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L. N. Allison

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COMMON DISEASES OF FISH IN MICHIGAN

By Leonard N. Allison, Ph.D.

Every year the Michigan Department of Conservation receives many inquiring letters from anglers who have caught or observed fish which appeared to be suffering from the effects of disease or parasitic infection. Since a great majority of the queries concern a relatively small number of widespread fish abnormalities, it would appear advisable to present a brief, non-technical account of the commoner ills of inland fishes, as a service to sportsmen, bait dealers, and proprietors of private fish ponds and hatcheries.

Fish, like humans, are subject to attack by a bewildering variety of microbes, viruses, and parasitic worms. For many of the aches and pains of fish, no cure is known--not a surprising fact when one considers how many human diseases remain unconquered. However, successful treatments have been devised for some of the more destructive fish maladies. And many fish abnormalities which may give concern to sportsmen probably bother the fish no more than a cold or spell of rheumatism incapacitates a man.

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.

When a fish is described as "diseased" in the pages to follow, it does not necessarily mean that the fish is sick or even visibly affected, but rather than it is infected with appreciable numbers of certain organisms (for example: "Black-spot," the tiny larva of a parasitic worm, which imbeds itself in the skin of a fish but apparently does little damage to it unless present in enormous numbers).

Although every species of fish is susceptible to parasitic invasion, some are more frequently attacked than others, depending somewhat on the type of lake or stream in which the fish live, for certain types of lakes and streams have a greater variety of parasites than do others. Many of the parasites which attack fish spend a part of their lives in the bodies of aquatic snails. The water in lakes and streams of southern Michigan is warmer and provides, for parasites of fish that live part of their life in snails, a longer period for attack than is afforded in the colder waters of the north. A certain degree of water warmth is required before infective larval parasites leave the snails to seek other hosts. Fish which inhabit a lake or stream having large areas suitable for snails are likely to be more heavily parasitized than those living in waters that harbor few or no snails.

Queries from some anglers indicate that they believe their health may be endangered if they eat parasitized fish. Actually, there is no danger if the fish are thoroughly cooked before they are eaten, as all parasites of fish are destroyed by cooking.

Only a few parasites of fish have been shown to be infective to humans. The broad tapeworm (Cestode: Diphyllobothrium latum), which is rare in Michigan, is infective to man, but only if eaten in poorly prepared fish (raw, improperly cooked, or pickled fish). The infective larva in the flesh of the fish vary from one twenty-fifth to four-fifths of an inch in length. Another parasite (Trematoda: Metorchis conjunctus) infective to man is carried in the flesh of the common sucker in Canada. There are no records, as yet, of its presence in the United States, although it is possible that it exists here. The larva is much smaller than that of the broad tapeworm, measuring only about one-fiftieth of an inch in diameter. Because it is very small and of the same color as the flesh of the fish, it may easily escape notice. As with other species of parasites, the high temperature (160° F. or more) of normal cooking will destroy it.

Disease and mortality among fish may be caused by one or a combination of organisms as well as by physical conditions of the water that may occur naturally or through pollution.

A few terms which may need defining will be used in the discussion. The word parasite, and variations of the word, will be used frequently. A parasite may be defined as:

(a) A plant living within or on an animal and supported at its expense (as fungi); or

(b) An animal living all or part of its life on or within another animal, feeding upon its food, blood, or tissue (as tapeworm).

A host is an animal or plant upon or within which the parasite lives.

Many of the parasites which infect fish are only immature forms, called larvae, that use the fish as a means of transportation to the host in which they may mature and produce eggs. Usually, the larva in the flesh of fish forms a wall, or membrane, around itself for protection. The immature worm, with its protective covering, is referred to as a cyst. Parasites are said to encyst when they form the protective shell and become dormant.

To aid in rapid identification, the afflictions described herein are grouped as external and internal, on the basis of whether they attack fish externally or internally, rather than according to customary technical classification.

