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Parasites of Fishes in South Dakota

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BULLETIN 484
JULY 1959

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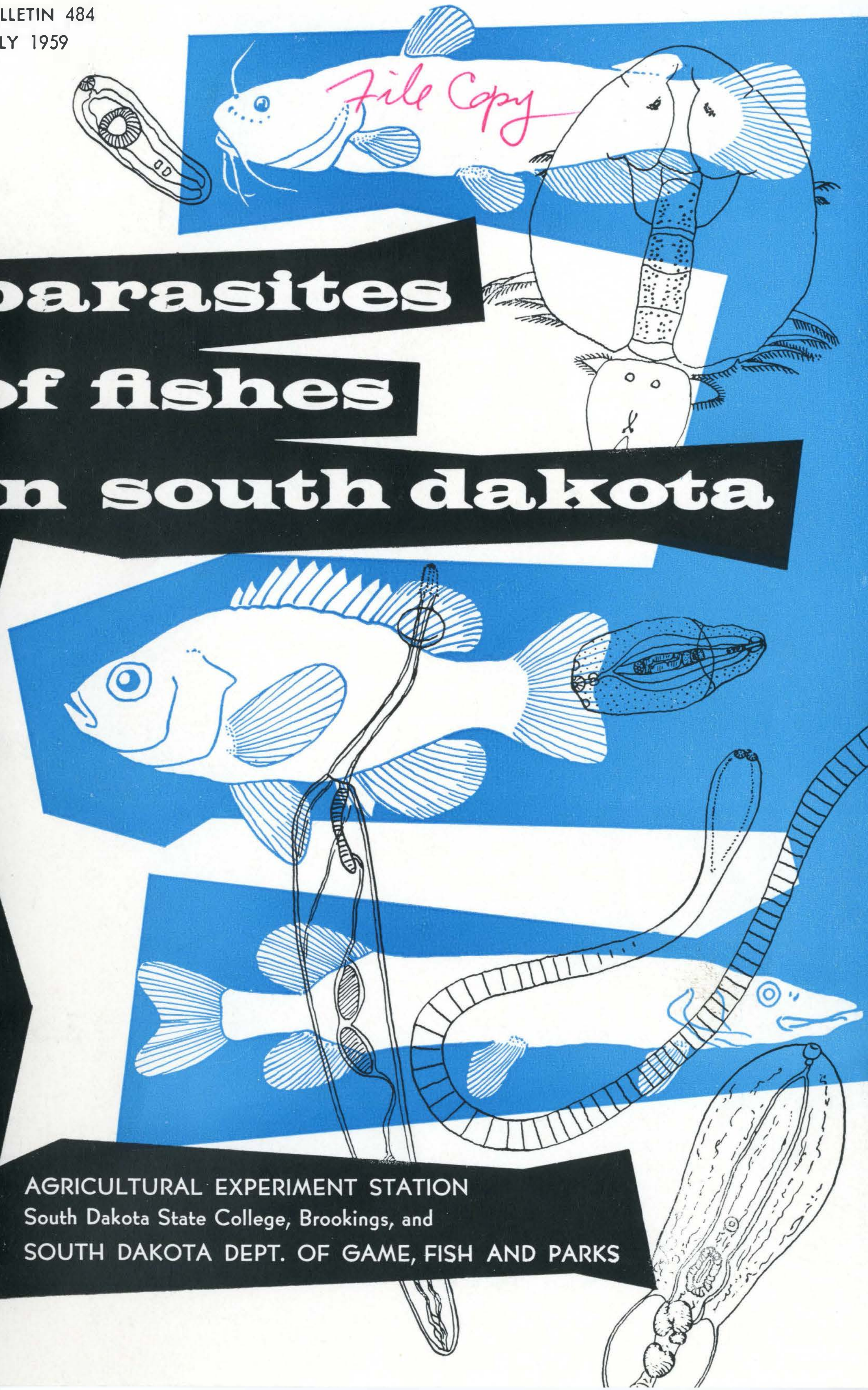

AGRICULTURAL EXPERIMENT STATION
South Dakota State College, Brookings, and
SOUTH DAKOTA DEPT. OF GAME, FISH AND PARKS

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ACKNOWLEDGEMENTS

Sincere appreciation is extended to the many people who helped make this project possible. Special thanks are due Dr. Gerald B. Spawn, head of the Entomology-Zoology Department at South Dakota State College, and William D. Clothier, formerly leader of Statewide Fishery Investigations, South Dakota Department of Game, Fish and Parks, for their activities in initiating the project and for their continuous interest and cooperation.

The study would have been impossible without the cooperation of Fisheries personnel who collected and brought in the fishes for examination; for that task special thanks are due Marvin F. Boussu, James T. Shields, and Joe W. Kathrein.

The author gratefully acknowledges the aid of Dr. Marvin C. Meyer, of the University of Maine, in identifying the leeches, and of Dr. Thomas E. Bowman, of the United States National Museum, in identifying the parasitic copepods. Also, much credit is due my fellow staff member, Marvin O. Allum, for collaborative observations on the epizootic of fish lice at Brant Lake and for his counsel on taxonomy of fishes.

Appreciation is extended to the New York Conservation Department and to the Maine Department of Inland Fisheries and Game for granting permission to use several life cycle charts from their publications. Grateful appreciation is expressed also to Dr. Lyell J. Thomas, of the University of Illinois, for permission to reproduce some of his life cycle charts.

5M—7-59—6958

parasites of fishes

IN SOUTH DAKOTA[1]

ERNEST J. HUGGHINS[2]

Introductory and Background Information

This study constitutes the first extensive investigation of the parasites of fishes in South Dakota. Previously, little technical information was available concerning the incidence and distribution of fish parasites in the state. The survey for the study involved the various kinds of parasitic worms (flukes, tapeworms, roundworms, spiny-headed worms, leeches) and the parasitic crustaceans (fish lice).

More than 500 fishes were examined from 33 different bodies of water, largely lakes. This gave a general idea as to the more prevalent worm and arthropod parasites, as well as records of some less common parasites. Undoubtedly many parasites have been missed, but it is hoped that additional fishes can be examined from time to time to increase the knowledge of parasite incidence and distribution in South Dakota.

The purpose of this publication is not only to list the parasites found, but also to briefly discuss each parasite, including prominent recognition features, information on life cycles, and position in the Animal Kingdom. It is hoped that the bulletin will aid in answering the questions of fishery biologists, game wardens, sportsmen, and others interested in parasites of fishes.

DEFINITIONS

A few basic terms will be considered first to give more meaning to the discussion that follows. Other terms will be explained as they arise.

Parasite—An animal which lives in or on another animal of a different species (usually larger) and gains its livelihood therefrom. There are several types of close associations between animals of different species, sometimes to the mutual benefit of both parties, but in the strictest sense the true parasite causes some degree of injury.

[1]Financed by cooperative agreement between the South Dakota Agricultural Experiment Station (Project 277) and the South Dakota Department of Game, Fish and Parks (Federal Aid to Fish Restoration, Dingell-Johnson Project F-3-R).

[2]Dr. Hugghins is associate zoologist with the South Dakota Agricultural Experiment Station.

Ectoparasite—A parasite which lives on the outer surface of the body of its host. In a fish an ectoparasite might be attached to the fins, scales, skin, or gills.

Endoparasite—A parasite which lives within the body of its host, either embedded in tissues such as muscle or liver, or lying in a cavity such as the intestine, bile duct, trachea, or air spaces of lung.

Host—The animal in or upon which the parasite lives.

Intermediate host—An animal harboring a larval stage of a parasite. In many life cycles of parasites there are one or more intermediate hosts involved before the parasite reaches the final host.

Definitive or final host—The animal which harbors the adult or sexually mature stage of the parasite. The eggs of endoparasites usually must escape from the body of the final host by way of excretions of the host.

Host specificity—The degree to which a parasite depends upon a particular kind of host for life. Some parasites are physiologically adapted for living in only one species of host and will die in other animals, even if introduced into them. This applies to intermediate as well as final hosts. Other parasites are not quite so host specific—they can develop and live in several species of hosts.

Larva—An immature stage which usually is quite different in appearance from the adult. Specialists give technical names to the various kinds of larvae of animals with which they work. See the life cycle charts for technical names of some larval stages of worm parasites. Most of the parasites found in the flesh of fishes are larval stages which cannot reach maturity until eaten by the final host.

In describing a parasite or in telling where it was found in a host, the following terms are useful to accurately designate regions of the body:

Anterior—The forward or head end, or toward the head.

Posterior—The hind or tail end, or toward the hind end.

Dorsal—Toward the upper surface or back.

Ventral—Toward the lower surface or belly.

Lateral—Toward the side of the body.

Medial—Toward the midline or middle of the body.

All of these terms may be used in a relative sense—the gill is in the anterior part of the body of a fish, but the gill is posterior to the eye, which is also in the anterior part of the body.

The layman may not be aware of the fact that in many of the lower animals, both male and female reproductive organs occur within the body of a single individual. When this condition occurs abnormally in higher animals, the individual is called a hermaphrodite. But when the condition is normal for the species, a different term is used.

Monoecious—No separate sexes—both male and female reproductive organs in same individual.

Dioecious—Separate sexes—distinct male and female individuals.

CLASSIFICATION

Need for taxonomy. In discussing the parasites of fishes scientific names must be used. To the layman this may seem confusing and unintelligible, but animals are often referred to by different common names in different regions of the country and in various foreign languages. For each animal there is the need for a scientific name which will be the same in any region and in any language. Further, since nearly 1,000,000 different kinds of animals have been described, there is the need for an orderly arrangement to avoid hopeless confusion. Thus, the purpose of taxonomy is two-fold: (1) for convenience in accurately identifying each kind of animal, and (2) to show relationships among groups of animals.

Binomial system of nomenclature. The following categories are used in the formal classification of an animal: Phylum, Class, Order, Family, Genus, Species. In common scientific usage only the last two are used. These are always italicized, and genus is capitalized while species is not. These two names alone are sufficient to identify the animal, hence the term "binomial system of nomenclature." This system was worked out by a Swedish naturalist, Linnaeus, and modern taxonomy dates from his tenth edition of *Systema Naturae,* published in 1758.

When a person's name follows the scientific name of an animal, it means the animal was named by that person. If the person's name is in parentheses, it means that another person subsequently changed the generic name, but not the specific name. For example, the complete scientific name of one particular fluke is written as follows: *Hysteromorpha triloba* (Rudolphi, 1819) Lutz, 1931. This means that Rudolphi described and named the species in 1819, but that Lutz had a reason for changing the generic name in 1931.

KEY FOR IDENTIFICATION

A person who is not familiar with parasites may have difficulty in separating them into major kinds, such as flukes, roundworms, etc. To aid such persons, a simple key to the major groups of fish parasites has been prepared. To use the key, begin with number 1. Note that following each arabic numeral there are two possibilities. If the parasite in question does not fit the first possibility, try the second and go to the number indicated at the end of the broken line.

SIMPLIFIED KEY TO MAJOR GROUPS OF FISH PARASITES

(Exclusive of Protozoa, Bacteria, and Fungi)

1. Parasite with appendages (legs and mouth parts). On skin, scales, fins, or gills .... Fish lice (Copepoda)
   Parasite without appendages 2

2. Body segmented (or with series of proglottids*) 3
   Body not segmented 4
3. Body elongate, muscular, with narrow segments, and with a sucker at each end. Found externally on fish .... Leeches (Hirudinea)
   Body of adult long and ribbon-like, composed of series of proglottids (except in Caryophyllaeidae), with suckers or grooves at anterior end only. Found in intestine of fish .... Tapeworms (Cestoda) (Larval tapeworm, the plerocercoid, does not have distinct "segments" and is found in flesh or body cavity; usually has either suckers or grooves at anterior end.)
4. Body usually flattened and leaf-like, with at least one sucker, usually two. Both larvae and adults found in various parts of the body of fish .... Flukes (Trematoda)
   Body without suckers 5
5. Body with spiny proboscis. Adults normally in intestine of fish .... Spiny-headed worms (Acanthocephala)
   Body without proboscis; cylindrical, slender-bodied worms. Occur in various parts of body .... Roundworms (Nematoda)

*For our purposes here, proglottids look like segments.

Life Cycles in General

The life cycle or life history is the series of stages through which a parasite passes in developing from the egg to the adult. Many parasites have complicated life cycles.

An understanding of the general types of life cycles found in the various groups of fish parasites is needed to comprehend how the parasite got to the fish and whether it has reached its final destination. Moreover, a knowledge of the life cycle is a prerequisite to control in most cases; sometimes it is possible to break the life cycle of a particular parasite by attacking it at some vulnerable point in the cycle.

FLUKES (Trematodes)

Figure 1

There are two major categories of flukes widespread among fresh-water fishes—the Monogenea and the Digenea. The monogenetic flukes (Order Monogenea) are essentially ectoparasites and have direct life cycles involving no intermediate hosts. The digenetic flukes (Order Digenea) are endoparasites which have indirect life cycles involving from one to three intermediate hosts, each having a different kind of larval stage of fluke.

Here only digenetic fluke life cycles involving fishes will be considered.

Fish as intermediate host. A great number of flukes use fish as the second intermediate host in their life cycle. Undoubtedly, the majority of the cysts seen in fresh-water fishes of North America belong to that large group of flukes referred to collectively as the "strigeids," of which the Families Strigeidae and

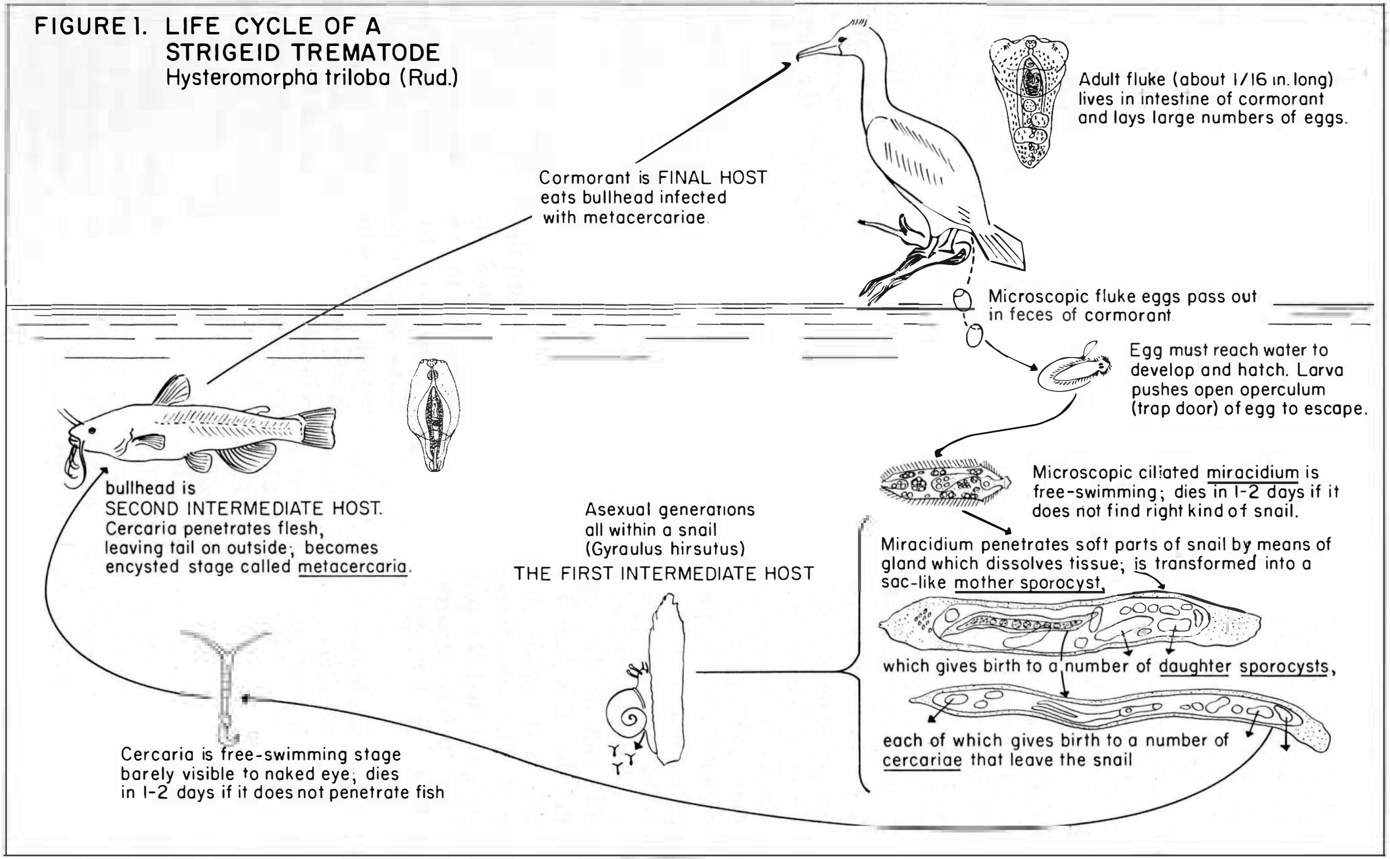


FIGURE 1. LIFE CYCLE OF A STRIGEID TREMATODE
Hysteromorpha triloba (Rud.)

Diplostomidae are the most familiar.

A very common family closely related to the strigeids is the Clinostomidae ("yellow grubs"). Some other families using fishes as intermediate hosts are the Heterophyidae and the Opisthorchiidae.

All of these groups of flukes have similar life cycles in that typically they use snails as the first intermediate host, fishes as the second intermediate host, and a fish-eating bird or mammal as the final host. In a few cases, a piscivorous (fish-eating) fish is the final host.

Refer to figure 1 for a diagrammatic presentation of a typical life cycle of a strigeid fluke. This particular cycle was worked out by the author (Hugghins, 1954). After reaching the water, the microscopic egg hatches in 7 to 25 days, depending upon temperature. The free-swimming miracidium which breaks out of the egg is covered with cilia, tiny hair-like structures which beat rapidly to propel the animal. This very active first larval stage must find the proper first intermediate host, a particular kind of snail, within 1 to 2 days or it will die.

The miracidium secretes a tissue-dissolving substance from its penetration glands to gain entrance to the soft parts of the snail. Within the body of the snail, the miracidium is transformed into an elongate, sac-like structure called a mother sporocyst. This second larval stage gives rise asexually to a number of new sac-like individuals called daughter sporocysts. Each of the daughter sporocysts gives rise asexually to a number of tailed larval stages called cercariae, which emerge from the snail and are free-swimming.

The most important point to remember thus far is that from a single newly hatched miracidium which enters a snail, there may eventually be scores of cercariae leaving the snail. As was the case with the miracidia, the cercariae will die within about 2 days unless they find the proper second intermediate host, a particular kind of fish.

The cercaria penetrates the fish and encysts, after which it is called a metacercaria. In the species of fluke shown in figure 1, the metacercariae occur in the muscle of the fish. Other sites for some species of strigeids are liver and other viscera, eye, and nervous system. Metacercariae often are visible from the exterior of the fish and are therefore the most likely flukes to be noticed by fishermen.

The metacercaria can develop no further until the fish is eaten by the proper final host; for the fluke shown in the chart, this has to be a cormorant. In the final host, the fluke reaches maturity and begins laying eggs which pass out in the host's excrement. If the fluke egg happens to fall into water it hatches, but the first larval stage is doomed unless it can penetrate the right kind of snail within a day or so to continue the cycle.

Fish as final host. There are many flukes which use fish as final hosts. They occur mostly in the internal organs and are not likely to be seen by the fisherman. In contrast to the type of cycle in which the cercaria must actively penetrate the fish, the final fish host must engest some animal harboring the encysted metacercaria. A number of interesting variations in cycles occur among the more common families listed below.

(1) In the families Gorgoderidae (parasites of the urinary ducts and bladder) and Allocreadiidae (tiny intestinal parasites), the first intermediate host is typically not a snail but a tiny "fingernail clam" of the genus *Pisidium, Sphaerium,* or *Musculium.* In most cases the second intermediate host is an aquatic larva of such insects as mayflies. The final fish host eats the aquatic insect larva.

(2) Members of the Family Bucephalidae (gasterostomes) use mussels as the first intermediate host, but the second intermediate host as well as the final host is a fish. (The cercaria encysts in the skin or fins of a fish, which is subsequently engested by a larger fish in which the fluke matures in the caeca or intestine.)

(3) In the Family Azygiidae the cercaria is of the peculiar cystocercous type (encysts in its own tail). The cercaria is very large, about the size of a mosquito larva, and the tail forks into two broad flaps at the end. Fish are attracted by the size and movements of the cercariae and engest them, after which the rather large adult flukes develop in the stomach of the fish. Thus, there is no second intermediate host.

