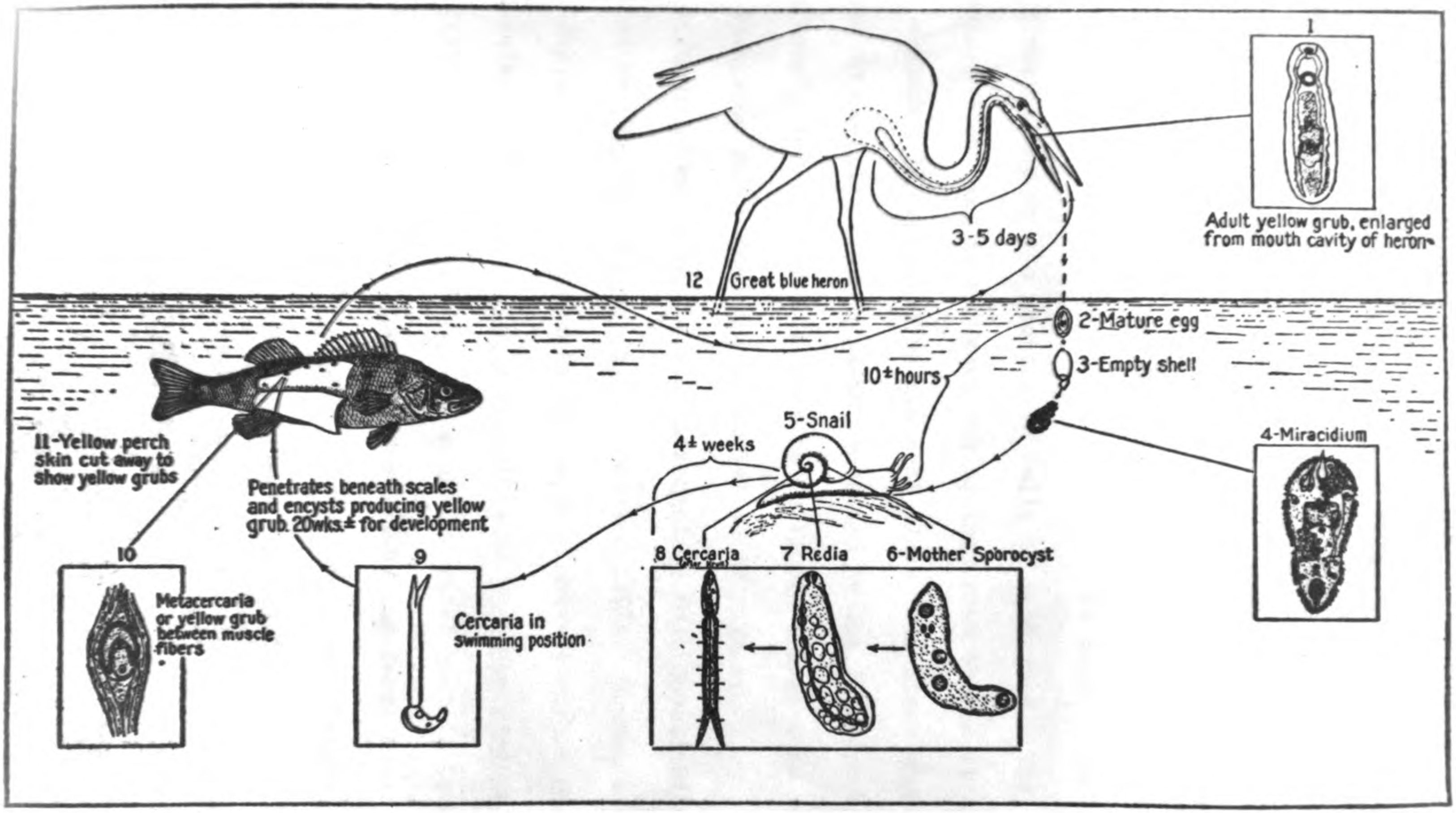
Family Heterophyidae
Cryptogonimus chyli Osborn, 1903

Host - Micropterus dolomieu

The sexually mature stage of Cryptogonimus chyli was found deeply imbedded in the pyloric caeca and upper intestine. The length of an individual is about 0.88 mm (Van Cleave and Mueller, 1934).

The life cycle of this species is unknown.

Plate II. The life cycle of the yellow grub of fish (*Clinostomum marginatum*) (Hunter and Hunter, 1935).


1
Adult yellow grub, enlarged from mouth cavity of heron
3-5 days
12 Great blue heron
2-Mature egg
3-Empty shell
10± hours
4-Miracidium
5-Snail
4± weeks
8 Cercaria
7 Redia
6-Mother Sporocyst
11-Yellow perch skin cut away to show yellow grubs
Penetrates beneath scales and encysts producing yellow grub. 20wks.± for development
10
Metacercaria or yellow grub between muscle fibers
9
Cercaria in swimming position

Family Strigeidae
Uvulifer amboplitis (Hughes, 1927)

Hosts - Micropterus dolomieu and Lepomis cyanellus

The larval stage (metacercaria) of Uvulifer ambloplitis produces black spot of bass (Figure 2). Black spot cysts were found under the scales near the base of the fins, between the rays of the fins, around the eye, in the mouth cavity and in the flesh of the host. The encysted larvae are surrounded by two protective walls or membranes. The thin inner membrane lies next to the worm and is laid down by the strigeid. The outer membrane is deposited by the host fish. The black appearance of the cyst is due to a black pigment deposited by the fish around the cyst (Fischthal, 1944). There appears to be little damage done to the host by black spot other than the accumulation of pigment.

The strigeids have a very rigid intermediate host specificity as demonstrated by Uvulifer amboplitis (Lachance, 1947). Hunter and Hunter (1934) report that the miracidium must penetrate either one of the two species of snails, Helisoma trivolvis or Helisoma campanulatum. Lachance (1947) found Helisoma anceps to be the snail host in Canada.

Krull (1934) exposed fry, medium sized fish, and large adult fish to the cercariae of Uvulifer ambloplitis. He found the cercaria infection produced a spectacular nervous response in fish and the smaller fish died in two to three days while the larger fish could stand heavier infections. He also reported that older sunfish previously infected were refractory to further infection. Ferguson (1943) working with Posthodiplostomum minimum and Hoffman (1956) working with Crassiphala bulboglossa did not find this to be true and were able to reinfect

Figure 2. Pyriform cyst of Uvulifer amblopiitis, (natural size about 300 microns long).

previously infected cyprinid fish.

The life cycle of Uvulifer ambloplitis is shown in Plate III.

Unknown species of metacercariae

Hosts - Micropterus dolomieu, Perca flavescens, Lepomis cyanellus and Catostomus commersoni.

Unidentified strigeids which produced black spot in the integument and musculature of the fishes examined were collected. The smallmouth bass and green sunfish were infected with two unknown strigeids. Photographs of cysts and free metacercariae can be seen in Figures 3, 4, 5 and 6. The perch and sucker also had still other unknown metacercariae.

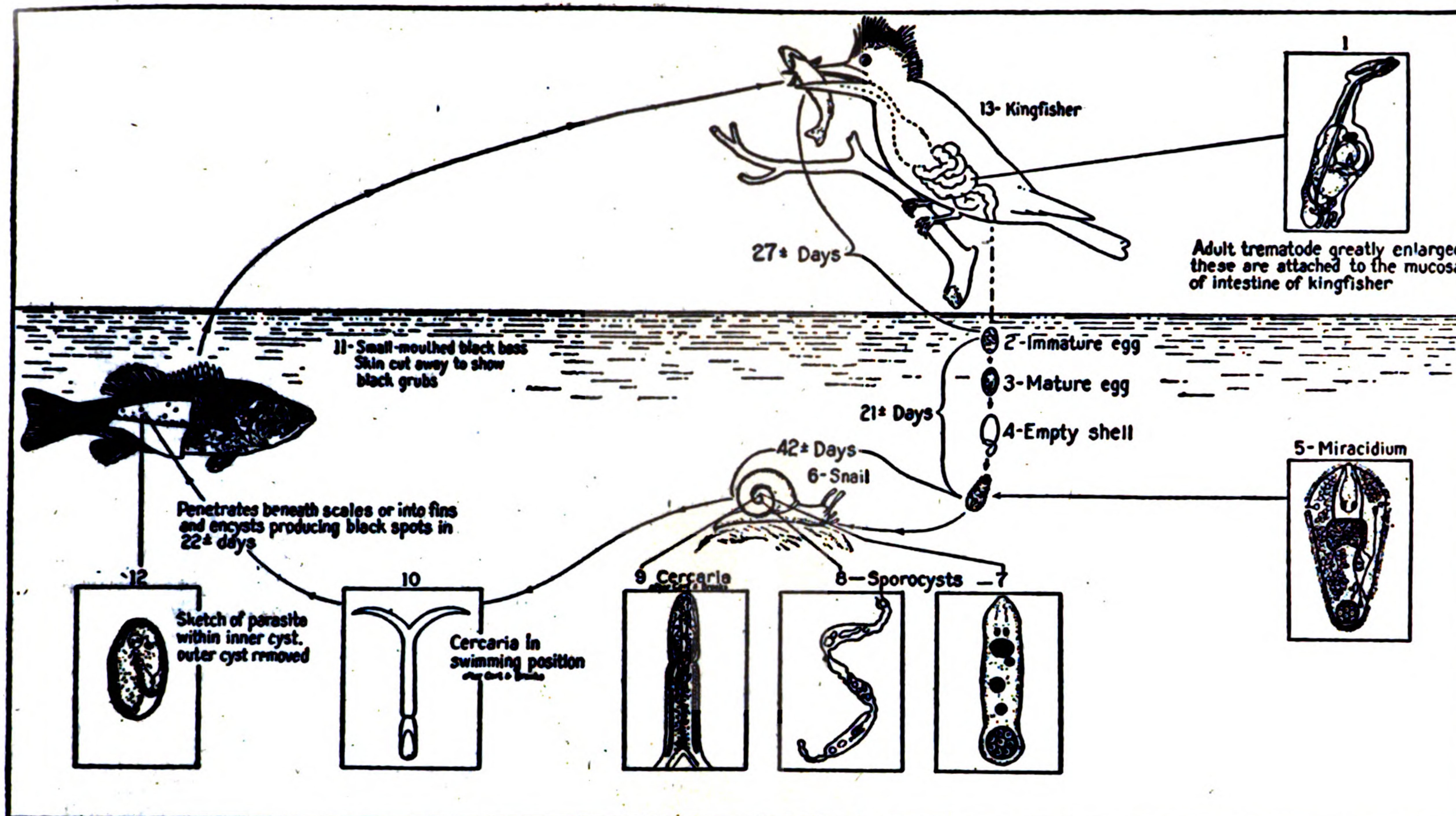
Posthodiplostomum minimum (MacCallum, 1921)

Hosts - Micropterus dolomieu, Perca flavescens and Lepomis cyanellus.