(4) A most unusual life cycle is that of *Triganodistomum mutabile* (Family Lissorchiidae), in which the cercariae are eaten by an oligochaete (a segmented worm in the same class with the familiar earthworm) living in commensal relationship with snails, and by Planaria (a free-living flatworm). This cercaria has no tail for swimming but creeps about where it can easily be eaten by the oligochaetes and planarians (Wallace, 1941). Lake chubsuckers, the final hosts, feed on the worms containing the metacercariae.

TAPEWORMS (Cestodes)

Figures 2, 3, 4

Most of the tapeworms found in fresh-water fishes belong in the pseudophyllidean and the proteocephalid groups. One of the most prominent differences in these two groups is in the head or scolex. In the great majority of the pseudophyllideans (Order Pseudophyllidea), the scolex has two lateral, elongate grooves or bothria for attachment to the intestinal lining of the final host; the scolex of proteocephalids (Order Proteocephala) has four round, in-cupped suckers and sometimes a fifth terminal sucker which is rudimentary. As with the flukes, there are no separate sexes.

Order Pseudophyllidea. Figure 2 illustrates a typical cycle for a pseudophyllidean tapeworm. The adult worm lives in the intestinal tract of the final host, which is some kind of vertebrate. The operculate egg reaches the water via the excrement of the host and hatches into a spherical, ciliated, free-swimming coracidium which contains a six-

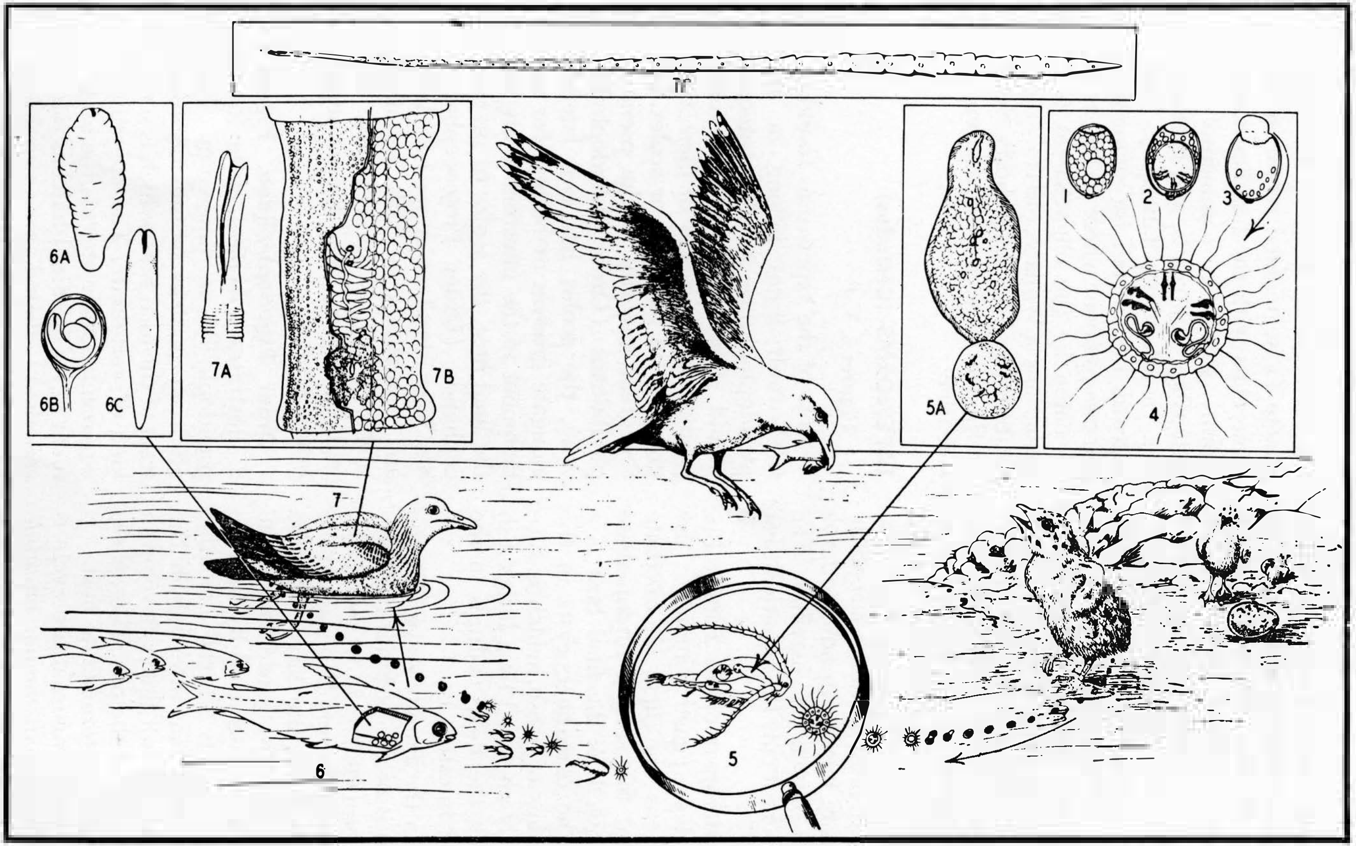


Figure 2. Life cycle chart of a pseudophyllidean tapeworm, *Diphyllobothrium oblongatum.* Operculate egg (1) has hexacanth larva develop within it (2) which hatches (3) into free-swimming coracidium (4). A copepod, *Diaptomus* (5), eats the coracidium, which develops into a procercoid (5A) within the body cavity. Herring or minnows (6) eating infected copepods develop plerocercoids (6A, B, C) encysted on the stomach wall or mesenteries. When young gulls are fed infected fish by parent birds, the adult tapeworm (7A, B, C) develops in the intestine. (Courtesy of L. J. Thomas, 1944.)

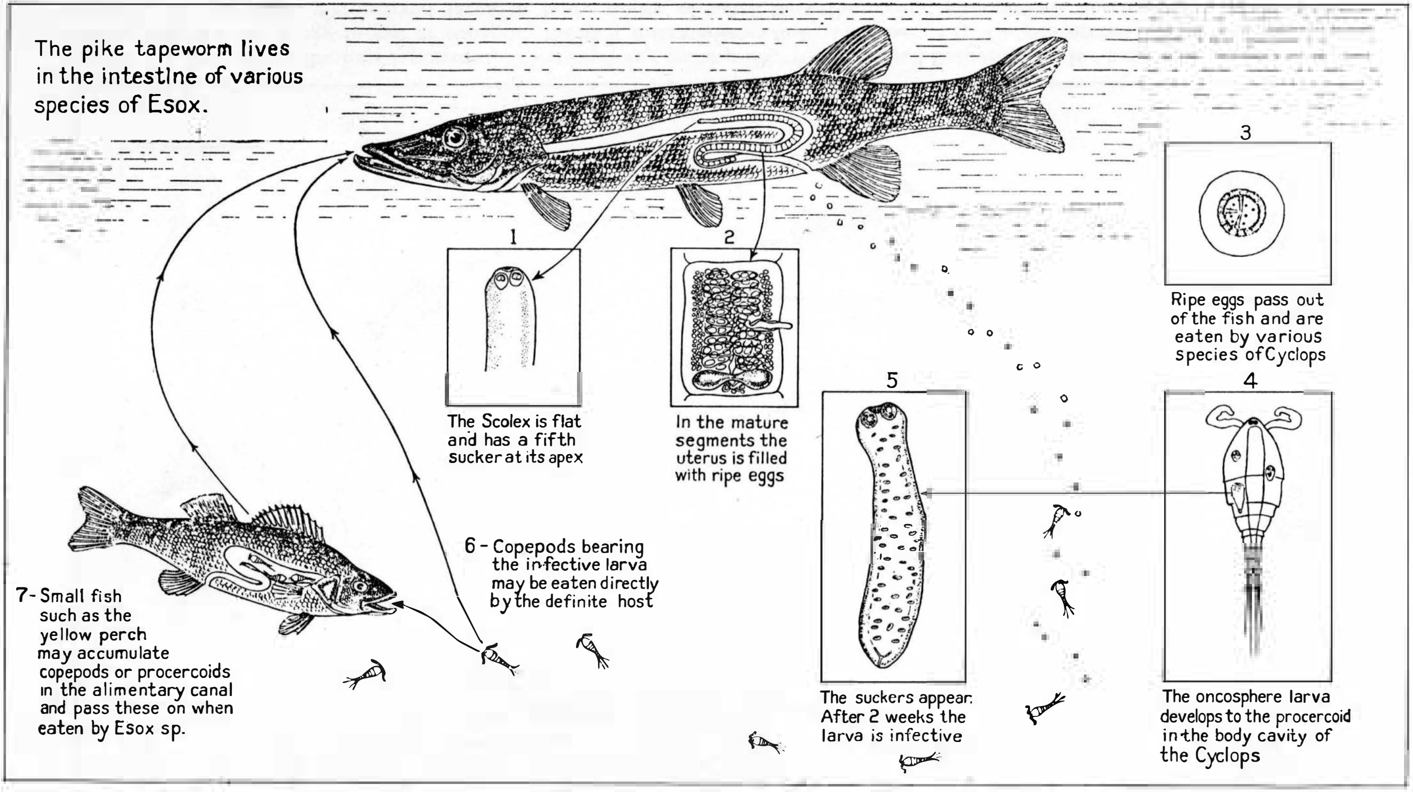


Figure 3. Life cycle chart of *Proteocephalus pinguis*, a tapeworm of northern pike. (After Hunter; courtesy of the New York State Conservation Department.)

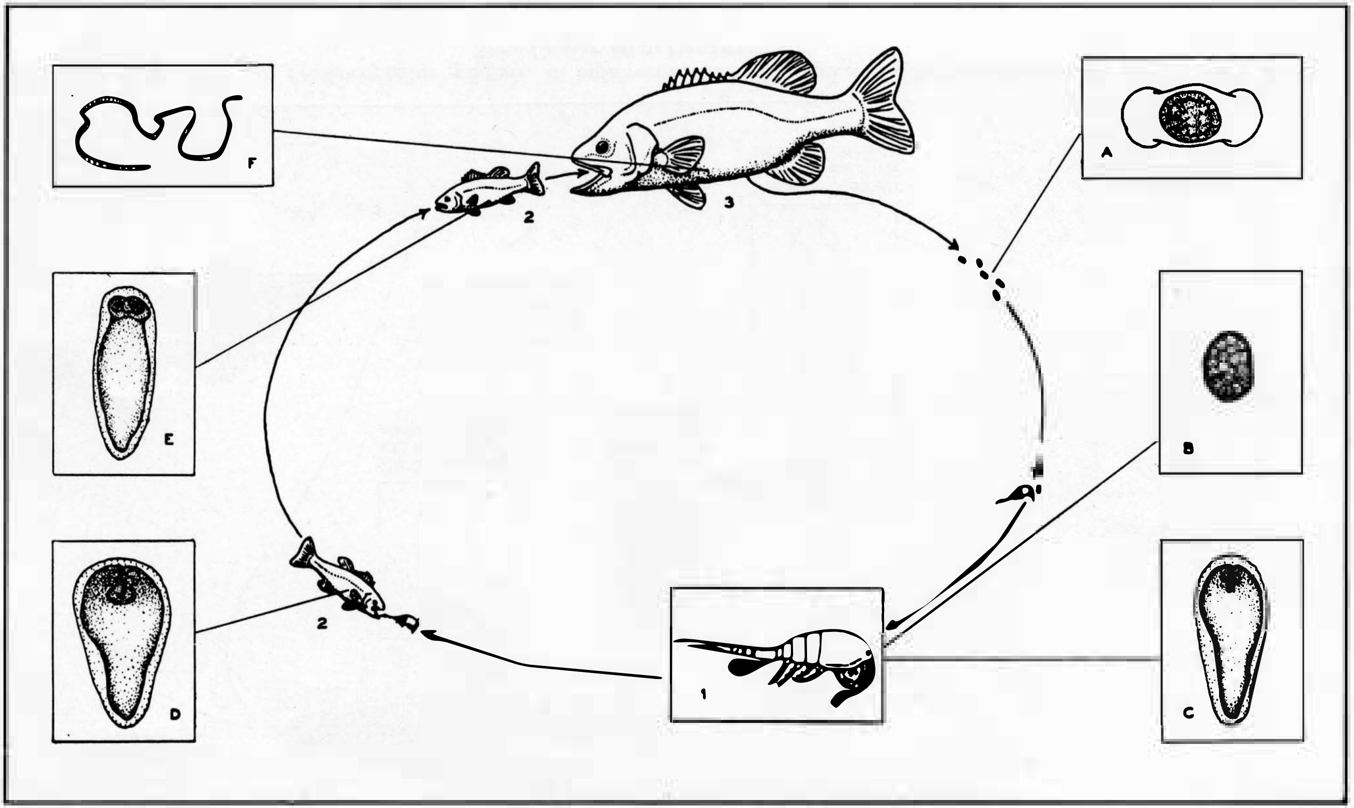


Figure 4. Life cycle of the bass tapeworm, *Proteocephalus amblоplitis.* A—dumbbell-shaped egg; B—hexacanth (six-hooked) larva which "hatches" from egg in gut of copepod, the first intermediate host (number 1); C—procercoid larva in body cavity of copepod; D—encysted plerocercoid larva in body cavity of small bass, the second intermediate host (number 2); E—later stage of same; F—adult tapeworm in intestine of larger bass, the final host (number 3). (Modified from Hunter and Hunter, 1929, by M. C. Meyer, 1954; courtesy of the Maine Department of Inland Fisheries and Game.)

hooked embryo (hexacanth embryo or onchosphere). The microscopic coracidia are engested by tiny crustaceans which are an important food item of fish, especially fry and fingerlings. Thus, from the viewpoint of the parasite, a microcrustacean is an ideal intermediate host.

Within the body of the copepod, which is the first intermediate host, the onchosphere develops into a procercoid, an oblong stage with a knob (the cercomer containing the six hooks) on the posterior end. When the copepod is eaten by a suitable fish, which serves as the second intermediate host, the procercoid develops into an elongate, nondescript worm, the plerocercoid. The cercomer is gone, and about all that can be distinguished is the pair of shallow grooves at the anterior end.

In some species of pseudophyllideans, the plerocercoids are found in the muscle of the fish, while in other species they are in the viscera. When the final host eats the infected fish, the tapeworm develops to maturity in the intestine and begins laying eggs.

Order Proteocephala. The proteocephalid tapeworms have life cycles which are quite similar to those of the pseudophyllideans but are somewhat simpler. There is no free-swimming coracidium; the copepod engests the tapeworm egg directly. In some species, such as *Proteocephalus pinguis* (figure 3), a second intermediate host is not necessary, while in others, such as *P. ambloplitis* (figure 4), a second intermediate host is needed.

The larval stages of this group can be easily distinguished from pseudophyllidean larvae by the presence at the anterior end of four and often five suckers instead of two grooves. Unlike the pseudophyllideans, adult proteocephalids do not occur in birds and mammals; they are most widespread in freshwater fishes, although a few species occur in amphibians and reptiles.

To review, if a fish is the final host for a tapeworm, the adult worms will be in the digestive tract; but if the fish is an intermediate host, the plerocercoids will be embedded in the muscle, liver, or mesenteries, or may even be free in the body cavity.

ROUNDWORMS (Nematodes)

Figures 5, 6

The life cycles of roundworms generally are not so complex as those of the flatworms discussed. There are separate sexes. The majority of this large group of worms are free-living in the soil or water, and the members which have adopted parasitic habits in plants and animals are not greatly changed morphologically from their free-living relatives. In fact, in a few species there is alternation between parasitic and free-living generations, and in some others the larvae are free-living for a period before entering a host.

There is little difference in the appearance of the larval stages within a species, and consequently there is no specialized terminology such at that for the larvae of flatworms. The larval stage is characterized by having four molts. The

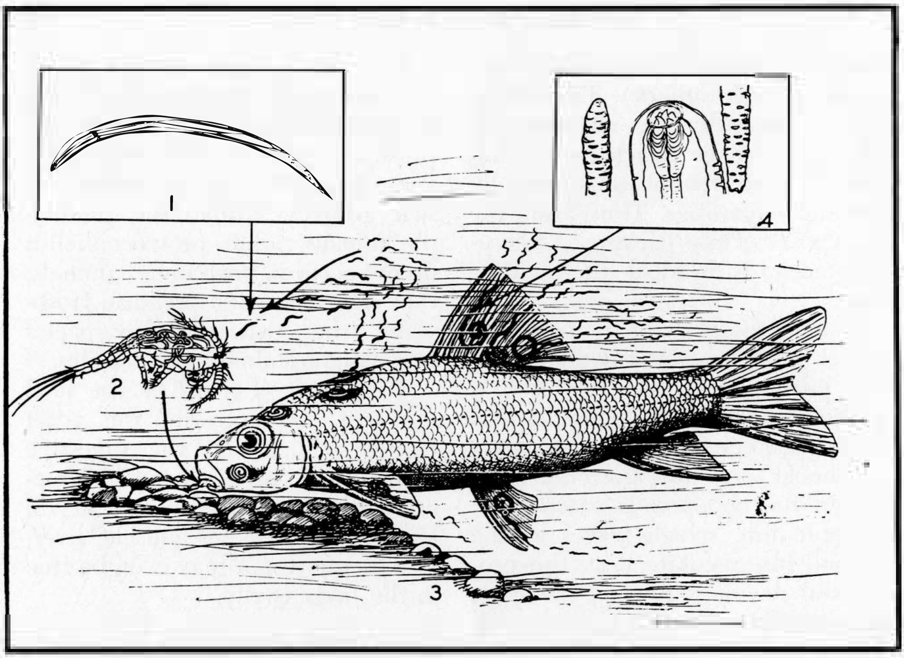


Figure 5. Life cycle chart of a fish "guinea worm," *Philometra nodulosa.* Larval worms (1) escape by rupture of fish's skin and are eaten by a copepod, *Cyclops* (2), in which they develop to the infective stage for fish within 2 weeks. Fish (3) which eat infected copepods have the female worms (4) appearing in the skin within a year. (Courtesy of L. J. Thomas, 1944)

cuticle (outer, non-cellular covering, including the lining of the mouth and rectum) is shed with each molt; in some species the old shed cuticle remains about the larva as a protective sheath. The larvae are not infective for the final host until after the second molt, when they are called third stage or infective larvae. In various types of life cycles, the first two molts may occur within the egg before hatching, in the soil after hatching, or within the body of an intermediate host.

Many nematode parasites have direct life cycles (no intermediate host), but in most known life cycles of nematodes of fishes, an intermediate host is required. An example is the fish guinea worm, *Philometra,* in which a copepod serves as the intermediate host (figure 5). This worm is an example of one of those few nematodes in which the eggs hatch within the uterus of the female so that active larvae emerge. A type of cycle in which a fish serves as the intermediate host is illustrated by *Contracaecum* (figure 6). This is one of the most common parasites of fishes; the final host is a fish-eating bird such as a cormorant. Thus, as was shown for the flatworms, fishes may serve either as intermediate hosts or as final hosts for various kinds of roundworms.

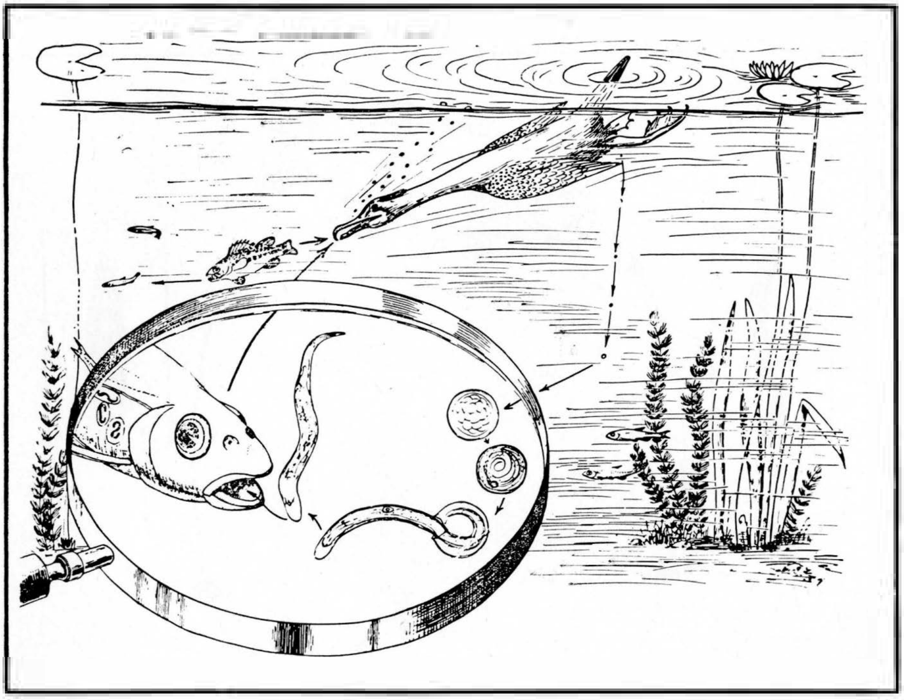


Figure 6. Life cycle chart of a roundworm, *Contracaecum spiculigerum*. The adult worms occur in the stomachs of fish-eating birds, and the worm eggs are passed in the feces of birds. Larvae hatch in the water and are eaten by minnows, in which the worms encyst on the liver or mesenteries. The worms may be transferred to larger fish feeding on minnows. Fish-eating birds acquire the parasite by eating either the infected larger fish or the minnows. (Courtesy of L. J. Thomas, 1944.)