The metacercariae were found encysted in or on the heart, liver, spleen, kidneys, reproductive organs and mesentaries of the hosts (Figures 7 and 8). The white grub of the liver, as this parasite is commonly called, is closely related to the various species of metacercariae producing black spot. The white grub is separated from its host by two membranes as is Uvulifer ambloplitis. The fish does not form a black pigment layer around the cysts of white grub.

The life cycle of Posthodiplostomum minimum is very complicated (Plate IV). A certain species of snail, Physa gyrina, is necessary for completion of its life cycle (Hoffman, 1958). Physa gyrina was collected from Lake Manitou and one of the 37 snails was infected with sporocysts. The sporocysts presumed to be Posthodiplostomum minimum were in a mass

Plate III. The life cycle of the black spot producing parasite (Uvulifer ambloplitis) of bass (Hunter and Hunter, 1935).



1
Adult trematode greatly enlarged these are attached to the mucosa of intestine of kingfisher
13- Kingfisher
27± Days
2-Immature egg
3-Mature egg
4-Empty shell
21± Days
5-Miracidium
42± Days
6-Snail
7
8—Sporocysts
9 Cercaria
10
Cercaria in swimming position
11- Small-mouthed black bass Skin cut away to show black grubs
Penetrates beneath scales or into fins and encysts producing black spots in 22± days
12
Sketch of parasite within inner cyst, outer cyst removed

Figure 3. Unknown strigeids, one in cyst and the other escaping from cyst, (length of cysts about 270 microns).

Figure 4. Same unknown strigeid as in Figure 3 completely free from cyst, (length of larva about 900 microns).

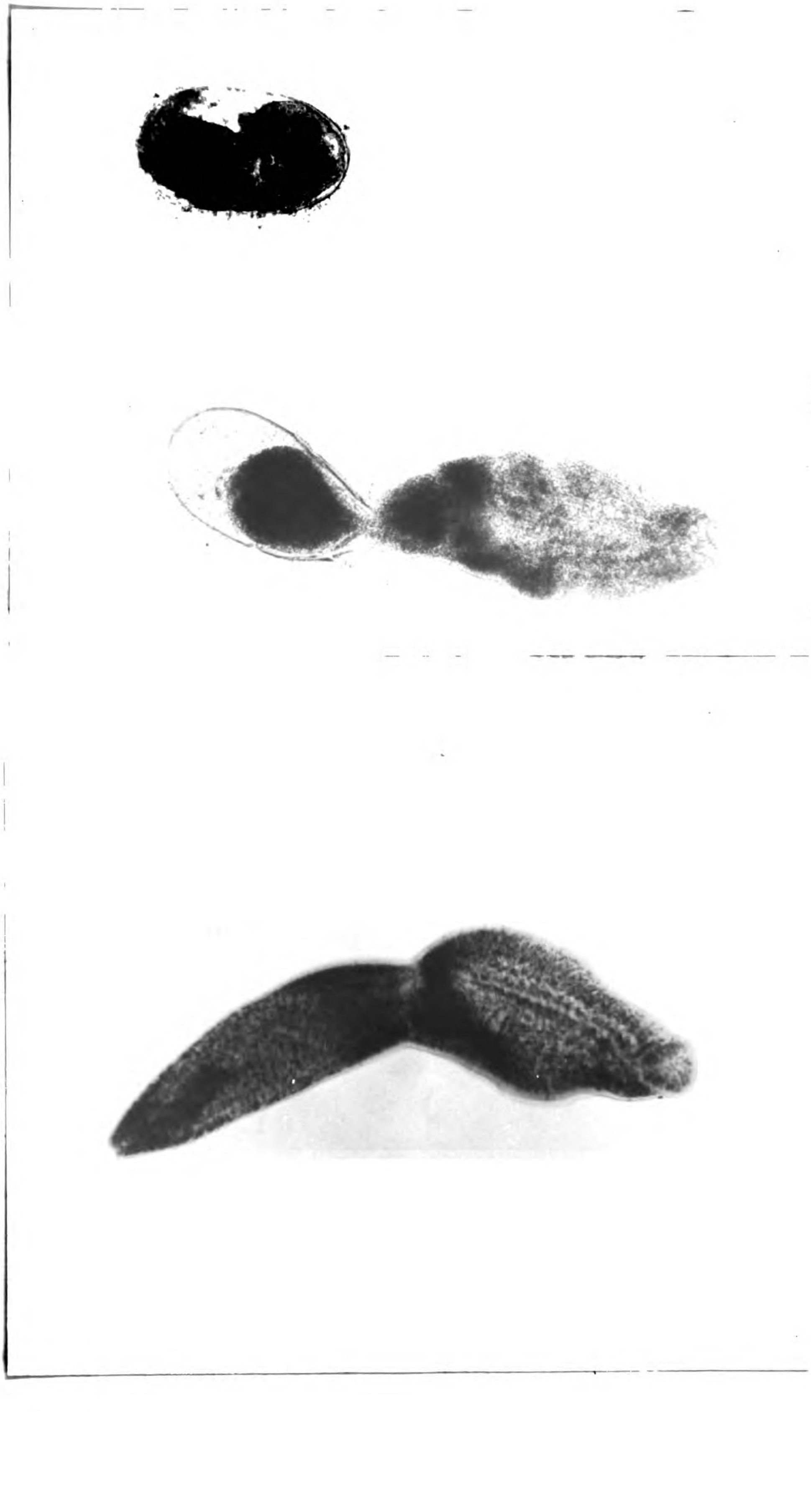
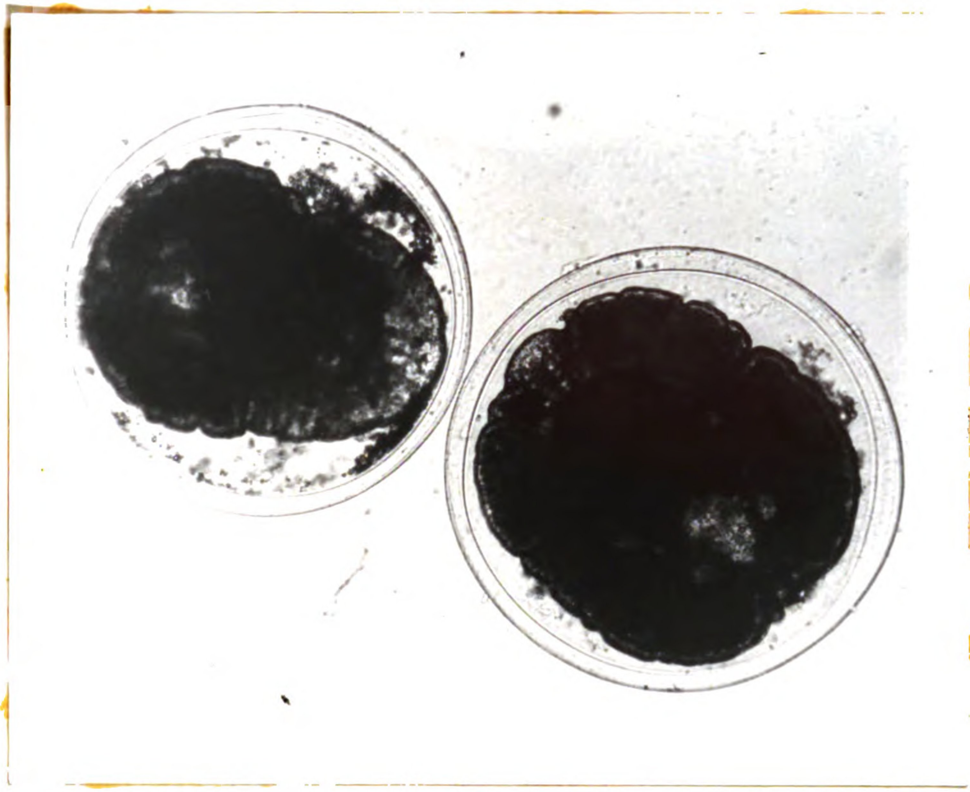


Figure 5. Unknown strigeid in cyst, (natural size about 300 microns).

Figure 6. Same strigeid as in Figure 5 free from cyst, (natural size about 600 microns long).



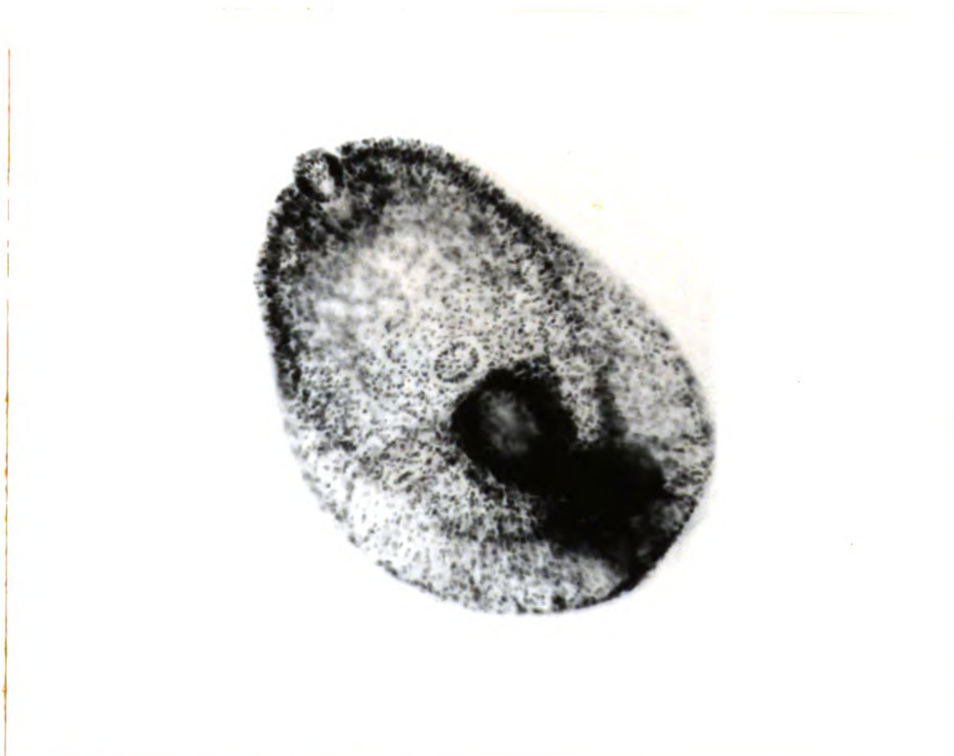
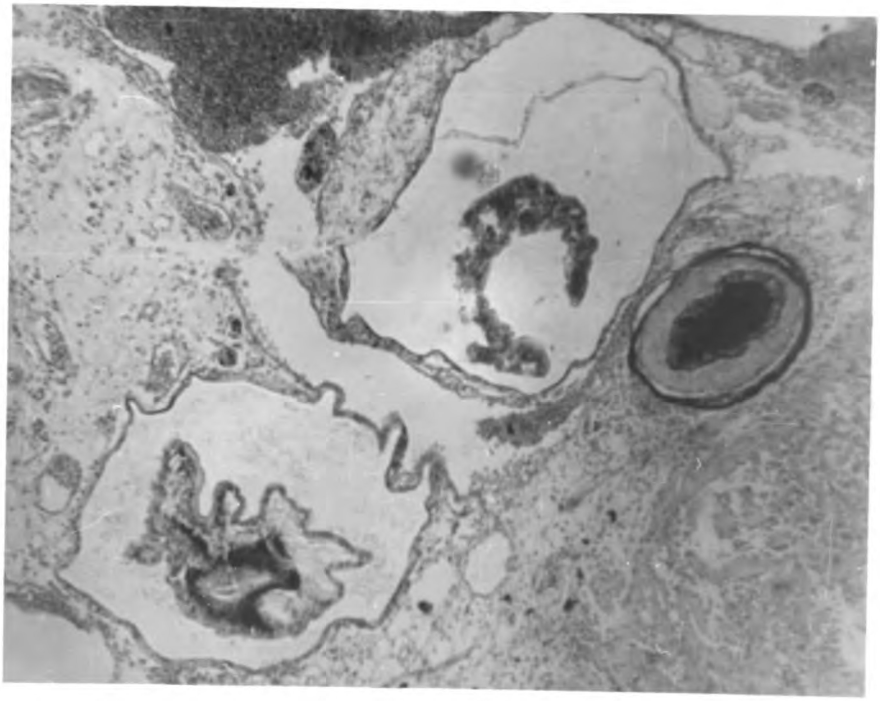


Figure 7. Section through the heart of a green sunfish containing three cysts of *Posthodiplostomum minimum*.

Figure 8. Metacercaria of *Posthodiplostomum minimum*, (natural size about 1 mm. long).



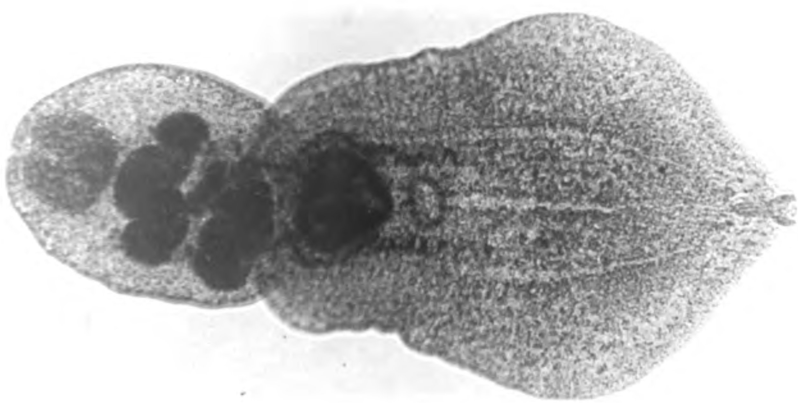
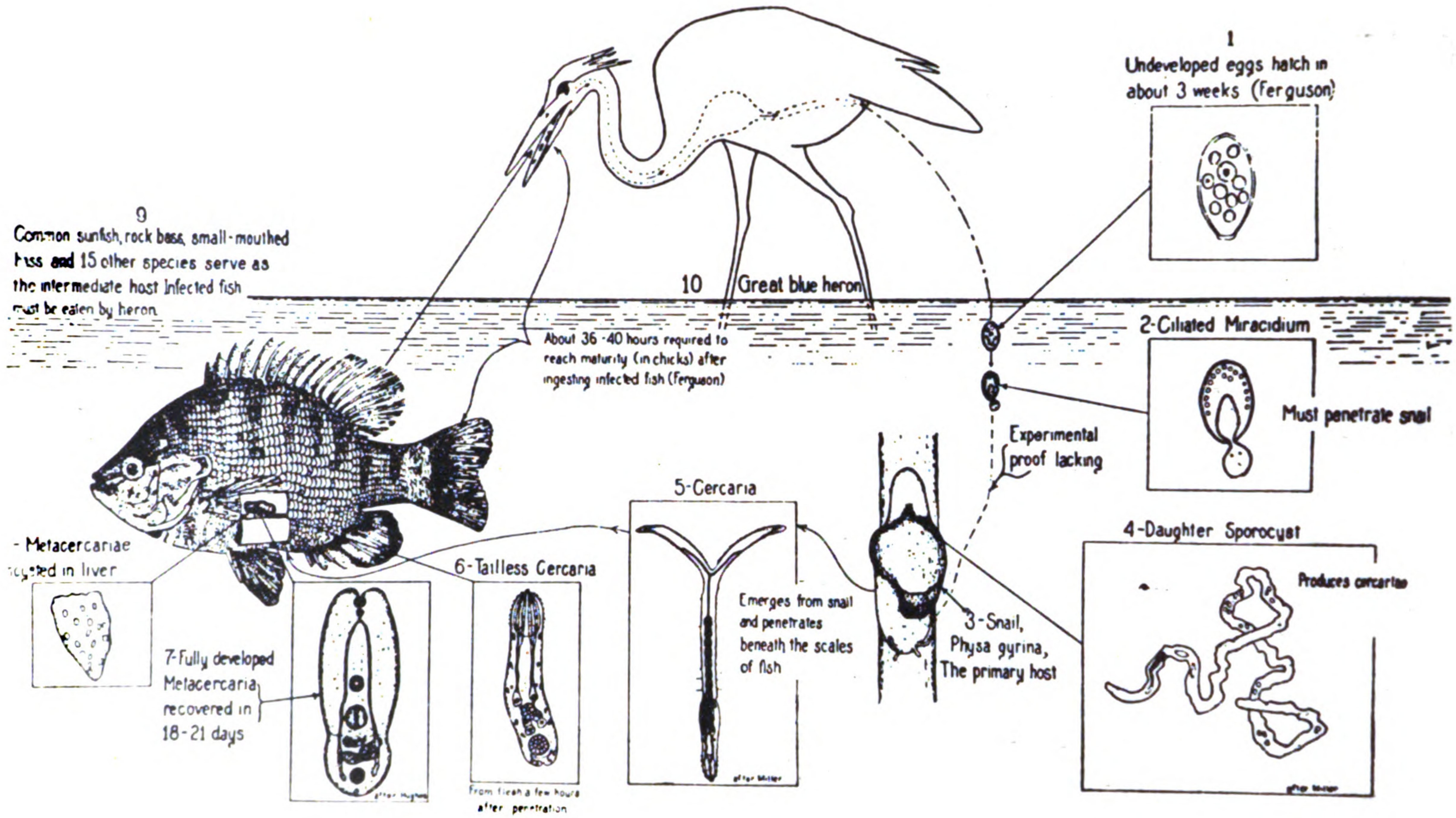


Plate IV. The life cycle of the white grub of the liver (*Postho-diplostomum minimum*) (Hunter, 1937).


1
Undeveloped eggs hatch in about 3 weeks (Ferguson)
2-Ciliated Miracidium
Must penetrate snail
Experimental proof lacking
3-Snail, Physa gyrina, The primary host
4-Daughter Sporocyst
Produces cercariae
5-Cercaria
Emerges from snail and penetrates beneath the scales of fish
6-Tailless Cercaria
From flesh a few hours after penetration
7-Fully developed Metacercaria recovered in 18-21 days
- Metacercariae cysted in liver
9
Common sunfish, rock bass, small-mouthed bass and 15 other species serve as the intermediate host Infected fish must be eaten by heron
10
Great blue heron
About 36-40 hours required to reach maturity (in chicks) after ingesting infected fish (Ferguson)

around the digestive gland of the Physa. The daughter sporocyst can be seen in Figure 9 and the fork-tailed cercaria in Figure 10.

Sillman (1957) reported at least 500 to 600 cysts in each of the livers of two common sunfish and one rock bass. The metacercariae were packed together so closely that one would believe that scarcely any functional tissue remained. However, the fish did not appear to suffer any distress over a period of several months prior to autopsy. Allison (1950) reports that the white liver grub may be more detrimental to fish than the other strigeids since they infect vital organs. Fish may be infected with great numbers of these worms without apparent detrimental effects. However, adverse environmental conditions may cause such fish to be less resistant than normal fish.

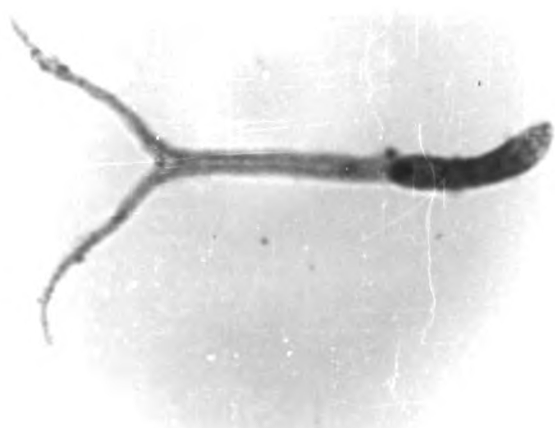
Class Cestoidea
Order Caryophyllidea
Family Caryophyllidae
Garidacres confusus Hunter, 1929

Host - Catostomus commersoni

One specimen was taken from the intestine of a common sucker. The caryophyllidids are small single segmented tapeworms. Garidacres confusus ranges from 3 mm to 7 mm in size (Van Cleave and Mueller, 1934). Hunter (1927) gives the life cycle of the Caryophyllidae: The egg or larva reaches the digestive tract of a tubificid worm and bores into the body cavity. The larva at this stage may possess a caudal vesicle. After a period of development in the tubificid, the larva is ready to infect the definitive host. Upon reaching the digestive tract of the host, the caudal vesicle is lost and the parasite matures.