SPINY-HEADED WORMS (Acanthocephalans)

Figure 7

Few life cycles have been worked out for the spiny-headed worms, but in the known cycles an arthropod intermediate host is required, and the parasite never has a free-living stage. The adult always lives in the intestine of a vertebrate. There are separate sexes. The pattern of the life cycle is that if the final host is strictly terrestrial, an insect serves as the intermediate host, while if the final host is aquatic (including some aquatic birds), a microcrustacean serves as the intermediate host. Figure 7 illustrates the life cycle of a common acanthocephalan of fishes, including the specialized names of larval stages.

In some cases, the life cycle includes a fish as a second intermediate host. For example, Ward (1940a) showed that *Neoechinorhynchus cylindratus* of white suckers and other fishes uses an ostracod crustacean as the first intermediate host and a bluegill as the second. In the latter, the larval stage is encysted in the liver. In some cases,

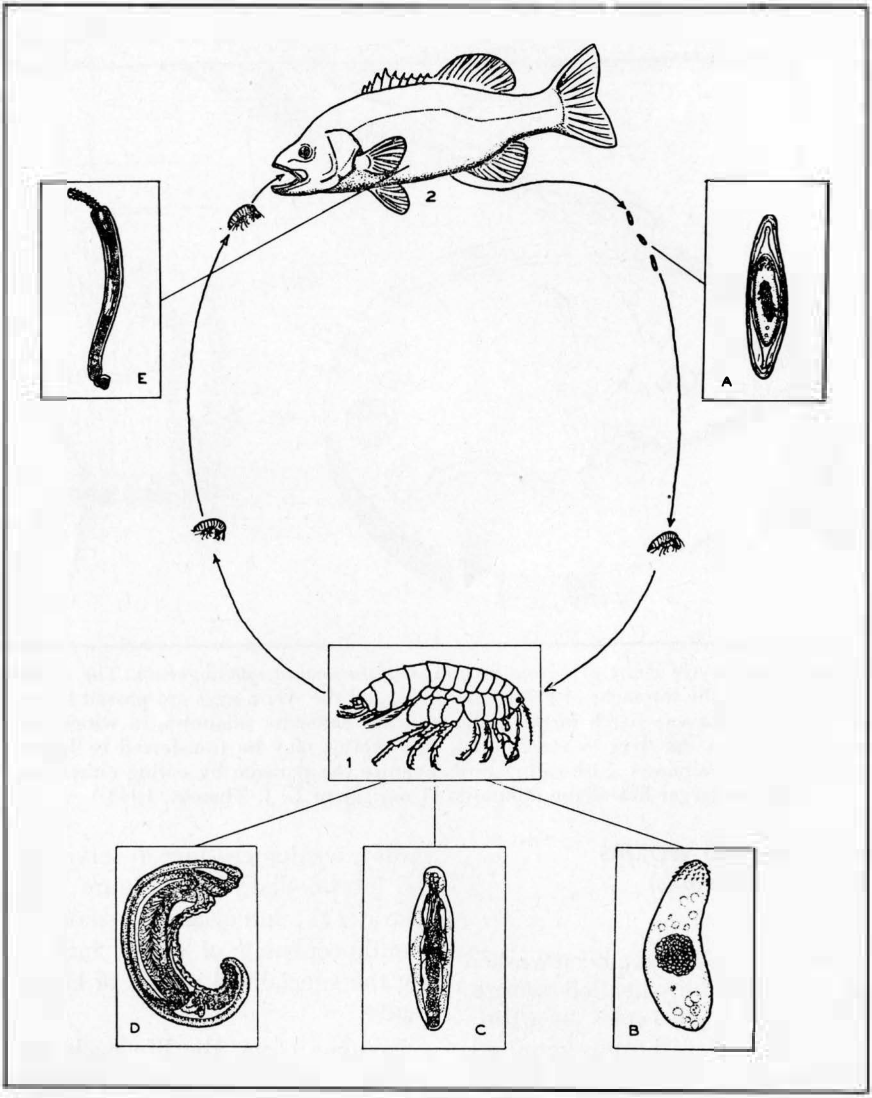


Figure 7. Life cycle chart of a spiny-headed worm, *Leptorhynchoides thecatus.* A—egg containing larva; B—acanthor larva after "hatching" from egg in gut of amphipod, the intermediate host (number 1); C—acanthella larva in body cavity of amphipod; D—cystacanth, a later larval stage in body cavity of amphipod; E—adult worm in intestine of smallmouth bass, the final host (number 2). (Modified from DeGiusti, 1949, by M. C. Meyer, 1954; courtesy of the Maine Department of Inland Fisheries and Game.)

acanthocephalans may encyst in animals which are not suitable as final hosts, and thus auxiliary or transport hosts may be interposed in the life cycle.

LEECHES (Annelids)

These ectoparasites have direct life cycles. They are monoecious, but even though testes and ovaries are present in the same body, cross-fertilization between two individuals is necessary. In most cases the eggs are enclosed in cocoons and attached to some stationary object in the water. The young which hatch look essentially like the adults. Contrary to popular belief, all leeches are not blood-suckers; some are scavengers and some are predatory on small aquatic animals. Those which take blood meals are transitory parasites—they attach themselves to the host for an interval of feeding, after which they leave the host.

FISH LICE (Parasitic Copepods)

The so-called fish lice are not really lice but are microcrustaceans; that is, they are allied with the familiar crayfish rather than the insects. As has been shown, free-living copepods serve as intermediate hosts for some tapeworms and roundworms; the "fish lice" are parasitic copepods which have become highly modified for the parasitic life. They are dioecious.

A single authority, C. B. Wilson, has done most of the detailed studies on parasitic copepods of fresh-water fishes in North America (see later section under Copepoda), and his long series of highly technical papers are in journals not readily available to the average layman. Readable condensed reviews on this group may be found in books by Davis (1953), Pennak (1953), and Cameron (1956).

There are three general life cycle patterns represented by the parasitic copepods found in fishes of South Dakota.

(1) In the group represented by *Argulus* (figure 40), both males and females move about freely on the surface of the fish and occasionally leave the fish to swim about in the water. They leave the fish to breed and the female deposits eggs upon submerged sticks or stones. The egg hatches into a free-swimming nauplius larva, the initial larval stage common to all crustaceans. This is a microscopic form which undergoes several molts before assuming the appearance and habits of the adult.

(2) In the group represented by *Lernaea* (figure 41), the females have two elongate egg sacs filled with eggs which are released while the parasite remains attached to the fish host. The eggs hatch into free-swimming nauplii which go through a series of molts until they reach an advanced larval stage called a copepodid. Male and female copepodids attach themselves temporarily to the gills of any fish available and copulate, after which the male dies and the female becomes free-swimming again. She soon becomes attached to the body surface of the fish host upon which she will spend the rest of her life. She changes shape into an elongate, worm-like

organism and buries the anterior portion of her body in the flesh of the fish, leaving the posterior portion (which eventually has two egg sacs) protruding. Anchor-like horns grow at the anterior end, so that this parasite is commonly called the "anchor parasite."

To recapitulate, *Lernaea* has two free-swimming and two parasitic phases in the life cycle.

(3) In the group represented by *Achtheres* (figure 43), the highly modified adult females are permanently attached to the gills or fins of the fish host. Little is known about the dwarfed males; they are attached to the fish during immature stages and later cling to the bodies of the adult females to breed, after which they die. In this group the early larval stages (nauplius, etc.) are passed within the egg, so that by the time the copepodid hatches, it must become attached to a fish host within a few hours or die. It is after attachment that the parasite undergoes its remarkable degeneration during which it loses its legs and most evidence of segmentation, being held on by a pair of highly modified mouth parts (the second maxillae). As in *Lernaea,* a pair of elongate egg sacs are present.

In summary, members of this group are obligatory parasites except for a few hours of their lives.

Fish Parasites Found in South Dakota

In this section the worm and arthropod parasites encountered in fishes of South Dakota are discussed with reference to taxonomic position, characteristics, life cycles, and incidence.

A total of 589 fishes of 28 different species were examined, and 449 (76%) of the fishes were parasitized by at least one of the 35 different species of parasites found. The fishes were collected from 33 different bodies of water in the state.

In tables 1 through 4, the data are summarized as to kinds and numbers of fishes infected with parasites, the kinds of parasites found, and the source of the fishes examined. Some pointers are given toward recognition of the parasites, but the layman should be cautioned that often painstaking techniques are required to accurately identify a parasite as to species. (For the worker who may wish to learn specialized techniques for preparing parasitic worms, some references are given in the section on literature.)

It will be noted in table 1 that bullheads had more different species of parasites than any other kind of fish. This may be due partly to the fact that far more bullheads were examined than any other kind of fish, and also the bullheads came from more different sources. It should be stated again that although this survey probably has revealed the most prevalent fish parasites occurring in South Dakota, there undoubtedly are many parasites here which were missed in this study.

Table 1. Fishes Examined for Parasites in South Dakota

Common name*	Scientific name*	No. fish examined	No. fish infected	Parasites found† No.	Parasites found† Species	Sources of fish No.	Sources of fish Location
Paddlefish	*Polyodon spathula*	1	1	3:	*Marsipometra hastata, Camallanus oxycephalus,* Nematoda sp.	1:	Ft. Randall Reservoir of Missouri R.
Brown trout	*Salmo trutta*	4	0	0		1:	Black Hills streams
Rainbow trout	*Salmo gairdneri*	6	0	0		1:	Black Hills streams
Brook trout	*Salvelinus fontinalis*	10	0	0		1:	Black Hills streams
Northern pike	*Esox lucius*	24	19	6:	*Proteocephalus pinguis, Camallanus oxycephalus, Contracaecum spiculigerum*‡, *Pomphorhynchus bulbocolli,* Neoechinorhynchidae sp., *Argulus biramosus*	9:	Lakes—Big Stone, Waubay, Willow, Madison, Crow, Louise, Cottonwood; Big Sioux R.; College Cr.
Bigmouth buffalo	*Ictiobus cyprinellus*	13	8	4:	*Philometra nodulosa,* Nematoda sp., *Pomphorhynchus bulbocolli, Argulus biramosus*	4:	Lakes—Big Stone, Poinsett, Goldsmith, Hendricks
White sucker	*Catostomus commersoni*	22	16	11:	*Triganodistomum* (2 spp.), "Black grub" sp‡., *Glaridacris catostomi,* Caryophyllaeidae (2 spp.), *Philometra nodulosa,* Nematoda sp., *Pomphorhynchus bulbocolli, Argulus biramosus, Lernaea cyprinacea*	11:	Lakes—Big Stone, Waubay, Willow, Poinsett, Goldsmith, Hendricks, Louise, Cottonwood; Big Sioux R.; College Cr.; Rapid Cr.
Mountain sucker	*Pantosteus jordani*	1	1	1:	*Posthodiplostomum minimum*‡	1:	Rapid Cr.
Carp	*Cyprinus carpio*	14	5	3:	Caryophyllaeidae sp., *Pomphorhynchus bulbocolli, Argulus biramosus*	8:	Lakes—Waubay, Poinsett, Oakwood, Brant, Chapelle, Cottonwood, Mina; Big Sioux R.
Creek chub	*Semotilus atromaculatus*	5	5	3:	*Uvulifer amblopliti*s‡, Spiruroidea sp., Neoechinorhynchidae sp.	2:	Medary Cr., College Cr.

Table 1 Continued

Common name*	Scientific name*	No. fish examined	No. fish infected	Parasites found† No.	Parasites found† Species	Sources of fish No.	Sources of fish Location
Western blacknose dace	*Rhinichthys atratulus meleagris*	3	3	1:	*Uvulifer ambloplitis*‡	1:	Medary Cr.
Longnose dace	*Rhinichthys cataractae*	4	4	1:	*Posthodiplostomum minimum*‡	1:	Rapid Cr.
Common shiner	*Notropis cornutus*	2	1	1:	*Uvulifer ambloplitis*‡	2:	Medary Cr., Big Sioux R.
Brassy minnow	*Hybognathus hankinsoni*	1	1	1:	*Uvulifer ambloplitis*‡	1:	Medary Cr.
Fathead minnow	*Pimephales promelas*	31	30	3:	*Uvulifer ambloplitis*‡, *Ligula intestinalis*†, *Lernaea cyprinacea*	3:	Pond near Waubay, Hydewood Cr., Big Sioux R.
Stoneroller	*Campostoma anomalum*	2	2	1:	*Uvulifer ambloplitis*‡	1:	Medary Cr.
Channel catfish	*Ictalurus lacustris*	6	6	3:	*Corallobothrium fimbriatum*, *Camallanus oxycephalus*, *Myzobdella moorei*	3:	Lakes—Brant, Menno; Ft. Randall Reservoir of Missouri R.
Black bullhead	*Ictalurus melas*	232	203	15:	*Hysteromorpha triloba*‡, *Clinostomum marginatum*‡, *Phyllodistomum staffordi*, *Proteocephalus* sp.‡ & *P. ambloplitis*‡, *Corallobothrium fimbriatum*, *C. giganteum*, *Contracaecum spiculigerum*‡, Nematoda sp., *Pomphorhynchus bulbocolli*, Neoechinorhynchidae sp., Gorgorhynchidae (?) sp., *Myzobdella moorei*, *Argulus biramosus*, *Achtheres ambloplitis*	21:	Lakes—Big Stone, Willow, Norden, Oakwood, Goldsmith, Hendricks, Madison, Brant, Wall, Beaver, Menno, Andes, Fish, Fraiser, Crow, Louise, Cottonwood, Mina; Big Sioux R.; Angostura Reservoir of Cheyenne R.; Black Hills streams.
White bass	*Morone chrysops*	3	3	3:	*Allacanthochasmus varius*, *Camallanus oxycephalus*, Neoechinorhynchidae sp.	1:	Big Stone L.
Largemouth bass	*Micropterus salmoides*	28	19	6:	*Proteocephalus ambloplitis*, *P. fluviatilis*, *Proteocephalus sp.*‡ *Contracaecum spiculigerum*‡, *Camallanus oxycephalus*, *Lernaea cyprinacea*	5:	Lakes—Big Stone, Chapelle, Mina, Red Plum; Ft. Randall Reservoir of Missouri R.

Table 1 Continued

Common name*	Scientific name*	No. fish examined	No. fish infected	Parasites found† No.	Parasites found† Species	Sources of fish No.	Sources of fish Location
Bluegill	*Lepomis macrochirus*	57	54	4:	*Posthodiplostomum minimum*‡, *Clinostomum marginatum*‡, Trematoda sp, *Bothriocephalus* sp.	9:	Lakes—Big Stone, Wilmarth, Menno, Fish, Louise, Mina, Red Plum; Angostura Reservoir; Black Hills streams
Rock bass	*Ambloplites rupestris*	10	10	1:	*Posthodiplostomum minimum*‡	1:	Rapid Cr.
White crappie	*Pomoxis annularis*	10	4	3:	*Posthodiplostomum minimum*‡, *Camallanus oxycephalus, Argulus biramosus*	4:	Lakes—Big Stone, Goldsmith, Chapelle, Louise
Black crappie	*Pomoxis nigromaculatus*	34	20	6:	*Posthodiplostomum minimum*‡, *Proteocephalus* sp., *Contracaecum spiculigerum*‡, *Camallanus oxycephalus*, Nematoda sp. *Argulus biramosus*	8:	Lakes—Big Stone, Hendricks, Brant, Wilmarth, Louise, Mina, Fraiser; Angostura Reservoir
Walleye	*Stizostedion vitreum*	28	17	5:	Lymphocystis, *Bothriocephalus cuspidatus*, Nematoda sp., Neoechinorhynchidae sp., *Argulus biramosus*	9:	Lakes—Big Stone, Waubay, Goldsmith, Hendricks, Brant, Madison, Fish, Cottonwood, Mina
Sauger	*Stizostedion canadense*	2	2	2:	*Bothriocephalus cuspidatus, Camallanus oxycephalus*	1:	Ft. Randall Reservoir
Yellow perch	*Perca flavescens*	34	15	8:	Trematoda sp., *Proteocephalus* sp., *Camallanus oxycephalus*, Nematoda sp., *Pomphorhynchus bulbocolli*, Neoechinorhynchidae sp., *Myzobdella moorei, Argulus biramosus*	11:	Lakes—Waubay, Willow, Goldsmith, Hendricks, Crow, Cottonwood, Mina; McNeil Pond; Medary Cr.; Ft. Randall & Angostura Reservoirs
Freshwater drum	*Aplodinotus grunniens*	2	0	0		1:	Big Stone L.
Totals	**28 species of fish**	**589§**	**449**	**(35 different species of parasites)**		**(33 different water sources)**	

*The scientific & common names used for the fishes conform to Spec. Publ. 1, Amer. Fish Soc., 1948, except for bullheads, which are changed from *Ameiurus* to *Ictalurus* according to Taylor, 1954.

†In a few cases, series of bullheads and minnows were examined externally only (for metacercariae & copepods)

‡Indicates larval stage of parasite.

§This number does not include the fishes examined for fish lice only, during the epizootics at Brant L. & L. Poinsett.

Table 2. Fish Parasites Found in South Dakota, with Aids for Recognition

Kind of parasite	Name of parasite	Fish host	Site in fish	Recognition features
Flukes (Trematoda)	*Posthodiplostomum minimum*, or "white grub of liver" (larval stage)	Bluegill, white crappie, black crappie, northern rock bass	Liver, sometimes other viscera	Thin-walled, transparent, ovoid cyst with tiny fluke inside. Figs. 8-10.
	Hysteromorpha triloba (larval stage)	Black bullhead	Musculature	Tiny white cysts about size of pin head; usually most noticeable at base of tail. Figs. 1, 11, 12.
	Uvulifer ambloplitis, or "black grub" (larval stage)	Minnows and sunfishes	Skin	Black spots in skin. Figs. 13, 14.
	Clinostomum marginatum, or "yellow grub" (larval stage)	Black bullhead	Skin	Large, yellow grub; intestine with wrinkled margin. Figs. 15,16.
	Phyllodistomum staffordi	Black bullhead	Urinary bladder	Narrow, neck-like forebody and expanded, discoidal hindbody. Fig. 17.
	Allacanthochasmus varius	White bass	Intestine	Extremely small flukes, covered with microscopic spines. Fig. 18.
	Triganodistomum spp.	White sucker	Intestine	Small flukes with large suckers; tiny spines covering portion of body.
Tapeworms (Cestoda)	*Glaridacris catostomi* & Caryophyllaeidae spp.	White sucker	Intestine	Elongate tapeworms with no proglottids, only one set of reproductive organs. Fig. 19.
	Bothriocephalus cuspidatus	Walleye and sauger	Pyloric caeca and upper intestine	Scolex resembles long rectangle, with 2 grooves on opposite sides. Fig. 20.
	Marsipometra hastata	Paddlefish	Stomach, pyloric caeca, intestine	Scolex shaped like arrowhead with groove on each side. Fig. 21.
	Ligula intestinalis (Larval stage)	Fathead minnow	Body cavity	Thick, fleshy worm, tapered at both ends, no proglottids; causes bulge in abdomen of fish. Fig. 22.

Table 2 Continued

Kind of parasite	Name of parasite	Fish host	Site in fish	Recognition features
	Proteocephalus ambloplitis, or "bass tapeworm"	Largemouth bass	Pyloric caeca, intestine	Scolex is globular, with 4 large suckers on sides and a "terminal organ" at apex. Eggs have dumbbell shape. Figs. 4, 24.
	Larva of bass tapeworm	Black bullhead	Liver	Tiny white worm; short, no proglottids; scolex has 4 suckers and large, spherical terminal organ. Figs. 4, 23.
	Proteocephalus fluviatilis	Largemouth bass	Intestine	Tiny scolex not set off from neck and with 5 tiny suckers. Fig. 25.
	Proteocephalus pinguis	Northern pike	Intestine	Broad, spatulate scolex bearing 5 small suckers at anterior end. Figs. 3, 26, 27.
	Corallobothrium fimbriatum	Black bullhead and channel catfish	Intestine	Scolex has pronounced collar of loose tissue forming folds; 4 suckers present. Fig. 28.
	Corallobothrium giganteum	Black bullhead	Intestine	Scolex has wrinkled appearance but no elaborate collar as above. Fig. 29.
Roundworms (Nematoda)	*Contracaecum spiculigerum* (Larval stage)	Black bullhead, black crappie, largemouth bass	Mesenteries around stomach and intestine	Stout white worms, loosely coiled. Fig. 6.
	Camallanus oxycephalus	Black crappie, white crappie, bluegill, largemouth bass, yellow perch, sauger, white bass, northern pike, channel catfish, paddlefish	Intestine, particularly near posterior end	Small red worms with pair of chitinous jaws. Fig. 30.
	Philometra nodulosa, or "guinea worm" of fish	Bigmouth buffalo and white sucker	Just below skin in head region	Position of worm marked by inflamed, tortuous ridge. Figs. 31, 32.

Table 2 Continued

Kind of parasite	Name of parasite	Fish host	Site in fish	Recognition features
Spiny-headed worms (Acanthocephala)	*Pomphorhynchus bulbocolli*	Carp, white sucker, yellow perch, northern pike, black bullhead	Intestine	Prominent spherical bulb between proboscis and long slender neck. Fig. 32.
	Neoechinorhynchidae	Creek chub, white bass, walleye, northern pike, yellow perch, black bullhead	Intestine	Proboscis knob-like and armed with relatively few hooks. Fig. 34.
Leeches (Hirudinea)	*Myzobdella moorei*	Channel catfish, black bullhead, yellow perch	On fins and skin	Two distinct body regions, being smaller anteriorly; suckers not expanded. Fig. 35.
Fish lice (Copepoda)	*Argulus biramosus,* or "fish lice"	Walleye, northen pike, yellow perch, black crappie, white crappie, carp, white sucker, bigmouth buffalo, black bullhead	On external surface	Circular, flattened body; a pair of suckers and 4 pairs of swimming legs ventrally. Figs. 36-40.
	Lernaea cyprinacea, or "anchor worm"	Fathead minnow, white sucker, largemouth bass	Embedded in flesh	Elongate portion with horns buried in flesh; posterior end protruding and bearing egg sacs. Figs. 41, 42.
	*Achtheres amblopliti*s	Black bullhead	On gill rakers	Short, plump body with 2 curved "arms" meeting for attachment. Figs. 43, 44.
Virus	Lymphocystis	Walleye	External surface	Gelatinous, wart-like growth. Microscopically, it has large round cells with thick walls. Figs. 45-47.
Fungus	*Saprolegnia* sp., or "water mold"	Many species of fish	External surface	Many fine filaments radiating outward to form fuzzy patches.

Table 3. Percentage of Parasitism in Families of Fish

Family	No. species examined	No. individuals examined	No. infected	% infection
POLYODONTIDAE—paddlefish	1	1	1	100
SALMONIDAE—trout	3	20	0	0
ESOCIDAE—pike	1	24	19	79.1
CATOSTOMIDAE—suckers	3	36	25	69.4
CYPRINIDAE—minnows (including carp)	8	62	51	82.2
ICTALURIDAE—catfish	2	238	209	87.8
SERRANIDAE—bass (white bass)	1	3	3	100
CENTRARCHIDAE—sunfish (including largemouth and smallmouth bass)	5	139	107	76.9
PERCIDAE—perch (including walleye)	3	64	34	53.1
SCIAENIDAE—drum	1	2	0	0
Totals	**28**	**589**	**449**	
Av. infection rate				**76.3**

PHYLUM PLATYHELMINTHES (flatworms)

CLASS TREMATODA (flukes or trematodes)

The flukes are all parasitic. For the most part they are small, leaf-shaped animals and have either one or two suckers for attachment. They have a simple digestive tract with a single opening, the mouth. They are monoecious except in one group, the blood flukes or schistosomes.

ORDER MONOGENEA

The monogenetic flukes of fishes are tiny ectoparasites of the fins, skin, or gills. None were observed on fishes examined here, but it would be difficult to believe they are absent in the state. Usually they die soon after the fish is removed from the water, and most of the fish in this study were examined after refrigeration.

These flukes are of greatest concern in fish hatcheries where their direct life cycle favors rapid increase and spread among crowded fish. The first evidence of their presence may be frayed fins or characteristic movements of the fish in scraping their sides as if trying to remove an irritant. A secondary effect is the appearance of fungus growths which have gained a foothold through the tiny breaks made in the skin by the hooks of the flukes. Cases of high fish mortality have been reported in hatcheries from epizootics of these flukes, which are frequently referred to as "gyros" or gyrodactyls. Methods of control in hatcheries are given by Allison (1950) and Davis (1953).

ORDER DIGENEA[3]

This order contains the vast assortment of endoparasitic flukes which have complicated life cycles involving one or more intermediate hosts, the first of which is always a mollusc (a snail or a clam). Refer to the section, "Life Cycles in General," for a discussion of larval stages. It bears repeating that as far as the fisherman is concerned, the digenetic flukes most likely

[3]La Rue (1957) has proposed a new system of classification in which he raises DIGENEA from Order to Subclass. However, the older, more familiar classification will be followed here.

to be seen are larval stages (metacercariae) occurring in the flesh of the fish.

Family DIPLOSTOMIDAE (STRIGEIDA)

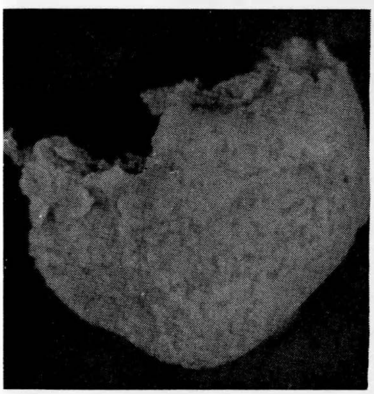
Most of the metacercariae found in flesh of fresh-water fishes in this country belong in the group Strigeida (or Strigeoidea). This group, collectively referred to as the strigeids, consists of several families, the most familiar perhaps being the Strigeidae (formerly Holostomidae) and the Diplostomidae. Two distinguishing anatomical features of the strigeids are (1) the division of the body into two distinct regions (forebody and hindbody), and (2) the presence of a large "holdfast organ" just posterior to the ventral sucker. Another unifying feature of the group is the close similarity in life cycles, including the presence of fork-tailed cercariae in the cycle. The most exhaustive treatment of this entire group is a monograph and its supplement by Dubois (1938, 1953).

As was indicated in the section on life cycles, most strigeid metacercariae found in fishes reach maturity in the intestines of fish-eating birds. Olivier (1940) gave a table outlining partially or completely the life cycles of 42 species of strigeids. A useful key to strigeid metacercariae (some 21 species) found in North American fishes was given by Hoffman (1955).

1. Posthodiplostomum minimum (MacCallum, 1921). Metacercaria, the "white grub" of liver (Figures 8, 9, 10).

Host: Bluegill, white crappie, black crappie, and northern rock bass. (Also reported from other fishes elsewhere.) In liver and sometimes other viscera.

In several South Dakota lakes the bluegills and crappie had their livers (and occasionally other viscera) riddled with these metacercariae (figure 8), which were enclosed by a thin, transparent membrane and often had the hindbody folded opposite the forebody (figure 9). This metacercaria has been recorded from 97 species of 18 families of fresh-water fishes, but it is predominant in the sunfish and minnow families. Apparently there are two physiological strains or subspecies of *P. minimum* metacercariae which



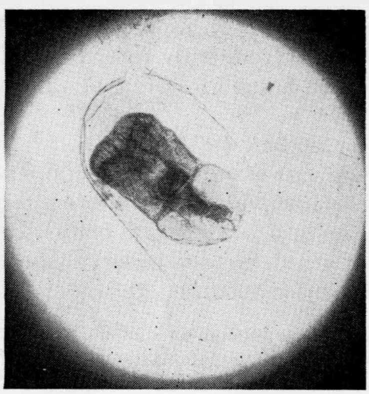


Figure 8. (left) Liver of bluegill packed with "white grubs," *Posthodiplostomum minimum* (X 2).

Figure 9. (right) Enlarged view of "white grub" to show loose-fitting, membranous cyst wall (X 33).

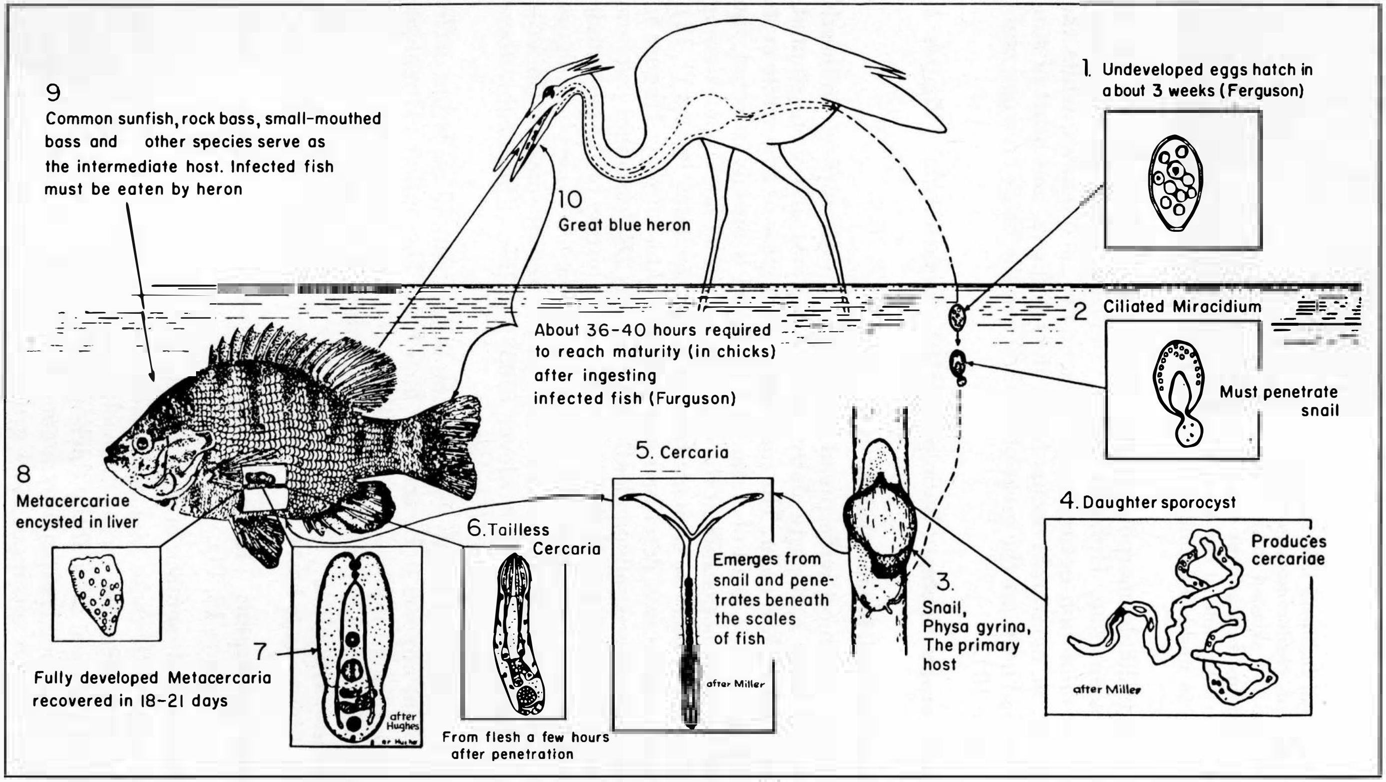


Figure 10. Life cycle chart of the "white grub," *Posthodiplostomum minimum.* (After Hunter; courtesy of the New York State Conservation Department.)

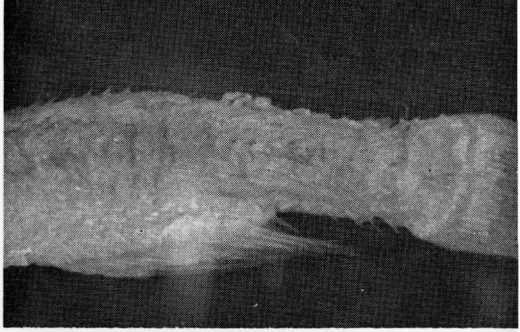


Figure 11. Small bullhead infected with metacercariae of *Hysteromorpha triloba* (X 1). The fish was skinned to show the tiny white cysts just beneath the surface. Cysts are most noticeable at the base of the tail, even in unskinned bullheads.

are indistinguishable morphologically (Hoffman, 1958a). In his key to strigeid metacercariae, Hoffman (1955) indicated that the subspecies *P. minimum minimum* occurs in the mesenteries of minnows, while the subspecies *P. m. centrarchi* occurs in the liver, kidneys, and heart of sunfishes. The final hosts are the great blue heron and the black-crowned night heron (figure 10).

2. Hysteromorpha triloba (Rudolphi, 1819). Metacercaria. (Figures 1, 11, 12).

Host: Black bullhead. In musculature.

This was the most widespread fluke found in the survey. Bullheads from several lakes had particularly heavy infections and were stunted, emaciated, and of bad color. The metacercariae appear as tiny white cysts about the size of the head of a pin. If a bullhead is heavily infected, the cysts will be most noticeable at the base of the caudal fin. Upon skinning the bullhead, cysts may be seen scattered through the flesh (figures 11, 12). This metacercariae was described as *Diplostomulum corti* by Hughes in Illinois in 1929. It was independently described as *Diplostomum trilobum* by Ciurea in Roumania in 1930. The complete life history of the trematode was worked out by the author (Hugghins, 1954; see life cycle chart, figure 1). The cysts have been listed as *D. corti* in two recent surveys: Haderlie (1953) in California and F. P. Meyer (1958) in Iowa. Presumably these cysts were metacercariae of *H. triloba*.

This trematode is highly host specific throughout all of its life cycle. The cormorant appears to be the only final host. The author (Hugghins, 1956c) fed infected bullheads to a pelican, which is closely related to the cormorant, but was unable to establish the adult flukes in the pelican. In other studies, Hugghins (1956a,b) found the focus of infection in snails (the first intermediate host) to be in the vicinity of cormorant rookeries.

3. Uvulifer ambloplitis (Hughes, 1927) and other "black grubs." Metacercaria. (Figures 13, 14).

Host: Minnows and sunfishes. In skin.

Infection with these metacercariae is called "black spot" or "black grub" infection. The tiny larvae themselves are white, but the fish host lays down black pigment around the thick-walled cysts. Black grubs are widespread and common, particularly among minnows (figure 13). Hoffman's (1955) key lists six species of black grubs belonging to the strigeid flukes,

Figure 12. Microphotograph of sectioned bullhead muscle containing metacercariae of *Hysteromorpha triloba* (X 90). Left, sagittal section through a metacercaria; right, cross section.

but the life cycles are known for only two (*Uvulifer amblopliitis* and *Crassiphiala bulboglossa*), both of which use a kingfisher as the final host (Hunter and Hunter, 1934, and Hoffman, 1956). The life cycle for *U. amblopliitis* is shown in figure 14. (Trout sometimes have black grubs, metacercariae of *Apophallus imperator* and *A. brevis,* belonging to a different group of flukes than the strigeids, the Heterophyidae.)

Family CLINOSTOMIDAE

Clinostomum marginatum (Rudolphi, 1819). Metacercaria, "yellow grub." (Figures 15, 16).

Host: Black bullhead. (Also widespread in other fishes.) In skin, particularly at base of fins.

This is one of the most familiar trematode parasites of wildlife. The large metacercaria is known to fishermen as the "yellow grub." It shows low host specificity in that is may occur in a wide variety of fishes, but in this particular study in South Dakota it has been observed only in bullheads. The adult flukes are found in the mouth and gullet of fish-eating birds such

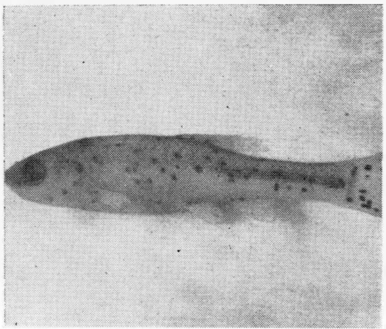


Figure 13. Minnow infected with "black grubs" (X 1).

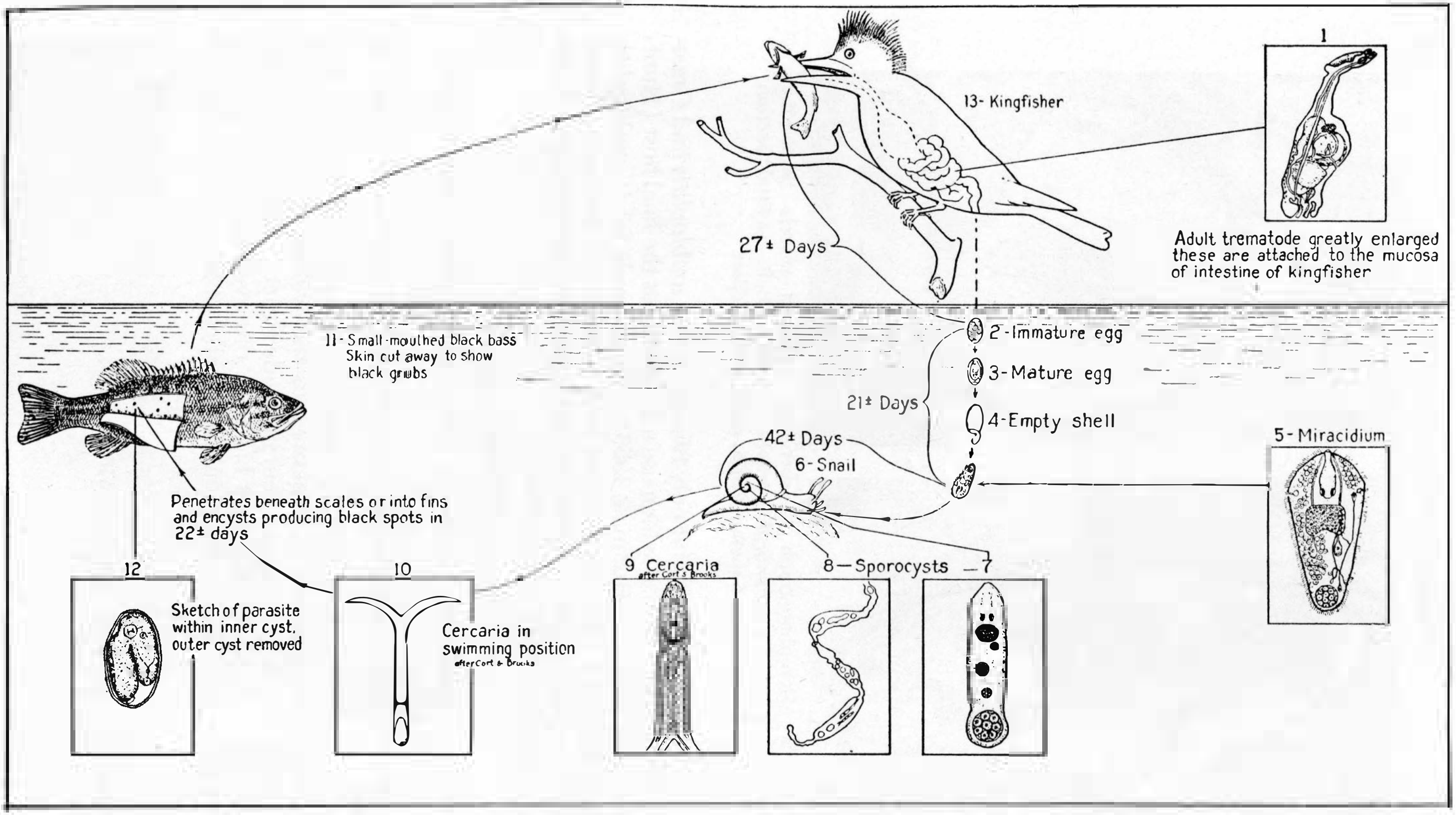


Figure 14. Life cycle chart of a "black grub," *Uvulifer ambloplitis.* (After Hunter and Hunter, 1934; courtesy of the New York State Conservation Department.)