Figure 9. Daughter sporocyst from Physa gyrina, (150 X natural size).

Figure 10. Fork-tailed cercaria from Physa gyrina, (length about 490 microns).



Order Proteocephala
Family Proteocephalidae
Proteocephalus ambloplitis (Leidy, 1887)

Hosts - Micropterus dolomieu, Perca flavescens and Lepomis cyanellus

The sexually mature stage of the bass tapeworm Proteocephalus ambloplitis was found in the caeca and intestine of smallmouth bass. Two of the bass examined had at least one adult tapeworm. Adults of this genus have a dorsal ventrally flattened head, circular or oval suckers, testes in a broad field between vitellana, parenchyma with close meshes, musculature well developed, and eggs in three membranes. They lack a rostellum, hooks, and a fold of tissue encircling the base of the head (Van Cleave and Meuller, 1934). The scolex of the mature bass tapeworm can be seen in Figure 11. According to Wardle and McLeod (1952) Proteocephalus ambloplitis eggs escape from the gravid proglottids by way of a median ventral slit (Figure 12).

The life cycle (Plate V) of the bass tapeworm has been investigated by Bangham (1927), Hunter (1928), and Hunter and Hunter (1929). Other fish which also serve as the definitive host for the bass tapeworm are: Largemouth bass (Micropterus salmoides), rock bass (Ambloplites rupestris), eastern burbot (Lota lota), bowfin (Amia calva), and the yellow perch (Perca flavescens) (Morrison, 1957). The yellow perch of Lake Manitou were not found to be serving as the final host of the bass tapeworm.

The procercoid larva of the bass tapeworm can use a number of crustaceans as first intermediate host. Bangham (1927) found Hyalella knickerbockeri serving as a host, and Hunter (1928) found that Cyclops

Figure 11. Scolex of *Proteocephalus ambloplitis* (adult), (about 40 X natural size).

Figure 12. Proglottids of mature bass tapeworm showing ventral slit, (about 20 X natural size).

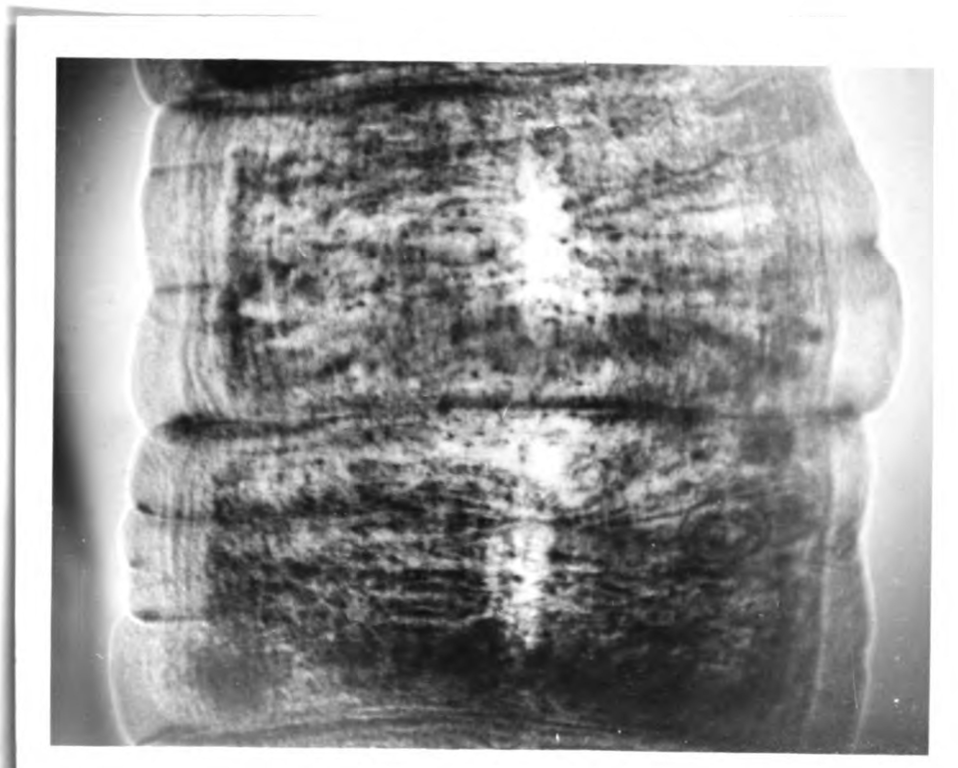
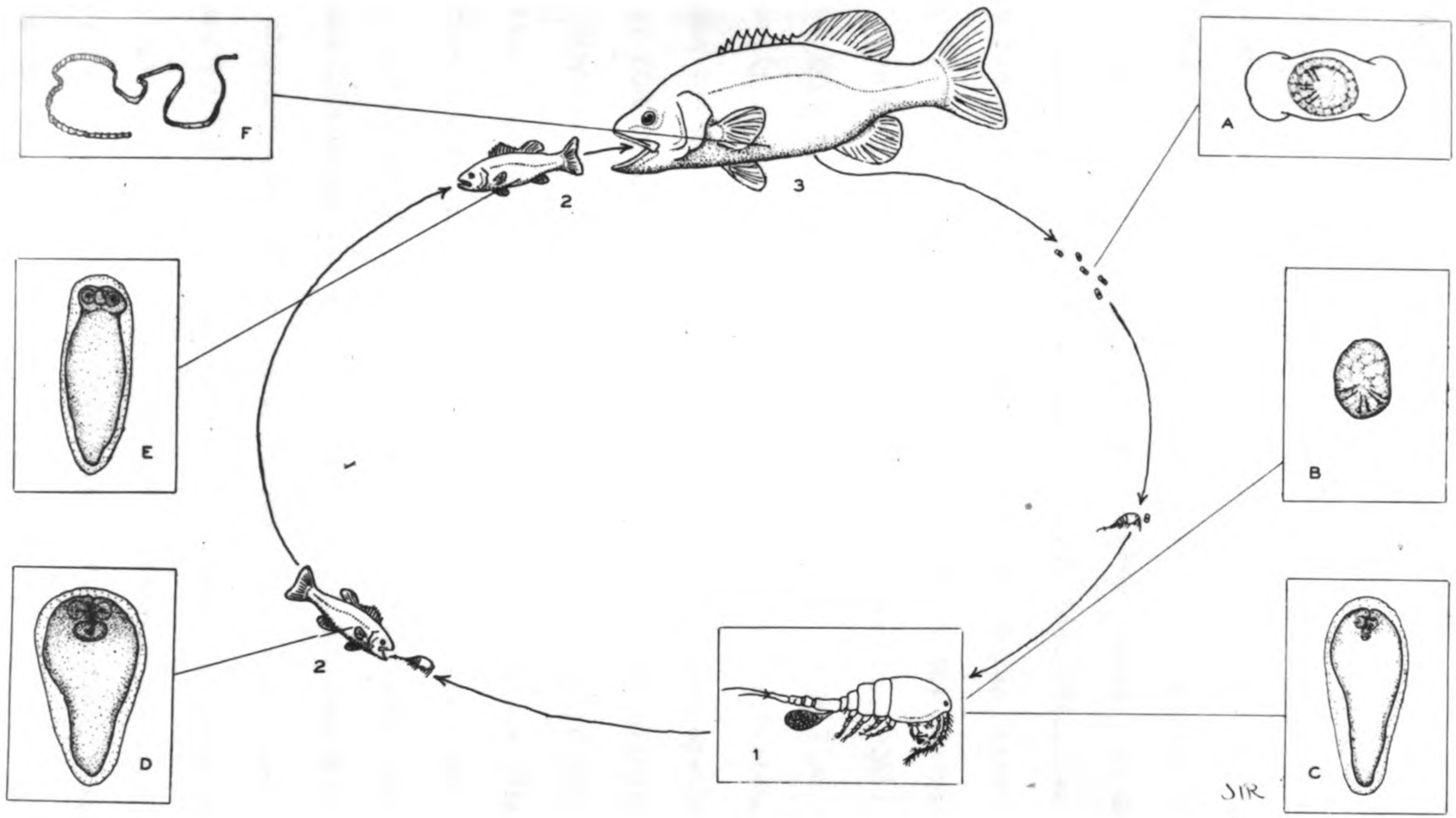


Plate V. Life cycle of bass tapeworm (Proteocephalus ambloplitis): A, dumbbell-shaped egg containing six-hooked (hexacanth) larva, before being ingested by copepod; B, hexacanth larva, after escaping from the outer hyaline, dumbbell-shaped membrane, within digestive tract of copepod; C, procercoid larva within body cavity of copepod; D, encysted plerocercoid larva within body cavity of fish; E, later stage of same; F, adult worm within intestine of smallmouth bass. Numbers 1, 2 and 3 indicate first, second and third or final hosts respectively (Meyer, 1954).


F
3
2
A
E
B
D
2
1
C
JIR

prasinus, Cyclops albidus and Cyclops leuckarti are also first intermediate hosts.

The pleroceroid larva of Proteocephalus ambloplitis which develops in the fish after a crustacean containing a procercoid larva is eaten was the most damaging fish parasite collected. The plerocercoid migrates to the liver, spleen, kidneys, gonads and body lining. It then goes through a period of development and encysts. Identification of the bass tapeworm plerocercoid is based on the presence of the fifth sucker (Figure 13). The fifth sucker is very evident in the plerocercoid larva and may even persist for a time in the adult (Hunter, 1928). Plerocercoid larvae of Proteocephalus ambloplitis ranged from .5 to 7 cm in length.

Heavily infected fish can be recognized by their "pot-bellied" appearance and matted resilience of the viscera. Upon opening the body cavity of fish it was very common to find the viscera clinging to the body wall by fiberous adhesions. The organs of these heavily infected fish were matted together and very difficult to differentiate (Plate 1). The pleroceroid larvae in the smallmouth bass and green sunfish were generally near the surface of the infected organ. In heavily infected fish they were found throughout the tissues. Sections of smallmouth bass viscera show an abnormal mass of connective tissue around the intestine, liver, gonads and pyloric caeca. Lesions caused by the migrating larva can be seen in Figure 14. The testes of several bass were examined during the spring of 1959. They showed a narrow band of functional tissue in the center of the organ. Ovaries had a few eggs in them, but due to the damage, it is doubtful they could have spawned.