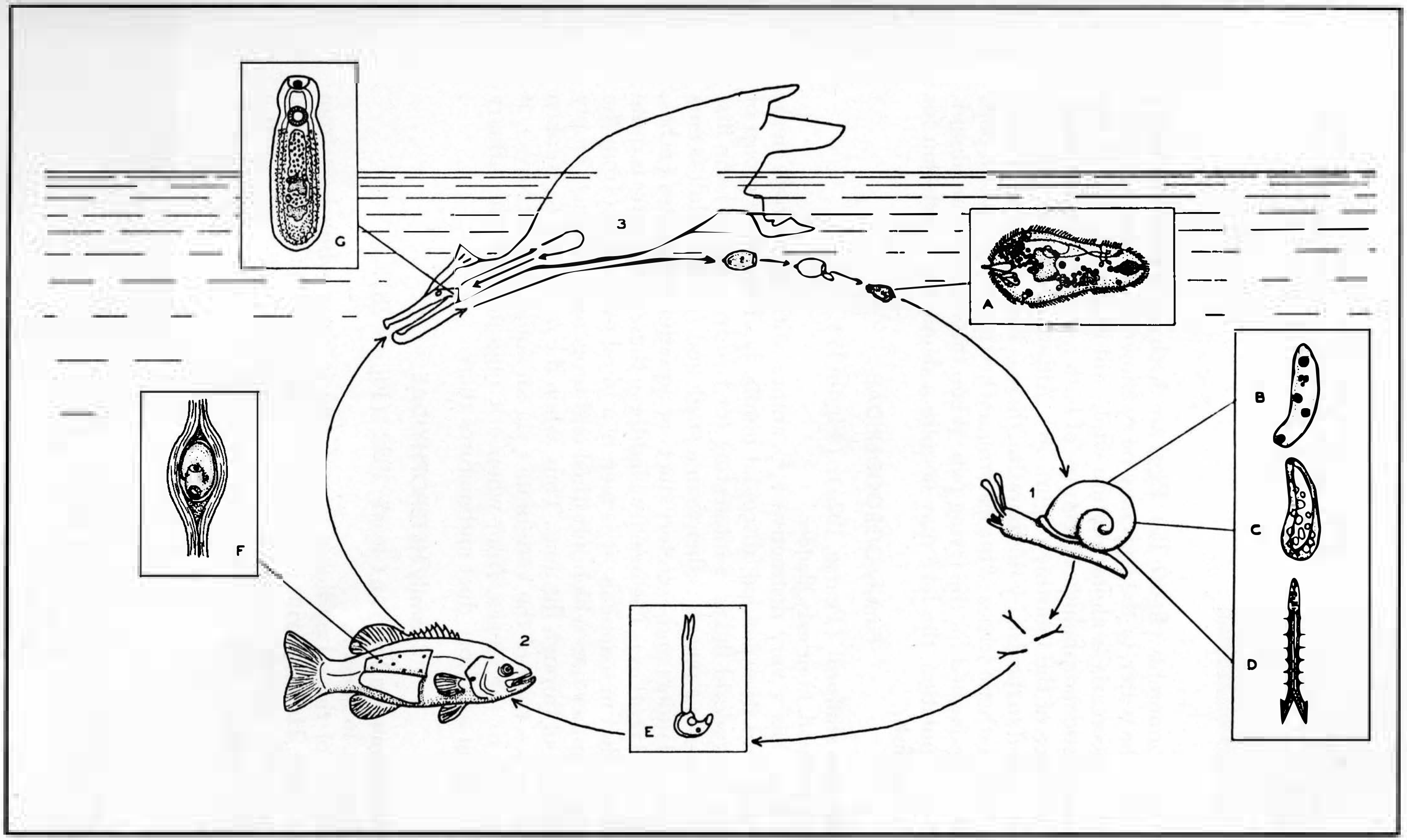


Figure 15. Life cycle of the "yellow grub," *Clinostomum marginatum.* A—free-swimming miracidium which hatches from egg in water; B—sporocyst; C—redia; D—cercaria. All are larval stages occurring within a snail, the first intermediate host (number 1). E—free-swimming cercaria which escapes from snail and penetrates flesh of fish, the second intermediate host (number 2); F—metacercaria encysted in flesh of fish; G—adult fluke in mouth and gullet of fish-eating bird, the final host (number 3). (Modified from Hunter and Hunter, 1934, by M. C. Meyer, 1954; courtesy of the Maine Department of Inland Fisheries and Game.)

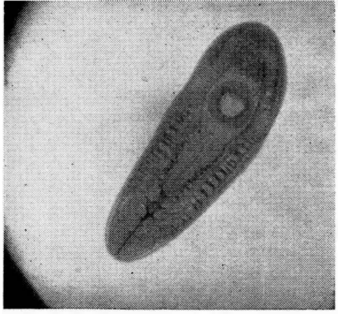


Figure 16. View or "yellow grub," *Clinostomum marginatum*, to show the distinctive intestine with its irregular borders (X 9).

as herons and cormorants (figure 15). Eggs are discharged when the bird's beak dips into the water, or the eggs may be swallowed and pass out in the feces. The metacercaria is almost mature while still in the fish; one of the most characteristic morphological features of both metacercaria and adult is the appearance of the intestine (figure 16). Although opinion varies as to damage caused to the fish by this parasite, there is little doubt as to damage done to the esthetic senses of the fisherman when this plump worm pops out of fish being cleaned for the frying pan. When these worms are abundant in a fish population, the lake may acquire a damaging reputation for having grubby fish.

Family GORGODERIDAE

Phyllodistomum staffordi (Pearse, 1924). (Figure 17).
Host: Black bullhead. In urinary bladder.

This fluke has a very distinctive appearance with its narrow, necklike forebody and its expanded, discoidal hindbody. The entire group of fresh-water gorgoderid flukes is interesting for two reasons: (1) the first intermediate host is a mussel rather than a snail, and (2) the adult occurs in the urinary bladders and excretory ducts of aquatic vertebrates (fishes, amphibians, and reptiles). The urinary bladder in these vertebrates is quite different from that in mammals; it is merely a blind evagination from the cloaca, that chamber into which intestinal and urogenital products empty before passing out through the anus. Thus, when the metacercaria is taken into the digestive tract of the vertebrate (via an aquatic insect larva), it passes through to the cloaca, from whence it migrates into the urinary bladder or up an excretory duct and matures there.

Family HETEROPHYIDAE

Allacanthochasmus varius Van Cleave, 1922. (Figure 18).
Host: White bass. In intestine.

Hundreds of these tiny flukes were found in three white bass from Big Stone Lake. Heterophyids are extremely small intestinal flukes which are covered with minute spines and have a distinctive structure called a gonotyl. The latter is a sucker-like structure surrounding the genital pore

Figure 17. *Phyllodistomum staffordi*, a gorgoderid fluke from the urinary bladder of bullheads (X 9). Note the narrow forebody and the discoidal hindbody.

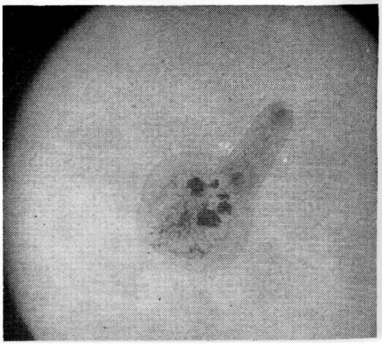
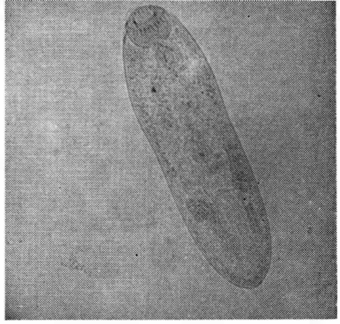


Figure 18. *Allacanthochasmus varius* (juvenile), a tiny fluke from the intestine of white bass (X 31). Note the large spines on the oral sucker surrounding the mouth.



and usually lying to one side of the ventral sucker. *A varius* is cylindrical with rounded ends. A single row of large spines surrounds the oral sucker, and very tiny spines cover the remainder of the body, becoming finer posteriorly. A pair of black pigmented "eyespots" are at the level of the pharynx, especially noticeable in young specimens. Minnows are believed to serve as the second intermediate host (Mueller and Van Cleave, 1932, 1934).

Family LISSORCHIIDAE

Triganodistomum spp.

Host: White sucker. In intestine.

These are small intestinal flukes which have relatively large suckers and often have microscopic spines covering a portion of the body. In the South Dakota study two species were found, which were believed to be *T. simeri* Mueller and Van Cleave, 1932, and *T. polylobatum* Haderlie, 1950, although F. P. Meyer (1958) gave reasons for suspecting that *T. polylobatum* might be a synonym of *T. attenuatum* Mueller and Van Cleave, 1932. For the one known life cycle of this genus, see the section on life cycles.

CLASS CESTOIDEA, SUBCLASS CESTODA (tapeworms)

This is the second class of flatworms in which all of the members are parasitic. The tapeworms are even more highly specialized for a parasitic life than the flukes in that they have no vestige of a digestive system and must absorb all of their food through their body wall. It is probably for this reason that adult tapeworms are restricted in habitat to the intestinal tract of the final host. The tapeworm attaches itself to the lining of the host's intestine by its tiny head, or scolex; the organs of attachment are either longitudinal grooves or in-cupped suckers in most tapeworms of fresh-water fishes. The body consists of a long series of segments, or proglottids, each of which contains a complete set of male and female reproductive organs. However, in the most primitive tapeworms there are no proglottids and the elongate body contains a single set of male and female reproductive organs.

ORDER CARYOPHYLLIDEA

This group of tapeworms is atypical in that there are no proglottids; hence there is only one set of reproductive organs per worm. Wardle and McLeod (1952) regard this condition of sufficient significance to justify setting up a separate order for the group, although the worms formerly were placed in the Order Pseudophyllidea on the basis of their scolex.

Table 4 Occurrence of Fish Parasites in Principal Bodies of Water Sampled

Numbers below=no. of fish infected with each kind of parasite	Big Stone Lake, Roberts & Grant Counties	Waubay Lake, Day Co.	Willow Lake, Clark Co.	Lake Poinsett, Hamlin & Brookings Counties	Oakwood Lakes, Brookings Co.	Lake Goldsmith, Brookings Co.	Lake Hendricks, Brookings Co.	Big Sioux R. & tributaries in Brookings Co.	Lake Madison, Lake Co.	Brant Lake, Lake Co.	Wall Lake, Minnehaha Co.	Beaver Lake, Minnehaha Co.	Lake Menno, Hutchinson Co.	Lake Andes, Charles Mix Co.	Fort Randall Reservoir, Missouri R.	Wilmarth Lake, Aurora Co.	Fish Lake, Aurora Co.	Lake Fraiser, Aurora Co.	Crow Lake, Jerauld Co.	Lake Chapelle, Hyde Co.	Lake Louise, Hand Co.	Cottonwood Lake, Spink Co.	Lake Mina, Edmunds Co.	Red Plum Lake, Stanley Co.	Rapid Creek, Pennington Co.	Black Hills streams	Angostura Reservoir, Cheyenne R., Fall River Co.
No. of fish examined	25	29	18	9	100*	32	11	44	20	21	2	5	8	7	18	10	14	23	9	7	26	26	28	32	16	25	11
No. parasitized	23	29	12	8	96	19	5	33	17	14	2	3	7	7	18	10	13	23	5	0	23	14	14	27	16	4	7
Posthodiplostomum minimum† (white grub)	4												4‡			4‡	5‡	9‡			16‡		1	17‡	10‡	3‡	1
Hysteromorpha triloba†	4‡		5		95‡	6	3			1			1	7‡			8‡	14‡			6	11	6				6‡
Uvulifer ambloplitis† (black grub)								21‡																	6‡		
Clinostomum marginatum† (Yellow grub)																1	4	2			1						
Phyllodistomum staffordi																							2				3
Allacanthochasmus varius	3‡																										
Triganodistomum spp.						3																					
Glaridacris catostomi			2							2																	
Caryophyllaeidae spp.	1‡		2‡			3																					
Bothriocephalus cuspidatus	1	4‡							2‡	7					2									3		1	
Marsipometra hastata															1‡												
Ligula intestinalis†		10																									
Proteocephalus ambloplitis (adult)																							1‡				
P. ambloplitis† (plerocercoid)									7														2				
Proteocephalus fluviatilis																							1	10			
Proteocephalus pinguis	4‡	7‡	3					2	2‡													2‡					
Proteocephalus sp.†		2	1						1	1	1				2						1		4				
Corallobothrium fimbriatum										1			2		2‡						1						
Corallobothrium giganteum			1			2						2															
Contracaecum spiculigerum†	2				3	2	3	1	13‡	1					2	1			5			4	2				
Camallanus oxycephalus	9‡														12‡	2		3			2						
Philometra nodulosa				7				2																			
Nematoda sp.†	2	1						1		1				5	1						2						
Pomphorhynchus bulbocolli	7	15‡						1													1						
Neoechinorhynchidae spp.	1	3						2				2															
Gorgorhynchidae (?) sp.							2							2													
Myzobdella moorei						2	1								5‡							1					
Argulus biramosus (fish louse)				9§			1			§																	
Lernaea cyprinacea (anchor worm)								11							1												
Achtheres ambloplitis						2	2‡				2‡																
Lymphocystis									1																		
Saprolegnia sp. (water mold)				7																							
Large tumors on fish									3		1											3					

*This was a long series of bullheads, most of which were examined for only one parasite, *H. triloba*.
†Indicates larval stage of parasite.
‡Indicates heavy infection in fish parasitized.
§Epizootics of *Argulus biramosus* not included in this tabulation.

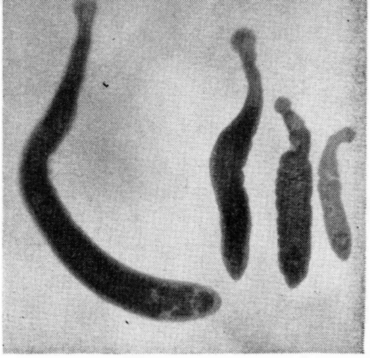


Figure 19. Carophyllaeid tapeworms of suckers (X 7). Note the absence of segmentation.

Family CARYOPHYLLAEIDAE

Glaridacris catostomi Cooper, 1920. (Figure 19).

Host: White sucker. In small intestine.

Infected suckers had large numbers of these worms in various stages of development. This species has three pairs of shallow depressions on the scolex, but they are not evident in mounted specimens. Tubificid oligochaetes (tiny, fresh-water annelids in the same class with earthworms) are believed to serve as intermediate hosts (Hunter, 1927; Van Cleave and Mueller, 1934).

Undetermined species

Two small undetermined species of caryophyllaeids were also found in white suckers. One species closely resembled *Monobothrium ingens* Hunter, both in morphology and in habitat, occurring in little pockets in the mucosa of the small intestine. John S. Mackiewicz (Cornell University) is in receipt of specimens of the two forms and has stated that they are new species which he is in the process of describing. Evidently, the listing of *Monobothrium ingens* in an abstract by the author (Hugghins, 1958a) was premature.

ORDER PSEUDOPHYLLIDEA

The most characteristic single feature of this group is the organ of attachment: a pair of longitudinal suctorial groves, or bothria, placed on opposite sides of the scolex. The body is made up of a long chain of proglottids, most of which are in a similar stage of development. Each proglottid releases eggs through a uterine pore. The life cycle typically involves a microcrustacean as the first intermediate host and a fish as the second intermediate host (see section on life cycles).

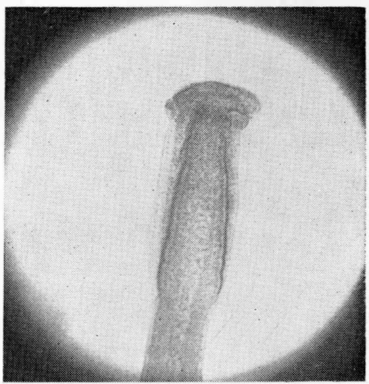
Family BOTHRIOCEPHALIDAE

Bothriocephalus cuspidatus Cooper, 1917. (Figure 20).

Host: Walleye and sauger. In pyloric caeca and upper small intestine.

This tapeworm was very common in walleys from lakes of eastern South Dakota, and it also was found in sauger from the Missouri River at

Figure 20. Scolex of *Bothriocephalus cuspidatus*, a tapeworm of walleyes (X 34), showing the rectangular shape with a pair of longitudinal grooves.



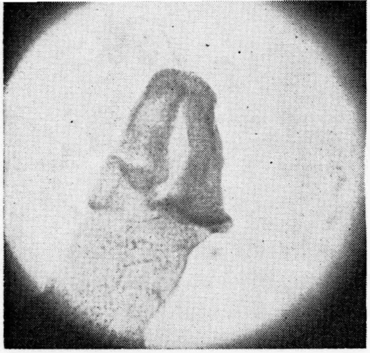


Figure 21. Scolex of *Marsipometra hastata*, a tapeworm of the paddlefish (X 34), showing the arrowhead shape with a pair of longitudinal grooves.

Fort Randall Dam. The worms were particularly abundant in the pyloric caeca (blind tubes leading off the stomach). Many tiny immature stages were often present, but even the smallest ones had the characteristic scolex.

The scolex of this species is easily recognizable because of its elongate, somewhat rectangular shape, with long bothria on opposite sides of the rectangle (figure 20). The proglottids are sharply demarcated, and a curious feature is that many are subdivided to give two proglottids in a segment. A feature of importance to the taxonomist is that the genital aperture and the uterine aperture open medianly on opposite surfaces of the proglottid. The eggs are atypical for the Order in that they lack an operculum. Copepods (several species of *Cyclops*) serve as the first intermediate host, and according to Essex (1928), a second intermediate host is improbable.

Family AMPHYCOTYLIDAE

Marsipometra hastata (Linton, 1891) Cooper, 1917. (Figure 21).

Host: Paddlefish. In stomach, pyloric caeca, and spiral valve of intestine.

This tapeworm occurs only in the primitive paddlefish, or "spoonbill," of the Mississippi drainage system. In our study a single fish was obtained from the Missouri River at Fort Randall Dam. It was comparatively small, 19 inches long (of which the bill comprised 7 inches), but the stomach and caeca contained more than 100 of the tapeworms, and the spiral valve had more than 35 worms. There was a wide range in sizes of the worms, many being very immature stages. All stages had the characteristic scolex which is shaped like an arrowhead (sagittate) with an oval groove on each side (figure 21). This pseudophyllidean has the genital apertures lateral instead of in the usual median position. The life cycle is unknown as yet, but F. P. Meyer (Iowa State University) is working on it. Beaver and Simer (1940) described two additional species of *Marsipometra* from paddlefish, but their two species were not found in our study.

Family DIBOTHRIOCEPHALIDAE (=DIPHYLLOBOTHRIIDAE)

Ligula intestinalis (Linnaeus, 1758). (Figure 22).

Host: Fathead minnow. In body cavity.

A number of fathead minnows from a small lake near Waubay had their abdomens bulging with these worms (figure 22). The form found in fishes is the plerocercoid, which is a thick, fleshy worm, tapered at both

Figure 22. Larval tapeworm, *Ligula intestinalis,* in abdomen of fathead minnow (X 1).

ends. It has no division of the body into proglottids and no functional bothria. There is a shallow median furrow along the entire length. This large, nondescript worm fills the body cavity of the fish and causes distention of the abdomen. Sometimes the body wall ruptures, and a portion of the worm pops out.

This larval tapeworm has been reported from a wide variety of fish hosts under a correspondingly large number of names, all of which were reduced to synonymity with *L. intestinalis* by Cooper (1918). He found that the size of the larval worm varied according to the size of the host. The adult worm has a very brief existence in the gut of fish-eating birds. In some areas gulls have been incriminated as final hosts (Pitt and Grundmann, 1957), while in other areas mergansers and great blue herons are believed to be the most likely hosts (Dence, 1958). More work is needed on the life history of *Ligula*.

ORDER PROTEOCEPHALA

These tapeworms have four in-cupped suckers on the scolex and sometimes a fifth or apical sucker at the anterior tip. This alone is sufficient to distinguish this group of tapeworms from the other major group (Pseudophyllidea) found in fresh-water fishes. However, should only a posterior portion of a tapeworm be recovered, it is still easy to distinguish between these two major groups. Some differences besides the scolex are as follows: adult proteocephalids have (1) proglottids in different stages of development (immature, mature, gravid), (2) genital pores lateral in position, and (3) yolk glands in lateral bands. In contrast, adult pseudophyllideans have most of the proglottids in the same stage of development, genital pores usually mid-ventral in position, and yolk glands scattered profusely in dorsal and ventral sheets. Usually the worm must be stained, cleared, and mounted to see these structures, but Southwell (1930) described a quick temporary method of clearing tapeworms by using carbolic acid. The life cycles of the two groups are quite similar, as was discussed in the life cycle section. The plerocercoid larvae are distinguished primarily on the basis of suckers versus bothria.

Family PROTEOCEPHALIDAE

1. **Proteocephalus ambloplitis** (Leidy, 1887). "Bass tapeworm." (Figures 4, 23, 24).

Host: Largemouth bass (also reported in other fish). In pyloric caeca and intestine.

The "bass tapeworm" is generally regarded as the most damaging tapeworm of fresh-water fishes. The life cycle (figure 4) involves a fish both as second intermediate host and as final host. It is the larval stage (plerocercoid) which is so damaging because it destroys reproductive

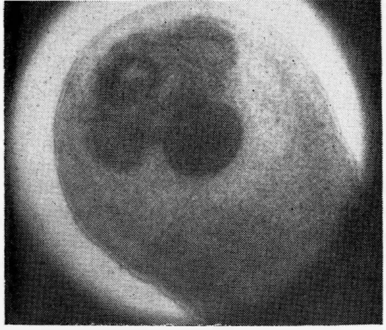


Figure 23. Plerocercoid of bass tapeworm, *Proteocephalus amblopitis*, anterior end (X 34). The dark, spherical structure beneath the four suckers is the characteristic "terminal organ" (vestigial fifth sucker).

potential in game fishes (see section on effects of parasites on fishes). Both the adults and the plerocercoids have been reported from several species of fishes, but they appear to be of greatest importance in the smallmouth and the largemouth basses.

Proteocephalid plerocercoids are widespread in fishes (occurring particularly in the liver) and most of them are very difficult to identify, but the plerocercoid of *P. amblopitis* can be separated from all the others by the peculiar and characteristic vestigial fifth sucker (Hunter, 1928). This is a large spherical, deep-staining organ which is posterior to the four smaller suckers and at the end of a tiny tube in earlier stages; after evagination of the scolex, this organ moves up to the level of the functional suckers (figure 23). The structure persists in young adults until well after proglottid formation, and even when it begins to degenerate, it differs from the apical sucker in other five-suckered proteocephalids because it is larger, more deeply set, and nonfunctional. The four functional suckers in *P. amblopitis* are much larger than those of most members of the genus and are set to the sides of a large, globular scolex (figure 24). In contrast, most other members of the genus have suckers set on the anterior face of a small scolex which is no larger than the neck in diameter (figure 25). Another recognition feature is the dumbbell shape of the egg, as shown in figure 4.

At Lake Mina, South Dakota, adult *P. amblopitis* were found in largemouth bass, and plerocercoids were in the liver of bullheads. Perch from the same lake had much smaller, slimmer proteocephalid larvae which had a tiny apical sucker rather than the large vestigial sucker of *P. amblopitis*. The bass in the lake also had other species of *Proteocephalus* which probably were the adults of the larval stages seen in perch.

Bangham (1925) in his studies on proteocephalids of bass found that the fish acquire their infections very early while 80-90% of the food is copepods (the first intermediate host). Bass stop feeding on microcrustaceans shortly after reaching 40 millimeters (about 1½ inches), after which their chances of acquiring larval tapeworms in their viscera are greatly reduced. When the bass get larger, they can acquire the adult tapeworm by engesting smaller fish infected with plerocercoids.

2. Proteocephalus fluviatilis Bangham, 1925. (Figure 25).
Host: Largemouth bass. In intestine.

This is one of the proteocephalids which has a tiny scolex, no larger than the neck, with four small suckers set well forward. It has a fifth apical

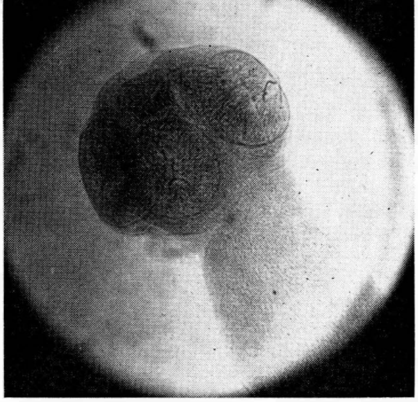


Figure 24. Scolex of adult bass tapeworm, *P. ambloplitis* (X 40), showing four large suckers set to side of globular scolex. The vestigial fifth sucker shows faintly near the apex.

sucker which is functional. One feature which separates this species from some other species with similar scolices is the small number (three, five, or seven) of lateral outpocketings of the gravid uterus on either side.

3. Proteocephalus pinguis La Rue, 1911. (Figures 3, 26, 27).

Host: Northern pike. In intestine.

This species was found in large numbers in northern pike (figure 26). A good recognition character is the broad, spatulate scolex set off from a slender neck and bearing five small suckers at the anterior end, one being apical (figure 27). Hunter (1929) was of the opinion that the pike could become infected either by engesting copepods containing the procercoid or by feeding upon other fishes which had engested infected copepods (see life cycle chart, figure 3). This might explain the heavy build-up of infections in pike.

4. Corallobothrium fimbriatum Essex, 1927. (Figure 28).

Host: Black bullhead and channel catfish. In intestine.

A catfish from the Fort Randall Reservoir had more than 30 of these worms; they were found sparingly in catfish and bullheads from a few other areas. The worms have a very distinctive scolex. The four suckers

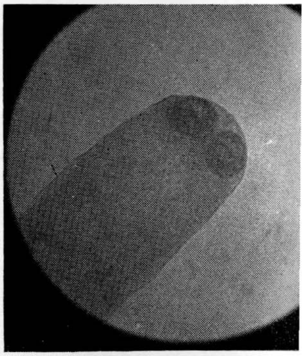
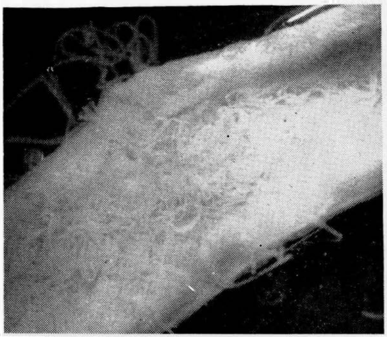
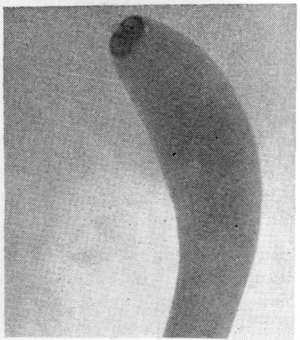


Figure 25. (upper) Scolex of *Proteocephalus fluviatilis*, a tapeworm of bass (X 60). The five small suckers (including the fifth apical one) are set on the anterior end of a tiny scolex.

Figure 26. (lower left) Opened intestine of northern pike heavily infected with *Proteocephalus pinguis*.

Figure 27. (lower right) Scolex of *P. pinguis* (X 21), showing the broad, spatulate shape with five small suckers (the fifth being apical) at the anterior end.





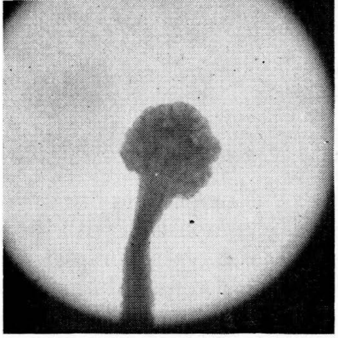


Figure 28. (upper left) Scolex of *Corallobothrium fimbriatum* (X 6), a tapeworm of bullheads and catfish. Note the elaborate collar of loose tissue surrounding the four suckers.

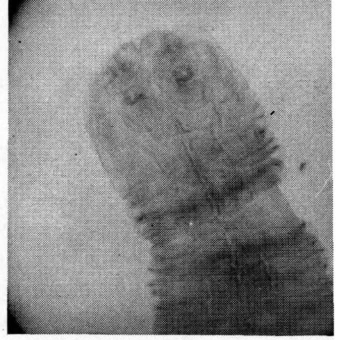


Figure 29. (upper right) Scolex of *C. giganteum* (X 11) of bullheads. The collar is lacking, but many folds and wrinkles are present.

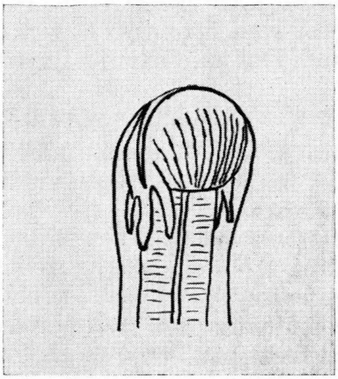


Figure 30. (lower left) Head of roundworm, *Camallanus oxycephalus* (X 105), showing the two valve-like jaws and the trident-shaped structures at their juncture.

Figure 31. (lower right) Bigmouth buffalo with fish "guinea worm," *Philometra nodulosa* (X 1). The position of the worm is marked by an inflamed, tortuous ridge.

are on the anterior face of the scolex and are surrounded by a pronounced collar of loose tissue forming irregular folds called fimbriae (figure 28). This species is quite small, usually about 1 inch in length. Essex (1927) showed that catfish could acquire the worms either by engesting infected copepods or by engesting minnows which had fed on copepods. His observations indicated that the larva would not mature during the winter months in the catfish.

5. Corallobothrium giganteum Essex, 1927. (Figure 29).
Host: Black bullhead. In intestine.

This species is much larger than *C. fimbriatum,* reaching a maximum length of 44 centimeters (about 1½ feet). Also, there is not so elaborate a collar on the scolex. A very large specimen was found in a bullhead from Beaver Lake, and immature specimens were found in bullheads from several other lakes.

PHYLUM ASCHELMINTHES

CLASS NEMATODA (Roundworms)

The nematodes were formerly placed in the Phylum Nemathelminthes, but many authorities now discard the latter term and place the nematodes rather loosely with several other groups in the Aschelminthes. As was mentioned in the life cycles section, the majority of the nematodes are tiny free-living forms in soil, fresh waters, and marine waters. The nematodes which have taken up parasitic habits in plants and animals are little changed morphologically from their free-living relatives, although some of the parasites of animals have become much larger than any free-living form. The nematodes are cylindrical, unsegmented worms which are rather stiff in comparison with the pliant flatworms. Unlike the flatworms, the nematodes have a complete digestive tract with a mouth at the anterior tip and a subterminal anus posteriorly. The sexes are separate; the male usually is smaller than the female and often is curved at the posterior tip.

The roundworms were not nearly as well represented as the flatworms in the fishes of South Dakota. Only the three species discussed next were widespread.

Family ASCARIDAE

Contracaecum spiculigerum (Rudolphi, 1809.) Larvae. (Figure 6).

Host: Black bullhead, black crappie, largemouth bass. Encysted in mesenteries, particularly around stomach.

These worms were most common in the mesenteries of black bullheads in the South Dakota study. The stout white worms were usually about 1 inch or less in length and were loosely coiled. In the cleared specimen, a useful recognition feature is the presence of an intestinal caecum projecting forward to lie beside the esophagus. Other features are a tiny boring tooth at the anterior tip and a tiny caudal spine at the posterior tip. Thomas (1937) worked out the life cycle (figure 6). The adult worms are very common in the stomachs of cormorants and pelicans, where they mingle with fish being digested.

Family CAMALLANIDAE

Camallanus oxycephalus Ward and Magath, 1917. (Figure 30).

Host: Black crappie, white crappie, bluegill, largemouth bass, yellow perch, sauger, white bass, northern pike, channel catfish, paddlefish. In intestine.

These worms occured in far more species of fishes than any other parasite encountered in the South Dakota study. They are tiny red worms which have a pair of jaws consisting of two chitinous, shell-like structures. On the jaws are longitudinal ribs, and on each side at the posterior juncture of the jaw is a trident-shaped structure (figure 30). On several occasions when fish were refrigerated for several days awaiting examination, some of these worms migrated out through the anus and attached themselves firmly to the soft skin surrounding the vent. Some were even found on the anal fin of a catfish. Usually the worms were most numerous in the posterior end of the intestinal tract.

Members of this genus use copepods as the first intermediate host. In studies on a similar species from turtles, Thomas (1944) found that the second intermediate host could be dragonfly and damsel fly nymphs or even young salamanders and fish. Possibly *C. oxycephalus* has a similar life cycle.

Family PHILOMETRIIDAE

Philometra nodulosa Thomas, 1929. (Figures 5, 31, 32).

Host: Bigmouth buffalo and white sucker. Just below skin in head region.

These worms were found in several bigmouth buffalo from Lake

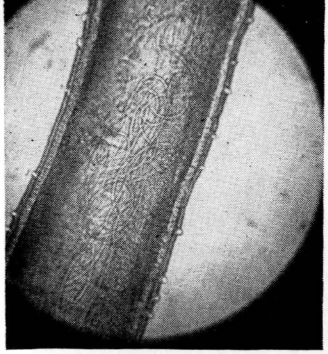
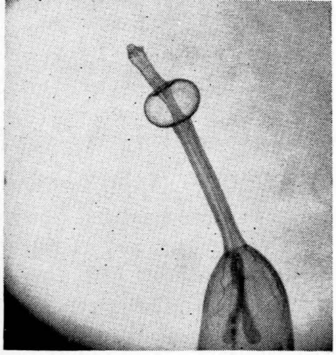
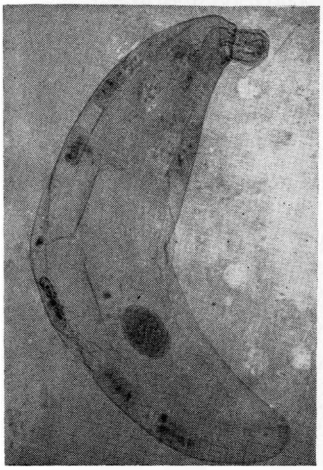
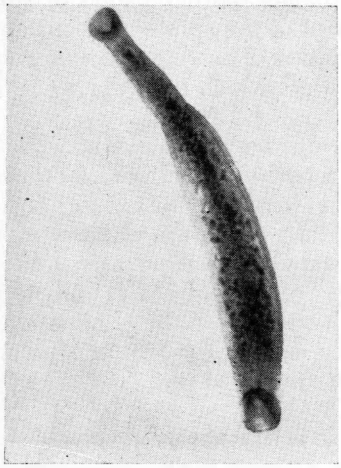





Figure 32. (upper left) Fish "guinea worm," ***Philometra nodulosa*** (X 62), showing characteristic papillae on cuticle (outer covering) and tiny larvae within body of worm.

Figure 33. (upper right) Spiny-headed worm, ***Pomphorhynchus bulbocolli*** (X 11) to show prominent bulb between slender neck and short, spiny proboscis.

Figure 34. (lower left) Neoechinorhynchidae (X 45) showing short globular proboscis with relatively few hooks. Note giant nuclei in body wall.

Figure 35. (lower right) Leech, ***Myzobdella moorei*** (X 7), showing the two body regions and the poorly developed suckers.

Poinsett and in two suckers from the Big Sioux River near Brookings. The long, slender worms were coiled just under the skin in the isthmus (ventral region between gills) and the preopercle (cheek) and sometimes extended across the lips. Their position was prominently marked by a raised, inflamed ridge (figure 31). Upon removing the worms, it was found that the posterior end lay considerably deeper than the anterior portion marked by the ridge. The longest worm measured was 70 millimeters (2¾ inches) in length. A recognition character for the species is the presence of refractive microscopic papillae on the outer covering (figure 32). As in all female dracunculid worms, the body was almost entirely occupied by the uterus filled with active larvae. When the worms were placed in water, the body wall ruptured, releasing hundreds of the tiny larvae. The average length of five larvae was 383 microns (a micron is 1/25,000 inch). The male of dracunculid worms is very minute and is seldom seen. The life cycle of this worm (figure 5) was worked out by Thomas (1929, 1944).

This worm is related to the large guinea worm, or "fiery serpent" (*Dracunculus medinensis*) of man, which has been known since ancient times in parts of Africa and Asia. The classical method of extraction was to slowly wind the worm out of the host's tissue onto a stick. A closely related species has been reported from wild carnivores in North America, including a raccoon from South Dakota (Hugghins, 1958b).

PHYLUM ACANTHOCEPHALA (Spiny-headed worms)

These worms have an elongate, unsegmented body which is flat in life within the host but quickly becomes cylindrical and turgid when placed in water or preservative. As in the nematodes just discussed, the sexes are separate, and the males are usually smaller than the females. The best recognition character is the protrusible proboscis which is covered with spines, hence the common name, thorny-headed or spiny-headed worm. The number and arrangement of the spines are constant within a species and are of value in classification. The spiny proboscis is anchored in the tissue lining the host's intestine, which often makes it difficult to remove the worm intact.

Like the adult tapeworms, the adult acanthocephalan is limited to a habitat in the intestinal tract of the final host, because the worm itself has no vestige of a digestive system and must absorb food through its body wall. Little is known about the mechanism of absorption in these worms. Bullock (1958) has demonstated enzyme activity in the subcuticula (just beneath the outer covering) of the body wall and stated that it is likely involved in absorption of foodstuffs or the elimination of the fatty acid waste products. Incidentally, one of the worms studied by Bullock was *Pomphorhynchus bulbocolli*, discussed next.

Family POMPHORHYNCHIDAE

Pomphorhynchus bulbocolli Linkins, 1919. (Figure 33).

Host: Carp, white sucker, yellow perch, northern pike, and black bullhead. In intestine.

Some authorities still retain *Pomphorynchus* in the Family Echinorhynchidae, but Ward (1951) placed the genus in the related Family Pomphorhynchidae as defined by Yamaguti. *P. bulbocolli* is easy to recognize because of the presence of a prominent spherical bulb between the short proboscis and the long, slender neck (figure 33). This is the only species of the genus recorded from North American fishes, although a few other species occur in Asia and Europe. Van Cleave (1947) described a new species, *Eocollis arcanus,* which superficially resembles *P. bulbocolli* but is basically different in that the bulb is on a narrow extension of the trunk rather than on the neck.

In the carp and suckers from Waubay Lake, South Dakota, literally hundreds of the worms were found, while few of the worms were found in other fish from the same lake. This supports Van Cleave and Mueller's (1934) statement that suckers and sucker-like fishes are the most frequent hosts of this species. Most of the worms were in the small intestine, but some were on the mesenteries and liver. In some instances, the spiny proboscis was protruding through the intestinal wall into the body cavity, and occasionally the worm's body was lodged in the perforation. Long ago, Van Cleave (1919) observed this tendency of *Pomphorhynchus* to penetrate the intestinal wall and to migrate into the body cavity of the host. Probably the alternate deflation and inflation of the bulb just posterior to the spiny proboscis aids in perforating the intestine. The life cycle has not been worked out experimentally, but Ward (1940b) observed juvenile stages of *P. bulbocolli* in an amphipod and in the mesenteries of small fishes. The cycle is probably similar to those of other acanthocephalans of aquatic vertebrates (see section on life cycles).

Family NEOECHINORHYNCHIDAE

Undetermined species. (Figure 34).

Host: Northern pike, creek chub, black bullhead, white bass, walleye, and yellow perch. In intestine.

The species of this family found in South Dakota are still awaiting positive identification. The family itself is easily recognized by its distinctive proboscis, which is short, globose, and armed with a relatively small number of hooks (figure 34). The hooks are widely spaced in three circles, those of the anterior circle being the largest. This is in contrast to other families in which the proboscis is longer and is covered with scores of rather uniform hooks set close together. Another characteristic of the family is the presence in the body wall of giant nuclei which typically are constant in number and arrangement, with five nuclei in the mid-dorsal line of the body and one in the mid-ventral line.

Family GORGORHYNCHIDAE (?)

Undetermined species.

Host: Black bullhead. In gastric mesenteries.

Two black bullheads from Lake Andes and two from Lake Hendricks had a few tiny female acanthocephalans which are believed to be in the family Gorgorhynchidae, as set up by Van Cleave and Lincicome (1940). It may prove impossible to identify them in the absence of male specimens.

PHYLUM ANNELIDA (Segmented worms)

CLASS HIRUDINEA (Leeches)

The leeches comprise one of several classes of the large phylum Annelida. They differ from the typical annelid in several respects, such as: presence of a sucker at each end of the body; usually flattened dorsoventrally; lateral diverticula or pouches branching off the intestinal tract for storage of food (many blood-suckers can go for months between meals); a constant number of 34 true segments, although each segment has several superficial annuli (rings). The layman might confuse a leech with a fluke, since both are usually flattened and have suckers. However, he can readily recognize the leech by a single external feature, namely segmentation.

Family PISCICOLIDAE

Myzobdella moorei (Meyer, 1940). (Figure 35).

Host: Channel catfish, black bullhead, and yellow perch. On fins and skin.

The Piscicolidae are rather small leeches found principally as ectoparasites on fishes. *Myzobdella moorei* (formerly *Illinobdella moorei*) was collected in South Dakota on fishes from a farm fish pond, a lake, and the Missouri River. This indication of wide distribution is in agreement with Meyer's (1946) finding that this species shows the greatest distribution of any piscicolid reported in North America. Meyer (1940) stated that this species has commonly been mis-identified as *Piscicola punctata*, and he gave a table of comparison for the two species. *M. moorei* (figure 35) has two distinct body regions, the anterior portion being smaller in diameter and shorter than the posterior. In fact, when the anterior segments contract, they give the illusion of telescoping into the larger posterior portion. The suckers are weakly developed; the small anterior sucker may show slight expansion, but the posterior sucker appears to be little more than a concavity in the body. This is in contrast to the expanded, well developed suckers typical of most leeches.