Figure 13. Larval stage (plerocercoid) of *Proteocephalus ambloplitis* with characteristic fifth sucker, indicated by arrow, (about 20 X natural size).

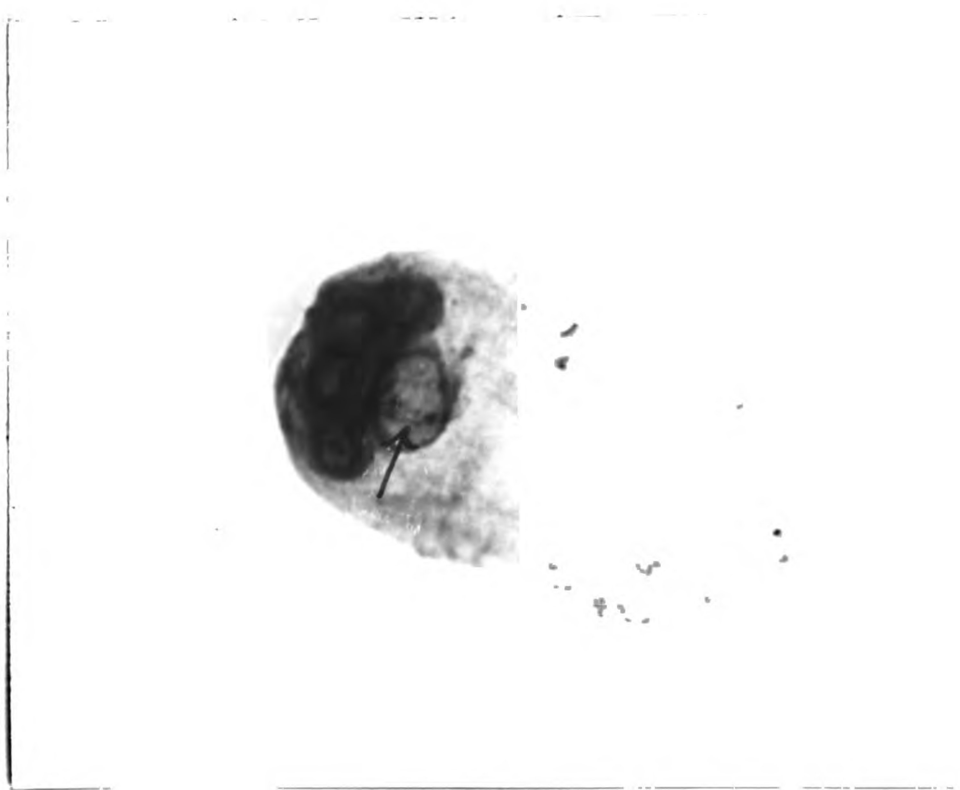


Figure 14. Section through the viscera of a smallmouth bass showing anterior end of a plerocercoid and adjacent damaged area. Large oval in larva is fifth sucker.

Damage in the centrarchids, based on histological evidence, seems to be very extensive to the vital organs. However, these fish do not show any external effects of the parasitism other than the apparent plumpness of the smallmouth bass. The growth rates of the smallmouth bass from Lake Manitou compare favorably with growth rates of smallmouths taken during a survey of 400 Michigan lakes (Beckman, 1946). The bass fought well on hook and line. There was no evidence that parasite infection had reduced the sporting qualities for which the smallmouth bass is well known.

The perch of Lake Manitou showed a different reaction to the pleroceroid larvae than shown by the smallmouth bass and the green sunfish. In the perch the cyst which was formed by the larvae was round and white. Cysts were commonly found in the liver and scattered throughout the mesentaries of the viscera. These cysts, unlike those found in the centrarchids, had a definite cyst wall that separated the larva from the surrounding host tissue. It is believed that this type of cyst in perch retards the growth of the tapeworm larva (Bangham, 1941). Perch, even though heavily infected, did not show the internal damage that was shown by the centrarchids of Lake Manitou.

Phylum Acanthocephala
Class Metacanthocephala
Family Rhadinorhynchidae
Leptorhynchoides thecatus (Linton, 1891)

Hosts - Micropterus dolomieu, Lepomis cyanellus, Perca flavescens and Cottus bairdi .

Leptorhynchoides thecatus was found in the pyloric caeca and intestine of the host fishes. The anterior region of the thorny-headed worm is provided with a specialized attachment organ known as the proboscis. The proboscis is capable of eversion and retraction into the anterior end of the body, and its surface bears numerous rows of recurved hooks which provide secure attachment for the worm (Figure 15). Meyer (1954) reported ulcer-like lesions and conspicuous areas of laceration and inflammation in the intestinal wall of the host caused by the proboscis. Venard and Warfel (1953) were unable to find sections where the proboscis remained attached. They attributed this to the retraction of the proboscis while the parasite was being killed with the preservative. However, they did find areas in the pyloric caeca where the mucosa and submucosa were completely disturbed and contained fragments of epithelium as isolated clumps of columnar epithelial cells. This cellular debris was also heavily infiltrated with erythrocytes and leucocytes.

Stained sections of smallmouth bass viscera from Lake Manitou showed a similar condition. Photographs of lesions produced by the proboscis in the pyloric caeca of smallmouth bass can be seen in Figure 16. In addition to the direct damage, Acanthocephala provide avenues for secondary infections by bacteria and protozoa.

The life cycle of Leptorhynchoides thecatus is presented in Plate VI. It is interesting to note that if the amphipod containing acanthellas or cystacanths are eaten by hosts incapable of bringing them to maturity, they become secondarily encysted and are known as juveniles. Then when the fish containing the juvenile is eaten by the proper final host, the worm attains sexual maturity (Van Cleave and Mueller, 1934).

Figure 15. A mature female of Leptorhynchoides thecatus with spindle-shaped eggs filling most of the body cavity, (natural size 12 mm. long).

Figure 16. The proboscides of several spiny-headed worms are shown deeply imbedded in the mucosa and submucosa of the pyloric caeca in a smallmouth bass.

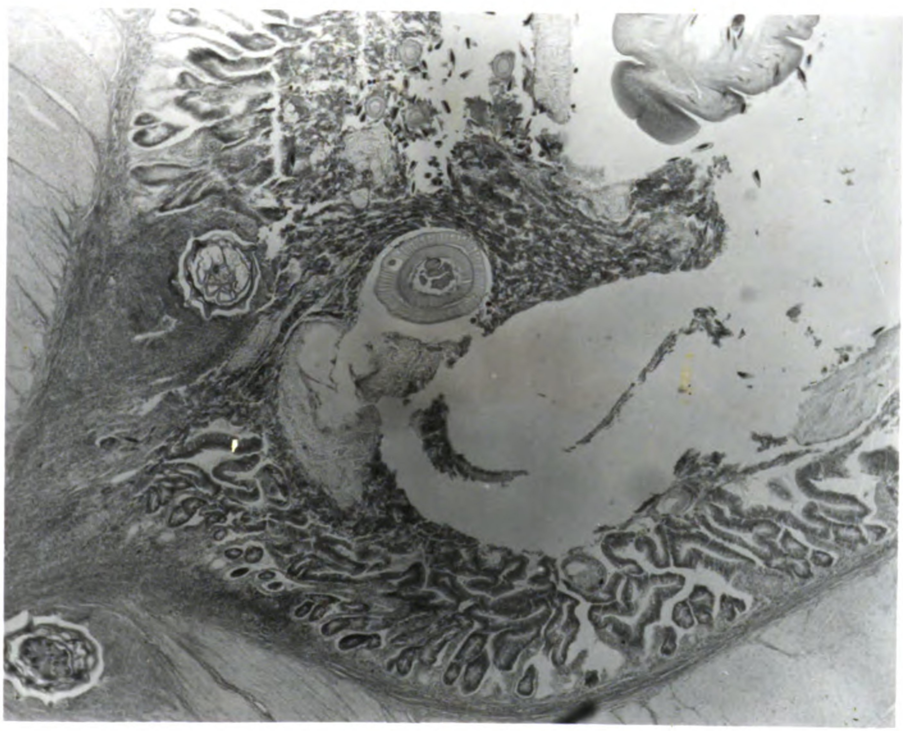
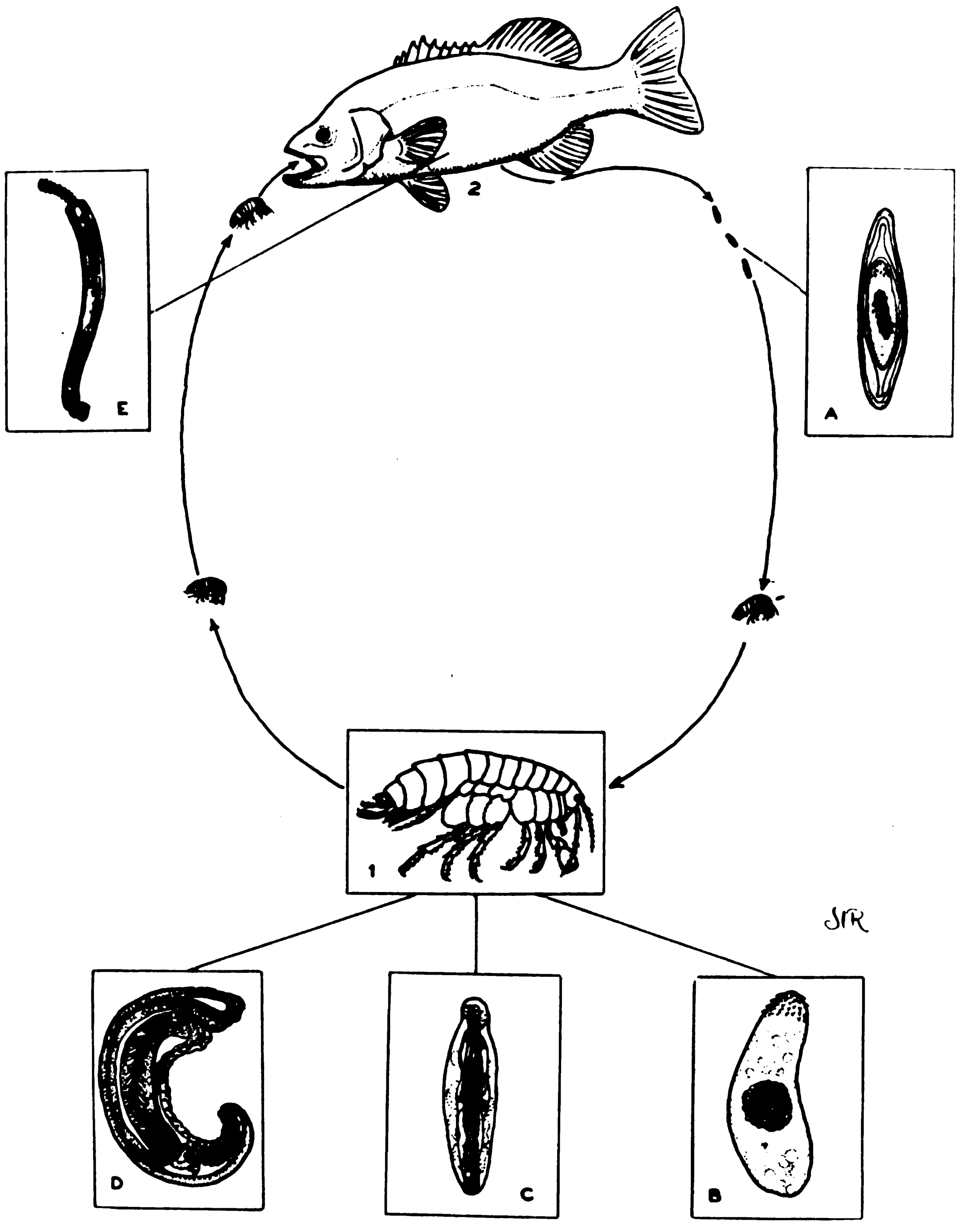


Plate VI. Life cycle of thorny-headed worm (*Leptorhynchoides thecatus*): A, egg containing larva (acanthor), before being ingested by amphipod; B, acanthor, after escaping from embryonic membranes within the digestive tract of amphipod; C, acanthella within body cavity of amphipod; D, cystacanth, later stage within body cavity of amphipod; E, adult worm within intestine of smallmouth bass. Numbers 1 and 2 indicate intermediate and final hosts respectively (Meyer, 1954).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Family Echinorhynchidae
Pomphorhynchus bulbocolli (Linkins, 1919)

Hosts - adult in *Micropterus dolomieu*, *Catostomus commersoni*, and *Cottus bardi* .

Pomphorhynchus bulbocolli was found in the pyloric caeca and upper intestine of the smallmouth bass, common sucker and northern sculpin. The worm is distinguished by the presence of a long cylindrical neck with a large spherical bulb near the distal end (Figure 17). This bulb serves as a secondary attachment organ. Tissues of the host growing around the bulb together with the spiny proboscis securely anchor the worm.

The common suckers in Lake Manitou were severely infected with *Pomphorhynchus bulbocolli*. The caeca and upper intestine of the sucker had well over 100 of the bright orange adults. They were so deeply imbedded that the bulb and proboscis extended through the digestive tract and were covered only by a thin outer layer of the gut. The smallmouth bass and northern sculpin had light infections of *Pomphorhynchus bulbocolli*.

The pathology connected with this spiny-headed worm is similar to that of *Leptorhynchoides thecatus*. The life cycle is also believed to be similar.

Phylum Nemathelminthes
Class Nematoda
Order Camallanidea
Dichelyne cotylophora (Ward and Magath, 1917)

Host - *Perca flavescens*

Dichelyne cotylophora was found in the intestine of yellow perch.

Figure 17. Pomphorhynchus bulbocolli, entire female, (natural size 15 mm. in length).

Mature females are about 5 mm long and the males are slightly shorter (Figure 18). Van Cleave and Mueller (1934) found a high incidence of *Dichelyne cotylophora* in the yellow perch of Oneida Lake. Only one yellow perch was found infected in Lake Manitou, but others may easily have been overlooked because of their size and color. No apparent pathology was noted as being due to the infection of this round worm. However, they may injure the host by tearing the wall of the intestine and in this way provide areas where protozoa and bacteria can secondarily infect. The life cycle of this species is unknown.

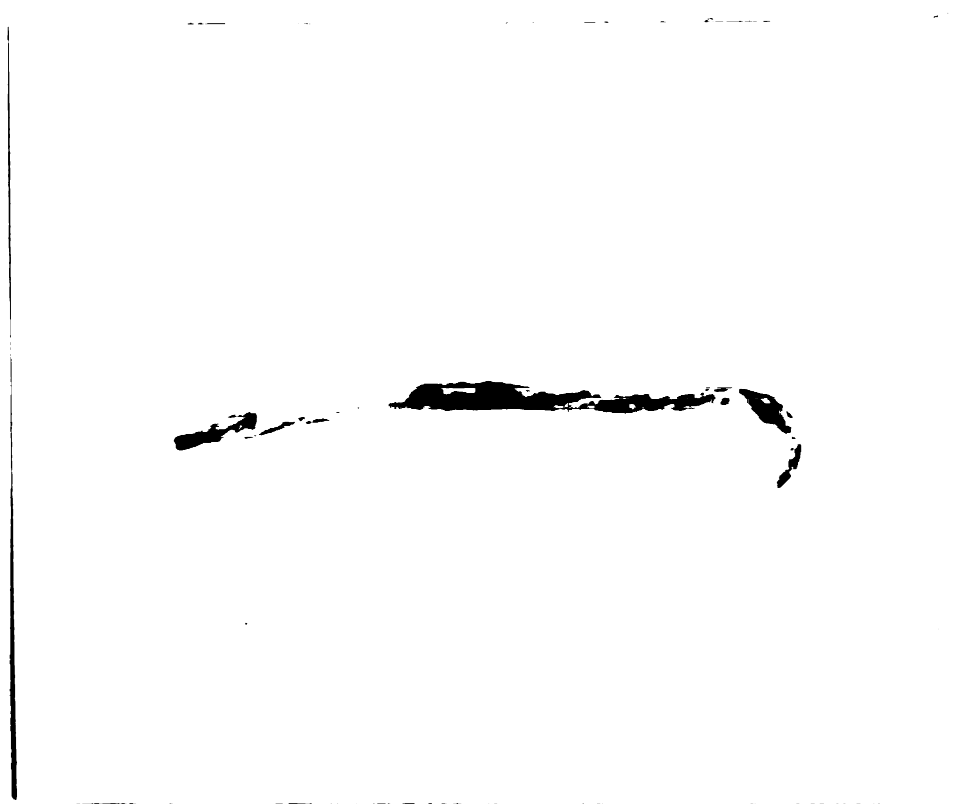
Order Dracunculoidea
Family Philometridae
Philometra cylindracea (Ward and Maganth, 1917)

Host - *Perca flavescens*

Philometra cylindracea was taken from the body cavity of yellow perch. The female worm is about 10 cm. long, reddish in color and a common parasite of yellow perch. No males were found. Van Cleave and Mueller (1934) report the male of this species is unknown, probably very minute. *Philometra cylindracea* is not a common parasite of the fish of Lake Manitou; only one yellow perch was found to be infected.

The life cycle of this species is not definitely known but life cycles of other members of the genus *Philometra* are known, and *Philometra cylindracea* is perhaps similar. Chitwood and Chitwood (1950) report two species of the genus *Philometra* using *Cyclops* as the intermediate host, then after a developmental period in *Cyclops*, the larva can infect the final host when the infected *Cyclops* is eaten.

Figure 18. Male of Dichelyne cotylophora from perch, (natural size 4.8 mm. long).



Phylum Protozoa
Class Sporozoa
Order Myxosporidia

Hosts - Lepomis cyanellus and Perca flavescens

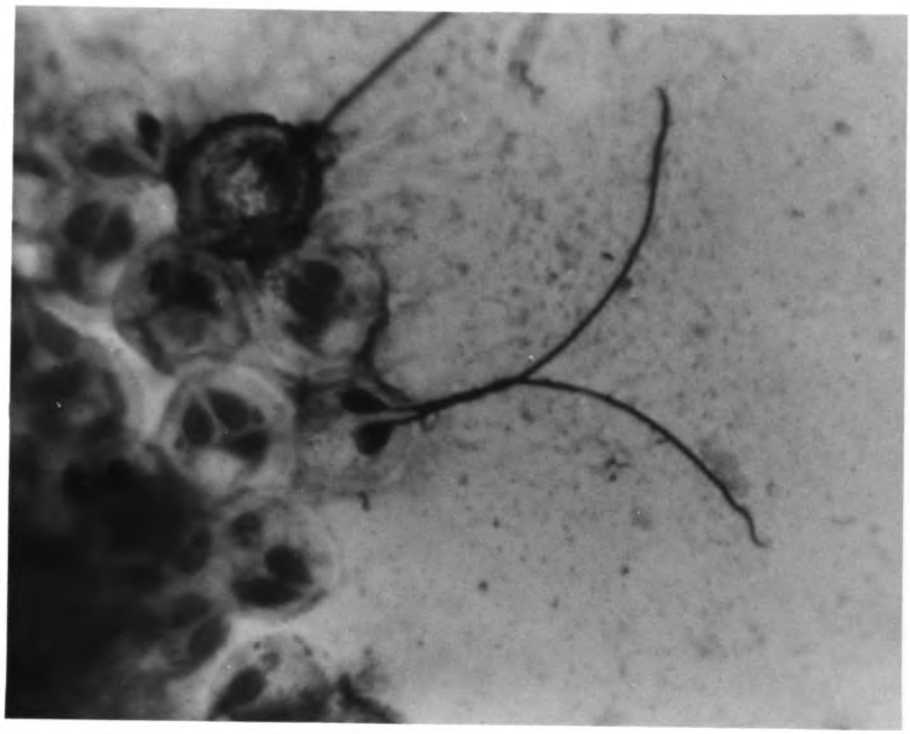
The Myxosporidia parasites of Lake Manitou fishes were found in the internal organs of the yellow perch and green sunfish. The hearts of two perch were covered with whitish cysts or pustules of Myxosporidia. Examination of a smear of this tissue revealed developing spores of Myxosporidia (Figure 19).

The cyst in the green sunfish was in the mesentaries next to the intestines. According to Kudo (1947) Myxosporidia infect almost all kinds of tissue and organs of the host, but each species has its special site of infection in the host fish.