PHYLUM ARTHROPODA (Joint-footed animals)

CLASS CRUSTACEA, SUBCLASS COPEPODA

Of the million species of animals which have been described, more than three-fourths are arthropods. One of their most prominent features is the presence of jointed appendages (legs, antennae, mouth parts). The insects comprise the largest class of animals in the phylum, but the crustaceans are not far behind in numbers. They are largely aquatic and breathe either by means of gills or through the body surface. As in the annelids, the body is made up of a series of segments, but in the crustaceans the body usually is separated into two distinct parts: an anterior cephalothorax (fused head and thorax) and a posterior abdomen. There are two pairs of antennae (in contrast to one pair in the insects), and usually there are many pairs of legs.

The copepods are among the large group of tiny aquatic crustaceans referred to as microcrustaceans. They occupy an important place in the food chain and are a major item of diet for most fish fry, as well as for some adult fishes. During this parasite survey, a number of stomachs of adult fishes were found to be crammed with microcrustaceans, even in mid-winter. This makes the copepods ideal as intermediate hosts for some of the parasitic worms of fishes. However, at this point a few copepods which have themselves become adapted for a parasitic life on fishes will be discussed.

ORDER BRANCHIURA

Family ARGULIDAE

The argulids are flattened ectoparasites which move freely over the external surface of the host. They are also good swimmers in the water, as was pointed out in the section on life cycles. The body is composed of a large, rounded cephalothorax, a small free thorax of three segments, and a small bilobed abdomen which is unsegmented. A pair of prominent eyes are near the anterior border dorsally. The body is quite transparent. The most prominent structures on the ventral surface are a pair of suckers and four pairs of swimming legs (figure 40)). During larval development the suckers are formed from the first pair of maxillipeds (appendages associated with the mouth parts). The mouth has a protrusible, spine-like stinger which is equipped with a poison gland. The sexes can be distinguished externally. The unpaired ovary of the female appears as a yellowish, granular, elongate structure in the mid-ventral line of the cephalothorax. The paired testes of the male are in the abdomen, causing this structure to be somewhat larger in the male than in the female. (For detailed descriptions of the anatomy and development of argulids, see papers by Wilson, 1902, 1907, 1944, and by Meehean, 1940.)

Argulus biramosus Bere, 1931. (Figures 36, 37, 38, 39, 40).

Host: Walleye, northern pike, yellow perch, white sucker, carp, bigmouth buffalo, black bullhead, white crappie, black crappie. On external surface of body.

A serve epizootic of fish lice occurred at Brant Lake in June and July 1956, with high fish mortality attributed to the ectoparasites (figure 36). Evidently this has been a recurring event in the past, but the outbreak of 1956 was most severe, with hundreds of fish being killed (figure 39). Almost all species of fishes in Brant Lake were attacked; this includes all of the hosts listed above except bigmouth buffalo.

Allum and Hugghins (1959) conducted an investigation of the outbreak. Many dying fishes were dipped out of the water from a boat and immediately placed in separate buckets so that reasonably accurate counts of the fish lice could be made. A 19-inch walleye weighing 2.9 pounds had 805 argulids on it. Counts of 300 to 400 argulids per fish were common. The skin of the fishes had many red, inflammatory patches which apparently were caused by the argulids. There were indications that the fish lice were predominent on one species of fish at a time. Eggs of *Argulus* were found on submerged snags; some of these were transferred to an aquarium, where the eggs hatched and larval stages were observed.

An outbreak with fish lice occurred at Lake Poinsett in June, 1958. This outbreak differed from the one at Brant Lake in that only one species of fish, the bigmouth buffalo, was infested to any great extent. When resort owners complained that hundreds of dead fish were being washed up in windrows on the beaches, the lake was visited and many large schools of bigmouth buffalo were observed swimming feebly close to shore. Most of the fish were 8 to 10 inches long and in many cases the fins were frayed and almost gone (figure 38). The fish had inflamed lesions and growths of fungus on their bodies. It was believed that the high mortality was due primarily to secondary infection with fungi (probably the ever present water mold, *Saprolegnia*) following the breaking of the protective slime film of the fish by the argulids.

When some of these fish were dipped up, argulids were found on them. The people at the lake had not noticed the fish lice because they had looked for them primarily on dead fish. The parasites soon leave dead fish, and even when a freshly caught live fish is placed on the boards of a pier, argulids can be seen scuttling off in trickles of water on the boards. On live fish the flattened, transparent argulids blend with the mucous coat on the fish (figure 37) and are not easy to detect unless they move. The easiest way to detect stationary argulids is to look for the black eye spots.

Apparently this is the first published record of argulids from South Dakota, but a recent paper (anonymous, 1952) reported several outbreaks in neighboring Minnesota in which there was high mortality among walleyes and bullheads. There are very few records of argulids occurring on any host other than fishes. Goin and Ogren (1956) reported *Argulus* from a salamander and a frog tadpole. Hargis (1958) reported a freak occurrence of an argulid in the eye of a human who acquired the parasite while swimming open-eyed in a river.

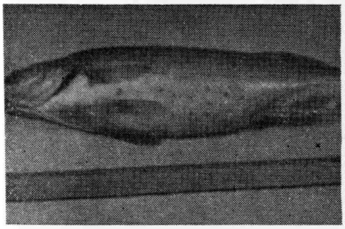
ORDER EUCOPEPODA

Family LERNAEIDAE

Lernaea cyprinacea Linnaeus, 1758. "Anchor worm." (Figures 41, 42).
Host: Fathead minnow, white sucker, and largemouth bass (fingerling). Embedded in flesh with posterior end protruding to outside.

Many fathead minnows and a few suckers from the Big Sioux River had these parasitic copepods. Also a largemouth bass fingerling from Fort Randall Reservoir was infected. *L. cyprinacea* is the oldest named species in the family, being the first of three species in Linnaeus' "*Systema Naturae*," 10th edition, 1758 (Wilson, 1917). The most striking anatomical structure of this parasite is the pair of branching "horns" at the anterior end, causing the whole animal to resemble an anchor (figure 41). At the base of the horns is a small button-shaped head bearing two pairs of tiny antennae. The slender body increases in size posteriorly, ending in a short abdomen beneath which is a pair of egg sacs. During the process of burrowing into the host's body, the long free thorax undergoes torsion, as is evidenced by the position of the five pairs of tiny swimming legs. These tiny legs are not degenerate; they simply do not grow after the close of the last copepodid larval stage.

The adult female parasite lies with the anterior half of the body deeply embedded in the flesh of the host, sometimes penetrating to the body cavity in minnows. The posterior portion of the thorax with its subterminal pair of egg sacs is easily visible on the outside of the host (figure 42). Since the tissues in which the horns are embedded are not destroyed, Wilson (1915a) surmised that the parasite must feed on the blood and lymph



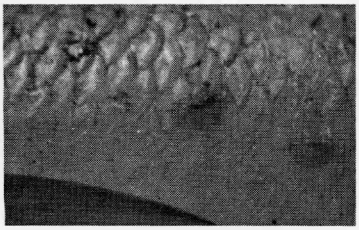


Figure 36. (left) Fish infected with fish lice, *Argulus biramosus*. The fish died of the infestation.

Figure 37. (right) Photographic close-up of *Argulus* on fish (X 1).

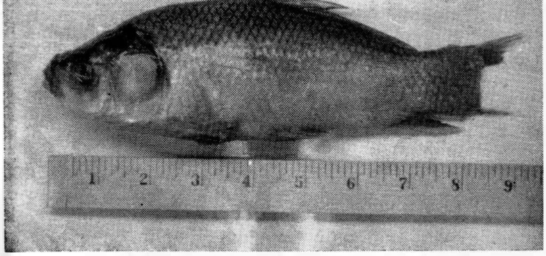


Figure 38. Bigmouth buffalo victim of *Argulus* at Lake Poinsett. This fish was typical of victims still feebly swimming during the epizootic.

Figure 39. Fish mortality from outbreak of *Argulus* at Brant Lake. Hundreds of dead fish were washed up on the beach.

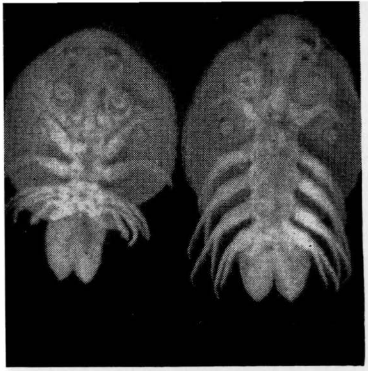
which supplies the tissues. He stated that if the parasite ever became abundant, it could be a serious menace to fresh-water fisheries. Uzmann and Rayner (1958) reported a severe epizootic among trout and warned of the danger of transplanting stocks of fishes from *Lernaea* -endemic areas. Hugghins (1959) has reviewed several recent reports which extended the known range of this parasite westward to the Pacific Coast.

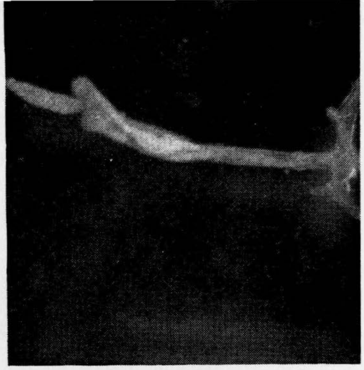
Family LERNAEOPODIDAE

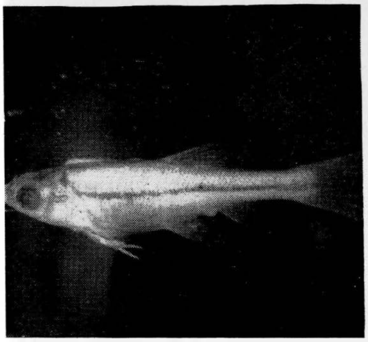
Achtheres ambloplitis Kellicott, 1880. (Figures 43, 44).
Host: Black bullhead. On gill arches and rakers.

These parasites were found attached to the gill arches of several bullheads from Wall Lake and Lake Hendricks (figure 43). Of the three kinds of parasitic copepods found in the survey, this group is the most highly modified for the parasitic life. Wilson (1915b) described the anatomy in detail. The legs have disappeared entirely from the short, plump body. The two appendages which look like curved legs are actually modified mouth parts, the second pair of maxillae (figure 44). Distally, they are joined to a small disc which is embedded in the gill arch for absorption of nutriment. This disc has an interesting origin. In the nauplius stage within the egg, a gland on the head secretes a long hollow filament with a mushroom-shaped disc at the end. When the egg hatches, the first copepodid stage immediately swims to a fish and attaches itself to a gill arch by means of this disc. Soon the filament is transferred from the head to claws at the tips of the second maxillae. In the adult, the claws disappear and the filament shortens, leaving the disc at the jointed ends of the modified maxillae (Wilson, 1911).

The specimens were identified as *Achtheres ambloplitis* by T. E. Bowman, of the U. S. National Museum. However, he mentioned the possibility that further taxonomic study might establish *A. ambloplitis* as a small form of *A. pimelodi* Kroyer, 1863. This is apparently the first report of *A. ambloplitis* from bullheads.







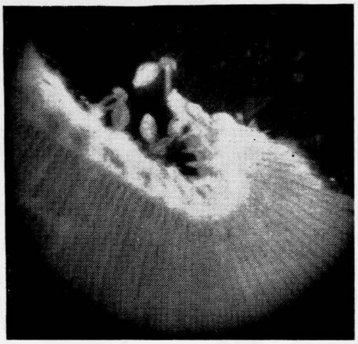


Figure 40. (upper left) Ventral view of fish lice, *Argulus biramosus* (X 5); male on left, female on right. Note pair of suckers near anterior end.

Figure 41. (upper right) "Anchor worm," *Lernaea cyprinacea* (X 5). The horns are on the anterior end at the extreme right of the picture; an egg sac is at the opposite end.

Figure 42. (lower left) Fathead minnow with "anchor worm" protruding from its body (X 1).

Figure 43. (lower right) Parasitic copepods, *Achtheres ambloplitis,* attached to gill rakers of bullhead (X 2).

OTHER DISEASES

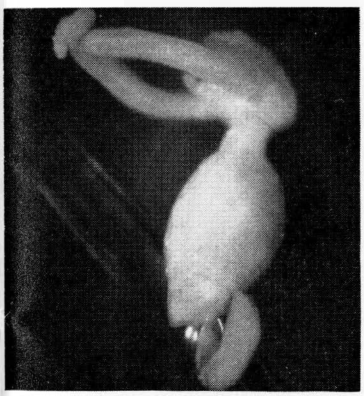
Fishes often are affected by bacteria, fungi, and viruses, many of which are poorly understood. One of the best general accounts of such diseases is given by Davis (1953). For some years, S. F. Snieszko and co-workers have been studying bacterial diseases of fresh-water fishes at the U. S. Fish Wildlife Service's Eastern Fish Disease Laboratory, Leetown, West Virginia. The present study was concerned principally with worm and arthropod parasites, but occasionally conditions were observed which were caused by fungi and viruses or by unknown agents.

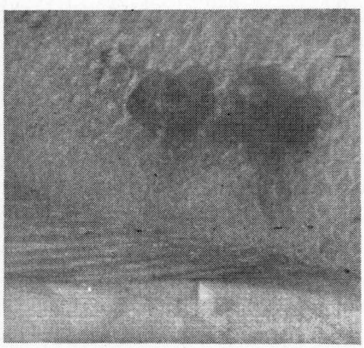
Lymphocystis. A walleye from Lake Madison had gelatinous wart-like growths on the body (figure 45). The fishery biologist who brought in the fish stated that walleyes with similar growths had been seen in lakes in the northern part of the state. When some of the wart-like tissue was examined microscopically, masses of enormous thick-walled cells were seen (figures 46, 47). Allison (1950) and Davis (1953) stated that apparently a virus infection within the connective tissue cells causes the tremendous growth of the cells. The disease is highly infectious, and walleyes are said to be especially susceptible.

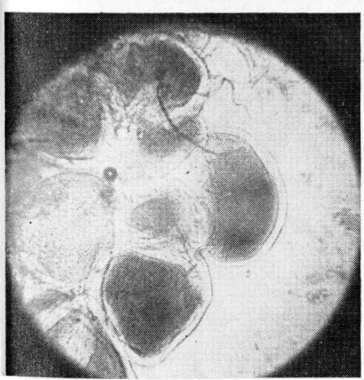
Water mold. During the epidemics of fish lice at Brant Lake and Lake Poinsett, hundreds of fishes of various species had patches of fungus on their bodies. Probably the fungus was *Saprolegnia*, a common and widespread water mold which attacks practically all fresh-water fishes. However, the ever present fungus normally cannot become established upon a fish unless the protective mucous coat of the fish is broken, as by an external parasite or some other agency.

The patch of fungus has a fuzzy appearance due to the multitudinous fine filaments which radiate outward. The filaments are naturally white, but debris and sediment often give them a dirty appearance. The most common means of spread is by minute, seed-like spores which are disseminated in enormous numbers by the fungus. The spore has two hair-like cilia which probably aid in sticking to the fish's body. An extensive growth of fungus may originate from a single spore.

Tumors. A number of black bullheads from Cottonwood Lake and from Lake Madison had large tumors. There seemed to be three different types. (1) Most numerous were subcutaneous fatty tumors of various sizes (¼ in. to 1¾ in. diameter). These could be easily shelled out, leaving shallow depressions in the muscle of the sides or back where they had been located. Histological sections showed typical fatty tissue. (2) A 12-inch bullhead had a huge tumor 3 inches in diameter extending from the pectoral fin almost to the pelvic fin and to the body cavity medially. It, too, was easily shelled out, but differed from the solid tumors above in that it had a thin wall about one eighth-inch thick and was filled with clear fluid. The outer surface was smooth and fatty, but the inner surface of the thin wall was criss-crossed with a network of raised strands of tough connective tissue. A few hard, white concretions were embedded in the inner wall. (3) Some bullheads had hard, bony tumors of connective tissue. They were usually associated with a pectoral fin and the spine of that fin. Histological sections showed connective tissue. On some bullheads, all that was left of the pectoral spines were bloody stubs with bony growths on the stubs. The cause of these tumors is unknown.







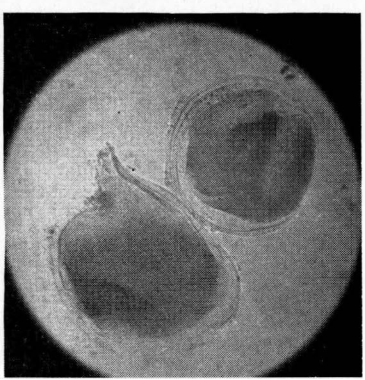


Figure 44. (upper left) Enlarged view of *Achtheres ambloplitis* (X 14) showing curved appendages at anterior end and pair of egg sacs at posterior end.

Figure 45. (upper right) Growth of Lymphocystis on walleye (X 1).

Figures 46 and 47. (lower) Large, thick-walled cells teased from growth of Lymphocystis (X 32).

Effects of Parasites on Fishes

Many fishermen are of the opinion that a few parasites in a fish are of little importance. It may be difficult to measure the damage done by a small parasite burden in a fish, but Meyer (1954) pointed out that "the simple fact that a sufficient number of parasites can weaken or even kill a fish is enough proof that each one does its share toward that end and is therefore harmful." The detrimental effects parasites, if sufficiently abundant, may have upon fish populations can be summarized as follows: stunting, emaciation, sterility, and mortality (Sinderman, 1953). There is a need for much work on the physiological relationships between parasite and host.

FLUKES

Some effects of parasites on fish populations were observed by Hubbs (1927) from the viewpoint of a fish taxonomist. In a population of minnows, he found some fish which differed so much from the others that at first he believed two species were present instead of one. The abnormal minnows had their viscera riddled with metacercariae. Abnormalities included retention of larval characters, increase in scale number, and differences in body proportions.

The white grub of liver, *Posthodiplostomum minimum,* was one of the most widespread and economically important parasites encountered in a Connecticut survey. Experimental infections in the laboratory demonstrated that if sufficient tissue were destroyed in the viscera, the fish would die (Hunter, 1942). Observations in Florida and Wisconsin indicated that this parasite caused adhesions in the mesenteries of sunfishes (Bangham, 1938, and Fischthal, 1953).

In the present study the black crappies from Lake Fraiser were very heavily parasitized by these strigeid metacercariae, and the fish appeared to be stunted and emaciated. Their digestive tracts contained abundant food, so that the poor condition of the fish probably was due to parasitism rather than insufficient food or over-crowding.

On the other hand, Sillman (1957) reported that three sunfish kept in his aquarium were found upon autopsy to have their livers riddled with *P. minimum* but that they had shown no apparent inconvenience from the parasitism. It is possible that ecological factors, or environment, could influence the effects of the parasitism.

A study on the effect of parasitism on perch in a Wisconsin lake showed that in the 2 to 5 year age groups, the fish with light infections were more than 10% longer and one-third heavier than those with heavy infections. Most of the parasites were larval flukes and tapeworms encysted in the flesh or viscera (Cross, 1935).

In controlled experiments with small-mouth bass infected with the black grub, *Uvulifer ambloplitis,* a statistically significant loss in weight was shown (Hunter and Hunter, 1938). It was believed that this loss was due to disturbance of the normal metabolism of the host, as all the experimental fish ate well. Besides absorbing nourishment from the host, the growing metacercariae must liberate their own waste metabolic products into the surrounding tissue. This may be one reason why tissue parasites often appear to be more harmful than intestinal parasites. Studies with another species of black grub *(Crassiphiala bulboglossa)*, showed that heavy experimental infections killed minnows in 10 to 15 days, due to extensive congestion of blood vessels (Hoffman, 1956).

Studies on the effects of the yellow grub, *Clinostomum marginatum*, on a yellow perch population in a Minnesota lake indicated that the heavy infections may have made the fish more susceptible to winter-kill, either because of increased oxygen demand or because of generally debilitated condition due to parasitism (Elliott and Russert, 1949). Another effect of the yellow grub is that heavily infected fishes swim more slowly than non-infected ones, making their capture by fish-eating birds more likely (Hunter, 1942).

The author (Hugghins, 1956a) reported on the extremely high rate of infection of another strigeid metacercaria, *Hysteromorpha triloba,* in the bullhead population of a large Illinois lake. The bullheads had thin bodies, large bony heads, and poor color.

In the South Dakota survey, a similar situation was found at Lake Fraiser. The larval parasites in this lake provided a good illustration of host specificity; that is, the musculature of the bullheads was heavily infected with metacercariae of *H. triloba,* while the liver and other viscera of the crappies were heavily infected with metacercariae of *Posthodiplostomum minimum.* Even though the lake was so small that probably both species of fishes were amply exposed to both species of cercariae, there was no intermixing of the two kinds of flukes in the fishes.