The generalized life cycle of the Myxosporidia as described by Kudo (1947) is as follows:

> A spore gains entrance into the digestive tract of a specific host fish, the sporoplasm leaves the spore as an amoebula which penetrates through the gut-epithelium and, after a period of migration, enters the tissues of certain organs where it grows into a trophozoite at the expense of the host tissue cells and the nucleus divides repeatedly. Some nuclei become surrounded by masses of dense cytoplasm and become the sporonts. The sporonts grow and their nuclei divide several times, forming 6-18 daughter nuclei, each with a small mass of cyloplasm. The number of the nuclei thus produced depends upon the structure of the mature spore, and also upon whether 1 or 2 spores develop in a sporont. When the sporont develops into a single spore, it is called a monosporoblastic sporont, and if two spores are formed within a sporont, which is usually the case, the sporont is called disporoblastic, or pansporoblast. The spore-formation begins usually in the central area of the large trophozoite, which continues to grow. The surrounding host tissue becomes degenerated or modified and forms an envelope that is often large enough to be visible to the

Figure 19. Myxosporidia spores with extruded polar filaments, (approximately 2200 X natural size).



naked eye. If the site of infection is near the body surface, the large cyst breaks and the mature spores become set free in the water. In case the infection is confined to internal organs, the spores will not be set free while the host fish lives. Upon its death and disintegration of the body, however, the liberated spores become the source of new infection.

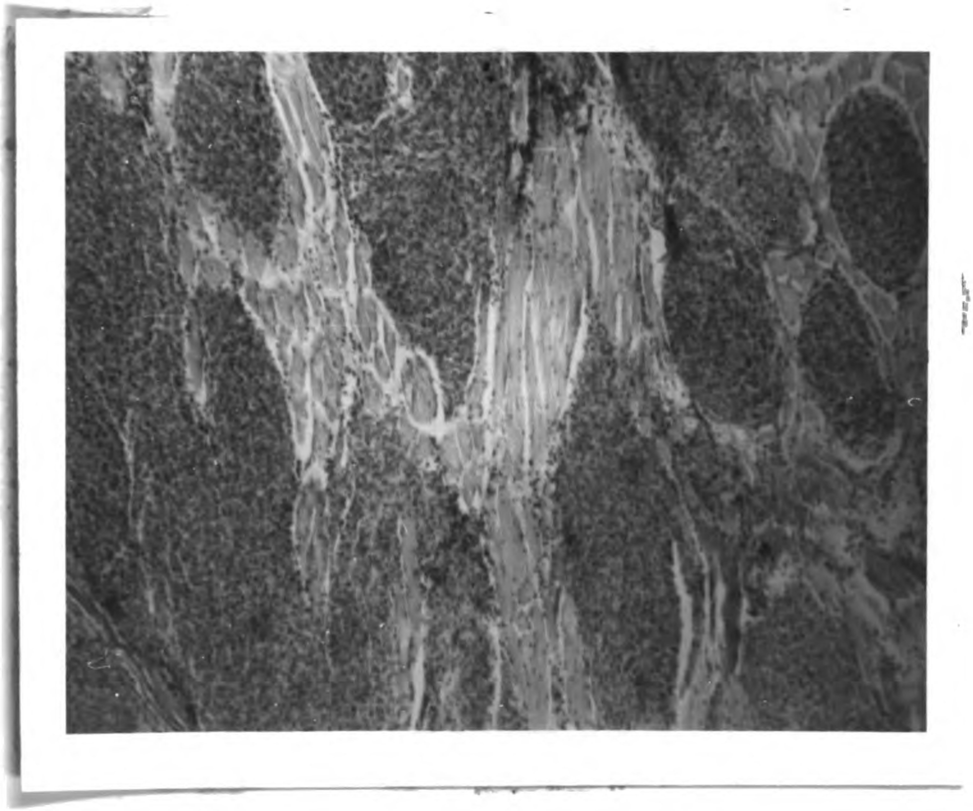
Order Microsporidia

Host - Perca flavescens

Microsporidia are parasites of various animals, but typically parasites of arthropods and fishes. The spore is quite small, usually measuring 3 to 6 microns long (Kudo, 1947). Slides of abnormal appearing tissue removed from the musculature of a yellow perch revealed the area was infected with a microsporidian. The Microsporidia had invaded this area and destroyed most of the host tissue over an extensive area (Figure 20). A normal section from a similar area in an uninfected fish would show mostly muscle fibers, but in this area of the infected fish the muscle had all been destroyed by the invading microsporidian.

The life cycle of a microsporidian is described by Kudo (1947): The spores are taken into the digestive tract of the host, the polar filaments extrude and anchor the spores to the wall of the intestine. The sporoplasms emerge through the opening after the filaments become detached, penetrate the intestinal epithelium, enter the blood stream or body cavity and reach the site of infection. They then enter the host cells and undergo multiplication. The trophozoites become sporonts, each producing many spores. These spores, depending upon the species, may be capable of germinating in the same host body, thus increasing the

Figure 20. Section of yellow perch muscle heavily infected with Microsporidia.



number of infected cells. Heavy infections are fatal because of the degeneration of enormous numbers of cells.

CONTROL OF INTERNAL PARASITES

The form of control used for internal parasites of fishes involves breaking of the life cycle at one point. The snail offers a vulnerable point in breaking the life cycle of the Trematoda. By destruction of the snail host the life cycle is effectively broken and further infection of the fish host is impossible. According to Meyer (1954), snails play an important role in the food chain of aquatic organisms and removal of snails may upset the entire balance of the lake. These consequences should be considered first before disturbing nature's balance. Control of a trematode parasite would demand complete extermination of snail intermediate hosts, and extermination of any animal is a task not to be taken lightly.

Calcium hypochlorite, chlorine gas, copper sulfate and copper carbonate are some of the common chemicals used to kill snails. Davis (1956) described two methods of removing snails in small ponds that can be drained in one day. The first is for a small pond rich in organic matter. The pond is first drained, then the bottom and sides thoroughly washed with stream water. This dislodges the snails and washes away much of the organic matter in which snails could hide. Water is then let back into the pond, treated with chlorine until a concentration of 10 p.p.m. is reached, allowed to stand overnight, drained and then refilled. The second treatment is for a pond with a gravelly bottom and clean water supply. The pond is drained and calcium hypochlorite (HTH) sprinkled into the water intake until the chlorine concentration in the pond reaches 10 p.p.m.

Larger bodies of water can be treated with copper sulfate, copper carbonate and copper ores. The Michigan Water Resources Commission, previously known as the Stream Control Commission, has used copper compounds to kill snails for the prevention of swimmer's itch. Swimmer's itch or water itch is caused by the cercaria of certain blood flukes, Schistosomatidae, that penetrate the skin of swimmers. They may or may not cause an itching rash depending upon prior invasion, sensitization or immunity. Usually bathers become more sensitized by repeated exposures (Chandler, 1952). A publication of the Michigan Stream Control Commission (1940) recommends one pound of copper carbonate and two pounds of copper sulfate per 1,000 square feet of bottom to be treated. Desired amounts of the chemicals can be dissolved in a drum or barrel and dispersed over a given area by siphoning the solution overboard. The copper compound mixture being heavier than water settles to the bottom, and does not disperse evenly through the treated area. This actually concentrates the toxic copper ions near the bottom where the snails are found. For this reason it is best to treat lakes on calm days or in areas where there is a slight onshore wind. This reduces rapid dispersion of chemicals and allows toxic concentrations of copper ions to be in contact over a longer period with the snails. Only shallow areas that snails are known to populate need be treated, the deeper areas having practically no snail populations.

A complete kill of the snail population with one treatment is practically impossible because some are able to leave the water while still others burrow deeply into the mud where chemicals fail to reach them. Therefore, two treatments - one in the spring and another in the fall - are necessary.

Control of tapeworms in infected natural populations of fishes has not proven successful. Miller (1952) has attempted to control *Triaenophorus crassus* in certain Canadian lakes. The sexually mature stage infects the northern pike (*Esox lucius*), the procercoid is found in *Cyclops bicuspidatus*, and the plerocercoid in ciscoes (*Leucichthys*) and whitefish (*Coregonus clupeaformis*). The plerocercoid is sometimes so abundant in the whitefishes, they cannot be marketed. Three methods of control attempted by Miller (op. cit.) were: (1) Killing the free swimming larvae (coracidia) by acidifying the lake, proved unsuccessful; (2) drastic reduction in the tullibee (*Leucichthys*) population, achieved a partial control; and (3) reduction of the northern pike population, which was not practical because of the ability of the northern pike to repopulate rapidly and also the high cost of operation. Miller (op. cit.) believed a long period of research to be necessary to conquer the problem.

Another approach to the problem would be destruction of the first intermediate host. Known intermediate hosts in the life cycle of *Proteocephalus ambloplitis* are *Hyalella knickerbockeri*, *Cyclops prasinus*, *Cyclops albidus*, and *Cyclops leuckarti*. Hunter and Hunter (1934) destroyed *Cyclops* in ponds by dessication and freezing. However, this method of control is limited to areas that can be drained and restocked with uninfected fish.

There are possibilities of controlling the microcrustacean populations in lakes by the addition of chemicals. Brown and Ball (1943) noted

Cyclops showed a sharp decline immediately following the rotenone poisoning in Third Sister Lake, Michigan. Dr. R. C. Ball, Department of Fisheries and Wildlife, Michigan State University, (personal communication) believes rotenone may be used in concentrations toxic to *Cyclops* but not toxic to fish. However, Bertil G. Anderson, Department of Zoology and Entomology, Pennsylvania State University, (personal communication) believes the difference in toxicity of rotenone is so small that it would be impossible to kill *Cyclops* without killing fish. The exact toxic concentration of rotenone for *Cyclops* is not known and if it were it would be difficult to apply uniformly in low concentrations.

The control of *Cyclops* in lakes should reduce the infection of the plerocercoid larva in the fishes. If *Cyclops* could be kept out of the lakes by two or three rotenone treatments per year over a period of four or five years, it seems the bass tapeworm or any other parasite that uses *Cyclops* in its life cycle could be drastically reduced or eliminated. The disadvantages to this method of treatment would be the expense involved in several treatments and the long duration over which it must take place.

The most widely used method of tapeworm control at the present time is complete reclamation of the lake. Hooper (1955), in a publication of the Michigan Department of Conservation, gives a method of fish eradication by rotenone. Toxaphene (chlorinated camphene) in the past few years has proven a useful management tool in removing fish populations. The use of toxaphene is described by Hooper and Grzenda (1955).