It is a common belief among many fishermen that fish lose their grubs during the winter. Fischthal (1949) did a study on the over-wintering of black grubs and yellow grubs in fish and found that the loss of grubs was negligible. He offered a possible explanation for the false belief of the fishermen. In summer the angler fishes inshore in weedy, shallow areas where infected snails and panfish often are closely associated, resulting in grubby fish; whereas, in winter he fishes through the ice in deep water where the fish are less likely to have grubs.

In a study with strigeid metacercariae of a different fluke, *Hysteromorpha triloba,* the author (Hugghins, 1954b) placed 36 heavily infected bullheads in a shallow metal tank outside; after remaining there for almost a year the fish were still heavily infected with living metacercariae. In February holes were chopped in the ice to recover eight near-frozen bullheads which were fed to eight uninfected cormorants. All eight birds became heavily infected from the single feeding, indicating that the extended low temperatures had not altered the viability of the larval flukes.

For fishes whose viscera contain large numbers of metacercariae, Hoffman (1958a, b) reported a remarkable phenomenon which he called the "self-cure"; the body wall of many of his fishes burst, allowing some parasites to fall out, followed by closure and healing of the wound. He suggested that accumulation of fluid in the body cavity might have contributed to the rupture.

For many years strigeid metacercariae (particularly *Diplostomum flexicaudum*) have been known to occur in the eyes of fishes, causing impairment or loss of sight. Fishes thus affected cannot feed properly and therefore eventually die.

Most of the flukes discussed here are larval strigeids. This group, together with larvae of the closely related *Clinostomum marginatum*, are undoubtedly the most widespread and important fluke parasites of fresh-water fishes in North America. Reports are more rare of mature intestinal flukes causing severe damage to fishes; but Wales (1958) recently attributed mortality in trout to a tiny intestinal fluke, *Crepidostomum* sp. Over a 2-year period he found many dead fish whose intestines were seriously inflamed, and large numbers of the flukes were present in the intestines.

TAPEWORMS

As was mentioned in the section on fish parasites in South Dakota, one of the most serious parasites of fresh-water fishes is the bass tapeworm, *Proteocephalus ambloplitis*. The adult tapeworm in the intestine of bass is not of nearly as much importance as the larval stages, plerocercoids, in the viscera of bass. (The life cycle of this worm is unusual in that the same species of fish may serve both as second intermediate host and as final host.)

The plerocercoids in the viscera frequently invade the reproductive organs, resulting in sterility of the fish. Another undesirable effect is adhesions or matting of the viscera.

Some of the more recent studies involving the bass tapeworm have been sponsored by Fish and Game Departments in the New England States: Massachusetts (Sinderman, 1953), Maine (Meyer, 1954), and New Hampshire (Morrison, 1957). The latter was an intensive survey for the plerocercoids of the bass tapeworm only, in an effort to find the cause for the decline in smallmouth black bass populations in New Hampshire. It was concluded that the bass tapeworm was a very serious parasite problem there.

However, before a decrease in smallmouth bass population in a lake or pond is blamed entirely on heavy plerocercoid infections, other factors should be considered, such as presence of suitable spawning facilities. Also the worm will develop in several other species of fishes besides bass, and these can be of importance in disseminating the infection.

In the South Dakota study, plerocercoids were found in the liver of bullheads from Lake Madison and Lake Mina, and the adult worm occurred in the intestine of largemouth bass from Lake Mina. So far as is known, the bass tapeworm is not a serious problem in South Dakota at present, but it is potentially dangerous to the bass population.

It has been shown that another plerocercoid larva, *Ligula intestinalis,* can have a demonstrable effect upon fishes. One study showed a progressive retardation in size of infected yellow perch as the fish got older; for example, 1-year-old infected perch were 37.5% shorter than noninfected ones, while 4-year-old perch were 55% shorter (Pitt and Grundmann, 1957).

Another study showed that the plerocercoids sometimes represented as high as 50% of the total weight of an infected fish, utilizing all of the available space in the body cavity. The pressure exerted on the organs of the fish by the plerocercoids frequently led to distortion and degeneration and evidently caused sterility in many cases (Dence, 1958). Infected fishes are more sluggish than noninfected ones, and consequently can be more easily caught by the fish-eating birds which serve as final host.

OTHER PARASITIC WORMS

Reports of damage to fishes from **roundworms** are not nearly as numerous as reports incriminating flatworms (flukes and tapeworms). One of the most damaging roundworms is a dracunculoid nematode, *Philonema agubernaculum,* which was reported by Meyer (1954, 1958) as being a serious parasite of landlocked salmon and Eastern brook trout in Maine lakes. The worms cause multiple adhesions in the viscera which may be so severe as to make normal spawning impossible. Moreover, fisheries personnel are unable to strip the eggs and milt from heavily parasitized fish.

The **spiny-headed** worms are injurious to their hosts because the spiny proboscis is buried in the wall of the intestine, often causing ulcer-like lesions and conspicuous areas of laceration and inflammation. *Pomphorhynchus bulbocolli* caused considerable damage to white suckers from Algonquin Park lakes (Bangham and Venard, 1946). In the South Dakota study this species of worm frequently had penetrated the wall of the intestine and had progressed through the perforation into the body cavity of the host.

The **leeches** ordinarily are of minor importance on fishes. Aside from sucking blood, the principal damage lies in the fact that the wound left in the fish may provide an avenue of entrance for fungi and bacteria. Occasionally leeches occur in epidemic numbers and cause extensive damage. Such an epidemic occurred among the redmouth buffalo being seined by commercial fishermen in the Rock River of Illinois. When the fishermen picked off the leeches, the places of attachment were marked by patches of bleeding and inflamed flesh which made the fish less desirable for market. Many of the infested fish were so thin they were discarded by the fishermen. The epidemic appreciably affected the fish yield (Thompson, 1927). Rupp and Meyer (1954) reported an unusual situation in which a number of brook trout were killed by attacks of leeches.

FISH LICE

Like the leeches, fish lice ordinarily are of minor importance to fishes but occasionally may reach epidemic proportions and cause much damage. The extensive fish mortality due to epizootics of *Argulus biramosus* at Brant Lake and Lake Poinsett, South Dakota, was discussed in the preceding section. Evidently, the fish mortality was due to a combination of two factors: (1) the injection of toxin by tremendous numbers of fish lice, and (2) the invasion of water mold through wounds left by the fish lice.

The "anchor worm," *Lernaea cyprinacea,* appears to be of little importance in South Dakota, but Haderlie (1953) stated that this parasitic copepod is a serious pest in California, where it produces numerous bleeding ulcers in the skin of infected fishes. In Oregon an epizootic of this parasite in rainbow trout destroyed the eyes of many fish (Uzmann and Rayner, 1958).

Gill lice, such as *Achtheres ambloplitis* found on bullheads in the South Dakota study and *Salmincola edwardsii* found on brook trout in many areas, are seldom of importance in streams or lakes. However, they can become a serious problem in trout hatcheries (Allison, 1950).

Importance of Fish Parasites to Man

FISH PARASITES WHICH CAN DEVELOP IN MAN

In various parts of the world there are a number of parasitic worms which can be acquired by man through eating raw or improperly cooked fish. In North America only three such species of worms are known to occur naturally in man: the broad tapeworm, *Dibothriocephalus latus (=Diphyllobothrium latum)*[4]; a liver fluke, *Metorchis conjunctus;* and a second species of *Diphyllobothrium*, different from *D. latum* but not definitely identified as yet, occurring in the Eskimo in Alaska. It is improbable that any stages of these parasites occur in South Dakota. However, the proper fish intermediate hosts are widespread here and therefore the potential is here for establishment of the life cycles, provided the proper first intermediate hosts are present also. For this reason these worms will be discussed.

The broad tapeworm, *Diphyllobothrium latum,* is endemic in the Baltic countries of Europe, from whence emigrants have taken the parasite to various parts of the world. One of the earliest studies on this tapeworm in America was conducted in the Upper Peninsula of Michigan, where the Finnish immigrants customarily served fish raw with sour cream or with salt. Plerocercoids of the worm were found in several species of food fishes in Portage Lake (Vergeer, 1928).

[4]Since many authors continue to use the generic name, *Diphyllobothrium,* for various species of the genus, that term rather than *Dibothriocephalus* will be used throughout this discussion for the sake of uniformity.

Areas of North America where the broad tapeworm is known to be present are: northern Minnesota (Long, Vermillion, Burntside, and Devils Track lakes), southeastern Manitoba (Lake Winnipeg), the Lake Nipigon district of Ontario, and the Portage Lake district of Michigan's Upper Peninsula (Allison, 1950). Also, the worm has recently been reported from Florida.

Various species of the copepod genus, *Diaptomus,* serve as the first intermediate host. Fishes which can serve as second intermediate host are the northern pike, walleye, sauger, yellow perch, and burbot. Besides in man, the adult worm will develop in a number of carnivores, such as bear, fox, mink, dogs, and cats; this makes it difficult to control.

Plerocercoids occurring in trout of Wyoming were thought for a time to be *D. latum,* until Woodbury (1935) tried unsuccessfully to infect himself by engesting a number of plerocercoids of various sizes. The normal final hosts proved to be pelicans and gulls. This case is mentioned to emphasize that often it is difficult even for specialists to identify plerocercoids of *Diphyllobothrium* as to species. Thus it is possible for rumors to get started that fish are infected with larval stages of the broad tapeworm of man, when in actuality the worm's final host may be some fish-eating bird. The best way to allay any fears is to thoroughly cook suspect fish.

Personnel of the Arctic Health Research Center of the U. S. Public Health Service have been studying diphyllobothriasis in Alaska for several years. Babero (1951) stated that the incidence of infection was as high as 30% of the native Eskimo population in the Kuskokwim region of southwest Alaska. Rausch and Williamson (1958) stated that the identity of the species of *Diphyllobothrium* occurring in the Eskimo still remains to be determined. However, they described a new species, *D. alascense,* from sledge dogs of the Eskimo, and since the Natives and their dogs eat the same species of fishes raw, it is suggested that they may harbor the same species of *Diphyllobothrium.*

The only fluke of fishes in North America which has been reported to occur naturally in man is *Metorchis conjunctus,* a liver fluke which uses white suckers as the second intermediate host. This fluke is widespread among fish-eating carnivores in Canada, where the human infection was reported (Cameron, 1944). In the United States the flukes have been reported from carnivores in Maine, New York, Wisconsin, and South Carolina (Meyer, 1949; Jordan and Ashby, 1957). These widely scattered reports indicate that this potential parasite of humans may be more widespread in this country than was once suspected.

IMPORTANCE COMMERCIALLY AND AESTHETICALLY

Several fish parasites are of commercial importance because of their effect upon the marketability of fish. One of the most troublesome of these is the plerocercoid larva of *Triaenophorus crassus.* The adult tapeworm lives in the intestine of the northern pike, but the plerocercoids occur in the flesh of members of the whitefish family. The parasites occur in the Great Lakes and other areas, but they are so abundant in Canadian lakes of the Prairie Provinces that the United States Food and Drug Administration bars importation of heavily infected fish from that region. This caused such heavy losses to commercial fisheries that the Canadian government sponsored a program to attempt control of the parasite (Miller, 1952).

The red roundworm, *Eustrongylides,* is of considerable economic importance because it frequently makes the flesh of fish unfit for table use. It occurs in many species of fishes, including bass, sunfish, crappie, yellow perch, pickerel, and suckers (Davis, 1953). A roundworm of importance to commercial fishermen in Lake Michigan is *Philometra nodulosa,* which occurs just beneath the skin of the redhorse sucker. Quantities of these suckers are shipped "in the round," and in late June and early July many of the fish are disfigured for market by the inflamed patches on the skin (Thomas, 1944).

Of economic importance are some of the parasites discussed under the section on effects of parastism upon fishes. For example, the author (Hugghins, 1956a) found that the heavy infection of bullheads with fluke larvae in their flesh had led to a serious decline in fishing activity at a large lake in Illinois. This was of prime importance to the operators of the store and boat livery at the lake, as their income from boat rentals alone had amounted to about $14,000 per year before the lake acquired a damaging reputation for having grubby fish. Undoubtedly there have been many such instances.

For the average sports fisherman, the greatest importance of fish parasites is the effect on his aesthetic senses. His first reaction may be one of revulsion when he finds parasites in the fish he plans to eat. If he decides to keep the fish, his next concern is for the effect on his health from eating parasitized fish. The few fish parasites in North America which can develop in man were discussed, but it is improbable that any of these occur in South Dakota. However, thorough cooking will kill all parasites in the flesh.

Allison (1950) stated that "an important consideration in securing full utilization of our game fish resources is proper evaluation by the angler of the condition of the fish in his catch. It is certain that many freshly caught fish are thrown away because of some minor, visible abnormality which, in actuality, has no effect on the edible qualities of the fish."

Control of Fish Parasites

In speaking of the place of parasitology in a program of conservation, La Rue (1933) stated that in many instances it is possible to control but not to eradicate parasites. In some cases it is undesirable to kill off intermediate or final hosts because of their position in the food chain or because of aesthetic considerations. In some instances, even though eradication might be possible, it is so expensive as to outweigh the good that might result.

La Rue emphasized that any proposal of a program to control or eradicate parasites in wildlife should be considered from all possible viewpoints by specialists in various fields. That is, a thorough study should be made of the ecological situation before tampering with nature.

Among the most objectionable fish parasites from the standpoint of the angler are the larval flukes (often called "grubs") which occur in the flesh and viscera of fishes. Aside from making the fish less desirable to the fisherman, many of these parasites may cause considerable damage to fish, as has been shown.

By far the most widespread of these flukes is a group which uses fish-eating birds as final hosts. It would be both impracticable and undesirable to try to kill off the fish-eating birds in an attempt to control the parasites. The most logical point of attack in the life cycle is the snail which serves as the first intermediate host. If the snails can be destroyed, the life cycle can be effectively broken.

For many years, copper salts were the principal molluscacides (snail killers) in use. Broadcasting copper sulphate crystals is a simple method of treatment in areas of shallow water up to 2 feet in depth. In areas where water currents are present and where water is deeper than 2 feet, better results are obtained by using a 2:1 mixture of copper sulphate and copper carbonate, as the latter chemical diffuses more slowly. McMullen and Brackett (1941) suggested using 3 pounds of the mixture per 1,000 square feet. Very effective control can be obtained for the season but the treatment usually must be repeated each year.

A distinct advantage of the copper salts is that they can be used in proper concentrations for killing snails without harming fish. Small ponds capable of being drained and refilled can be treated for snails with calcium hypochlorite or chlorine gas introduced at the inlet pipe during refilling (Ferguson and Hayford, 1941).

Of 33 chemical compounds screened for molluscacidal properties by Batte, Swanson, and Murphy (1951), only copper sulphate and dinitro-O-cyclohexylphenol met the first of their requirements, that is, 100% mortality of lymnaeid snails following 24-hour exposure in concentrations of 1 part per million. In further screening Batte and Swanson (1952) increased the number of compounds tested to 98 but found only two additional compounds which met their first requirement.

In recent years, much work on molluscacides has been done by personnel of the U. S. Public Health Service and of the medical research organizations of the Army and Navy. They have been interested primarily in controlling snails in foreign countries where human schistosomiasis (blood fluke infection) is a problem; but many of their findings may prove applicable in controlling fresh-water snails in this country where larval flukes in fish are a problem, or where adult flukes in livestock are a problem.

One of the most promising compounds they have tested is sodium pentachlorophenate. Field tests with this compound showed the following advantages: very effective molluscacide, soluble in water, relatively cheap, not toxic to mammals tested (rodents, calf, monkey), vegetation other than algae not affected, crustaceans not harmed. However, it was very toxic to fish (Berry, Nolan, and Gonzalez, 1950).

In further evaluation studies of sodium pentachlorophenate in the field, Kuntz (1956) found that the compound was very toxic to fish at 6 p.p.m., but that no ill effects were reported by natives who collected and ate considerable quantities of the fish. The compound was an effective ovocide (killed snail eggs) as well as molluscacide. The residual toxicity dropped sharply a few days after treatment. It has occurred to the author that sodium pentachlorophenate might be an ideal chemical to use in a situation where it is desired to kill both snails and grubby fish at the same time in order to make a fresh start by restocking.

The tapeworms and spiny-headed worms of fishes use microcrustaceans as the first intermediate host, and many of them use fishes both as second intermediate host and as final hosts. This makes control of the worms very difficult, since microcrustaceans are very important food animals for fishes. In the South Dakota study it was noteworthy that many of the fishes taken in midwinter had their stomachs filled with microcrustaceans. Even if it were possible to eradicate microcrustaceans, it would be inadviseable because of the importance of the animals in the food chain, particularily for fish fry. The Canadian government sponsored large scale efforts to attempt control of *Triaenophorus crassus*, a tapeworm which uses *Cyclops* and ciscoes as first and second intermediate hosts, and northern pike as the final host. It proved either futile or impractical to attack the worm at any point in the life cycle (Miller, 1952).

For a parasite like the bass tapeworm (life cycle chart, figure 4), care in stocking is the most important control. It may be advisable to either drain or rotenone a pond to destroy all infected fish and then start over, using care in stocking and in bait fish used. This parasite cannot be introduced by a fish-eating bird; it is introduced to a pond only by transfer of infected fish. Even for those tapeworms which use a fish-eating bird as the final host, control of larval stages in fishes usually is impractical.

Another group of parasites controlled by care in stocking is the fish louse group. In fish hatcheries, fish lice as well as ectoparasitic flukes ("gyros") can be controlled (see Allison, 1950, and Davis, 1953). But in the wild, little can be done besides care in stocking lakes, ponds, and streams.

It seems fitting to close this discussion with a quotation from Otto (1958): "To know the parasite completely we must know more than its taxonomy, morphology, and life cycle, fundamental as these are. . . . An understanding of the ecology of of a parasite and the resulting parasitism requires an appreciation of many facets, including the ecology of the host and how parasite and host influence each other. . . . The future offers opportunities unlimited to the ecologically minded parasitologist."

Aids Towards Use of Literature on Fish Parasites

Most of the information on parasites of fishes is scattered through the scientific periodicals. For the reader who may wish to investigate some fish parasite further, but who is unfamilar with the literature, a few brief suggestions will be given.

INDEXING AND ABSTRACTING SERVICES

Three very useful abstracting periodicals are "Biological Abstracts," "Wildlife Review," and "Helminthological Abstracts." The first of these should be familiar to every biologist. The second is more specialized and is published by the Patuxent Research Refuge (Laurel, Maryland) of the U. S. Fish and Wildlife Service. The third is still more highly specialized, reviewing world literature on parasitic worms only; it is published in England. All three of these publications have both subject and author indexes.

A very useful author index is the "Index-Catalogue of Medical and Veterinary Zoology," published by the Animal Disease and Parasite Research Division, ARS, USDA, Beltsville, Maryland. This index can be of great aid when only an author's name is known, and the worker's problem is to locate references to papers by that author.

SURVEY TYPE STUDIES

One of the earliest extensive surveys of fresh-water fishes for their parasites in this country was conducted at Oneida Lake, New York, by Van Cleave and Mueller and was reported in the Roosevelt Wild Life Annals of Syracuse University, 1932-34. Another pioneer series of studies of this type by G. W. Hunter, III, was published by the New York State Conservation Department, 1929-37. A number of surveys in different areas of the United States and Canada were made by Bangham over a long period of years.

Some of the more recent surveys, several of which were sponsored by state fish and game departments, are Haderlie (1953) in California, Fischthal (1953) in Wisconsin, Cook (1954) in Colorado, Sinderman (1953) in Massachusetts, Meyer

(1954) in Maine, and Miller and Bennett (1957, preliminary report) in Louisiana.

REFERENCE BOOKS

Most of the books on general parasitology deal primarily with human and veterinary parasites. Among the few books giving comprehensive treatment to particular classes of parasitic worms, including many parasites of fishes, are the following: Dawes (1946) on flukes, Wardle and McLeod (1952) on tapeworms, Yorke and Maplestone (1926) on roundworms. The most recent monumental effort at bringing together information on parasitic worms is the series entitled "Systema Helminthum," by Satyu Yamaguti. Volume I (1958) is on the digenetic flukes of vertebrates. Still in preparation are volumes on the tapeworms and the roundworms of vertebrates.

MANUALS ON TECHNIQUE

The nonparasitologist who wishes to learn some techniques of making permanent preparations of parasitic worms will find very helpful information in any one of the following laboratory guides:

Thomas, L. J. 1955. "Laboratory Manual for Helminthology." (Mimeographed at University of Illinois, Urbana; 1950 edition formerly published by Edwards Bros., Ann Arbor, Michigan.)

Cable, R. M. 1958. (4th ed.). "Illustrated Laboratory Manual of Parasitology." 165 pp. Burgess Pub. Co., Minneapolis.

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