By removing all the fish the adult and plerocercoid stages of the tapeworm are eliminated. If rotenone is the toxicant used, the Cyclops would also be killed thus removing most of the procercoid stages. In time the microcrustaceans would become free of the procercoid stage since there would be no tapeworm eggs to feed on. The reclaimed lake could then be restocked with non-parasitized fish.

The possibility of stocking the reclaimed waters with species of fish not infected by bass tapeworm should be considered. For example, Lake Manitou may prove to be suited for trout. But only after a mid-summer survey involving water chemistry, dissolved oxygen and temperature at all depths can this be determined. If the waters are not suited for cold water species, warm water species will have to be used in the re-stocking. Morrison (1957) suggests the possibility of capturing small bass fry as they rise from the nest and using them to restock the re-claimed lake. These fish would just be completing the absorption of the yolk sac, thus, will not have begun to feed and would be free of any bass tapeworm.

Once waters are free from infection with bass tapeworm, action should be taken to prevent reintroduction of the parasite. The use of all bait and the indiscriminate transfer of fish from other bodies of water which might be infected should be prohibited.

The control of Acanthocephala and Nematoda would be similar to that of the bass tapeworm, since both of these parasites have larval stages that infect microcrustaceans. Any attempt to control the bass tapeworm would also be an adequate control for these parasites in fishes. Insofar as can be determined, there have been no attempts to control Myxosporidia or Microsporidia infections. The fact that they, for the most part, are tissue parasites makes them very difficult to treat (Davis, 1956).

SUMMARY

A serious parasite problem has manifested itself in Lake Manitou, North Manitou Island, Michigan. During the fall of 1958 and spring of 1959 fishes from the lake were examined for parasites. Of the 67 fishes examined, representing five species, not a single fish was found to be free of parasites.

Undoubtedly the most harmful of the fish parasites found in Lake Manitou is the bass tapeworm. In the smallmouth bass, yellow perch and green sunfish the plerocercoid larva of the bass tapeworm was present and produced considerable damage to body tissues and organs. Plerocercoids cause a pot-bellied appearance in the heavily infected smallmouth bass and give internal organs a hard resiliance. The migrating larvae cause inflammation, bloody areas, and fibrous adhesions, thus the reproductive organs are not able to function properly and the fish may be rendered sterile. The plerocercoids of the bass tapeworm do similar damage in the green sunfish and the yellow perch, although the yellow perch does not seem to be affected as seriously as the centrarchids. The adult bass tapeworm was found in only two of the smallmouths.

Proteocephalus ambloplitis was not found in two species of fish, the common sucker and the northern sculpin, due perhaps to their feeding habits and the fact that they both tend to occupy deeper water in which *Cyclops* and *Hyalella* are not abundant.

The Acanthocephala were perhaps the next most damaging parasites

to the fishes, causing considerable damage, particularly to the digestive tracts of the fishes. Leptorhynchoides thecatus infected all the fishes of Lake Manitou except the common sucker. Pomphorhynchus bulbocolli was found primarily in the common sucker, one smallmouth bass and the northern sculpin. The proboscis of the Acanthocephala penetrates the wall of the pyloric caeca and upper intestine causing lesions and lacerations to the fish host. These lesions also provide direct avenues for secondary infection by protozoans and bacteria.

The trematode parasites, although very numerous in the fishes, did not seem to be doing any great harm. The yellow grub and various strigeids are present in the integument or musculature of the fish. They are quite easily noticed by the fisherman when present in the numbers found in the infected fish of Lake Manitou. The acceptability for table use of fish heavily infected with yellow grub and black spot is greatly reduced. The author would not consider eating fish as heavily parasitized as those from Lake Manitou even though it is realized that complete cooking destroys the viability of the parasites and that man cannot serve as a host. If black spot and yellow grub were controlled, the fishes would, after a period of time, be acceptable to most fishermen since they were the principal parasites found in the musculature of the fish.

The remaining internal fish parasites were not of major importance in the fishes of the lake, at least as far as could be determined. However, one must remember that under certain conditions the parasites that now seem unimportant can become a serious problem in a short period of time. The protozoa with their tremendous reproductive capacity often reach epidemic proportions rapidly. The Myxosporidia, for example, are generally believed to be non-pathogenic parasites present in most fish (Davis, 1955). They can be present in hatcheries and seemingly cause little or no damage. In other situations they completely destroy the entire fish population (Noble, 1950).

The control of parasites in natural fish populations is very complex and is usually dependent upon breaking the life cycle of the parasite by removing one of its intermediate hosts. Trematode parasites can be controlled by removal of the snails which are intermediate hosts. Possibly the bass tapeworm may be controlled by controlling the *Cyclops*, but this would be an extremely long-range program that might not show any appreciable effect until after a period of four or five years. The common approach is complete removal of the fish population and restocking with uninfected fishes. The control method selected for any parasite must be derived only after an extensive study of the waters and consideration of all possible consequences.

LITERATURE CITED

Allison, Leonard N.
1950. Common diseases of fish in Michigan. Mich. Dept. Conserv., Misc. Publ. No. 5, 27 pp.

Anonymous
1940. Water itch distribution in Michigan and observations on its control with application for assistance. Mich. Stream Control Comm., Misc. Publ., 18 pp.

Bangham, R. V.
1927. Life history of bass cestode, Proteocephalus ambloplitis. Trans. Amer. Fish. Soc. 57: 206-208.

Bangham, R. V.
1941. Parasites of fish of Algonquin Park Lakes. Trans. Amer. Fish. Soc. 70: 161-171.

Beckman, W. C.
1946. The rate of growth and sex ratio for seven Michigan fishes. Trans. Amer. Fish. Soc. 76: 63-68.

Brown, C. J. D. and Robert C. Ball
1943. An experiment in the use of derris root (rotenone) on the fish-food organisms of Third Sister Lake. Trans. Amer. Fish. Soc. 72: 267-284.

Chandler, Asa C.
1952. Introduction to parasitology. John Wiley & Sons, Inc., N. Y., 277-278.

Chitwood, B. G. and M. B. Chitwood
1950. An introduction to nematology. Monumental Print. Co., Baltimore, Md., 245.

Davis, H. S.
1956. Culture and diseases of game fishes. Univ. California Press, Berkeley, 225-250.

Ferguson, M. S.
1943. Experimental studies on the fish host of Posthodiplostomum minimum (Trematoda: Strigeida). Jour. Parasitol. 29: 350-353.

Fischthal, Jacob H.
1944. Grubs in fishes. Wisconsin Conserv. Bull. 9(5): 7-10.

Fischthal, Jacob H.
1953. Parasites of northwest Wisconsin fishes. IV. Summary and limnological relationships. Trans. Wisc. Acad. Sci. 42:83-108.

Hoffman, Glenn L.
1955. Neascus nolfi n. sp. (Trematoda: Strigeida) from cyprinid minnows with notes on the artificial digest recovery of helminths. Amer. Midl. Nat. 53:198-203.

Hoffman, Glenn L.
1956. The life cycle of Crassiphiala bulboglossa (Trematoda: Strigeida) development of the metacercaria and cyst and effect on the fish host. Jour. Parasitol. 42:435-444.

Hooper, F. F.
1955. Eradication of fish by chemical treatment. Mich. Dept. Conserv., Fish Div. Pam. No. 19, 6 pp.

Hooper, F. F. and A. R. Grzenda
1955. The use of toxaphene as a fish poison. Trans. Amer. Fish. Soc. 85:180-190.

Hunter, G. W.
1927. Notes on the Caryophyllaeidae of North America. Jour. Parasitol. 14:16-26.

Hunter, G. W.
1928. Contributions to the life history of Proteocephalus ambloplitis (Leidy). Jour. Parasitol. 14:229-243.

Hunter, G. W.
1937. Parasitism of fishes in the Lower Hudson area. Suppl. 26th Ann. Rep. N. Y. S. Conserv. Dept. Biol. Survey XI Lower Hudson Watershed (1936):264-273.

Hunter, G. W. and W. S. Hunter
1929. Further experimental studies on the bass tapeworm Proteocephalus ambloplitis (Leidy). Suppl. 18th Ann. Rep. N. Y. S. Conserv. Dept. Biol. Surv. Erie Niagara system (1928):198-207.

Hunter, G. W. and W. S. Hunter
1934. Studies on fish and bird parasites. Suppl. 23rd Ann. Rep. N. Y. S. Conserv. Dept., No. VIII Rep. Biol. Surv. Raquette Watershed (1933):245-254.

Hunter, G. W. and W. S. Hunter
1935. Further studies on fish and bird parasites. Suppl. 24th Ann. Rep. N. Y. S. Conserv. Dept. No. IX Rep. Biol. Surv. Mohawk-Hudson Watershed (1934):267-283.

Krull, W. H.
1934. Cercaria bessiae Cort and Brooks, 1928, an injurious parasite of fish. Copeia, 69:73.

Kudo, Richard R.
1947. Protozoology. Charles C. Thomas, Pub., Springfield, Ill. 643-678.

Lachance, Francois De S.
1947. Black spot disease of bass. Canad. Fish Cult., 1(2):16-21.

Meyer, Marvin C.
1954. The larger animal parasites of the fresh-water fishes of Maine. Maine Dept. of Inland Fish. and Game, Fish. Res. & Mgt. Div. Bull. No. 1, 76 pp.

Miller, R. B.
1952. A review of the Triaenophorus problem in Canadian lakes. Fisheries Res. Board Canada. Bull. No. 95, 42 pp.

Morrison, George R.
1957. The incidence and distribution of the bass tapeworm (Proteocaphalus ambloplitis in southern New Hampshire waters. Mgt. & Res. Div. of the New Hampshire Fish & Game Dept. Tech. Circ. No. 13, 34 pp.

Noble, E. R.
1950. On a myxosporidian (protozoan parasite of California trout). Jour. Parasitol. 36:457-460.

Sillman, E. I.
1957. A note on the effect of parasite burden on the activity of fish. Jour. Parasitol. 43(1):100.

Van Cleave, H. J. and J. F. Mueller.
1934. Parasites of Oneida Lake fishes. III. A biological and ecological survey of the worm parasites. Roosevelt Wild Life Ann. 3:161-334.

Venard, Carl E. and John H. Warfel
1953. Some effects of two species of Acanthocephala on the alimentary canal of the largemouth bass. Jour. Parasitol. 39(2):187-190.

Wardle, Robert A. and James A. McLeod
1952. The zoology of tapeworms. Univ. of Minn. Press, Minneapolis 175-226.