EXTERNAL PARASITES AND DISEASES

Black-spot. (*Neascus* sp.) Fig. 1. Small black spots, about the size of the head of a pin, are found commonly in the skin and flesh of fish. These spots are cysts of a certain group of worm parasites (trematodes) that have a complicated life cycle which involves at least three different hosts (Fig. 2). When kingfishers and other fish-eating birds eat infected fish, the worms break out of the cysts into the digestive tract of the bird and grow into adult worms. The adult lays eggs which pass out of the bird. If these eggs fall into water, they hatch in about three weeks as free-swimming larvae (miracidia). These "first-larvae" swim around until they find a certain species of snail, into which they burrow and begin another stage of their life. However, they must find the right species of snail within a few hours or they die. Each "first-larva" that penetrates a snail multiplies in numbers a thousand-fold, and in about 42 days the progeny leave the snail as "second-larvae" (cercariae) and swim free in the water. Unless a suitable fish host presents itself within a few hours, these larvae perish. If they find a suitable fish host, they burrow through the skin and build a cyst wall around themselves. They are then called "third-larvae" (metacercariae). Around the cyst the tissues of the fish build a protective wall which becomes darkly colored, giving the parasite its common name of "black-spot." Within the cyst the parasite undergoes only slight development, and remains dormant until fish and parasite are eaten by a kingfisher, in whose intestinal tract it grows into an egg-laying adult worm.

As many as 700 cysts have been recorded from a single yellow perch, but, as yet, there is no evidence to indicate that they are detrimental. At least, they do not seem to affect the growth-rate or longevity of the fish host. They are incapable of attacking man.

Yellow Grub: This worm will be discussed in detail under the "internal" group. It is mentioned here because occasionally it may encyst just beneath the skin, especially in the region of the throat, and be plainly visible from the surface of the fish. It is easily distinguished from "black-spot" by its yellow color and greater size. It may be nearly one-eighth of an inch long, whereas black-spot cysts rarely exceed one-sixteenth of an inch in length.

Gyro (Trematoda: Gyrodactyloidea): "Gyro" is a small parasitic worm about one-fiftieth of an inch long that lives on the body, fins or gills of fish (Fig. 3). The common name is derived from an abbreviation of the name of the group (Gyrodactyloidea) to which they belong. These parasites are scarcely visible to the unaided eye, but their presence may be suspected by certain effects on the fish, such as frayed fins, patches of fungus, or by the actions of the fish as they attempt to rid themselves of the parasites by scraping their sides on the bottom of the stream or lake. The posterior end of the worm is disc-shaped and equipped with hooks which are used to hold the parasite to its host. The hooks damage the skin of the fish, making tiny gashes through which bacteria or fungus may enter. "Gyro" seldom becomes a serious menace to fish life in nature, but may be a troublesome pest in fish hatcheries where the fish are closely crowded and the worms may easily spread from one fish to another. The spread of infestation may be rapid because these worms do not need a different host in their life cycle, as does "black-spot," but can multiply directly on the fish. When present in large numbers they may cause the fish to die, either by direct damage to the gills or by the growth of fungus or bacteria that gain foothold through wounds made by the anchoring hooks of the parasite.

In hatcheries, effective control of "Gyro" is obtained by subjecting the trout to a 1:4000 solution of formalin for one hour. Treatment is done in the pond or raceway. The water level may be drawn down considerable, so that less water (therefore less formalin) is involved in the treatment. The calculated amount of formalin is sprayed over the water, in dilute form so as to avoid local high concentrations which would be harmful to the fish.

Cataract Worm (Trematoda: Diplostomulum gigas and D. flexicaudum): Cataract worm is closely related to "black-spot" and its life cycle is very similar. It derives its common name from the habits of the "third larvae," which, instead of encysting in the skin after burrowing into the fish, continue to migrate through the fish's tissues until they reach the crystalline lens of the eyes. There they establish themselves and cause the lens to become white and opaque, thus blinding the fish. Eventually, the lens becomes smaller and a cataract is formed over the eye. The infection is spread from one place to another by the herring gull in which this parasite matures and produces eggs. Cataract worm causes blindness in rainbow trout and common suckers. In some Michigan lakes over 90 per cent of the suckers have been found to be blinded by this parasite. In fish hatcheries, danger of infection by cataract worm can be eliminated by destroying all snails in the ponds, but, unfortunately, such a procedure in most lakes would not be practicable because of the prohibitive expense.

Fish Lice: Under this heading fall a variety of forms of which the most common are the parasitic copepods, or "fish lice." These organisms are small white or yellow wormlike organisms usually less than half an inch long, that attach to the gills, fins, or the body of the fish in general. The body of the copepod has a hard covering, for it is a crustacean and is allied to crabs and crayfish.

In general, "fish lice" are comparatively harmless to the fish, although they make the fish less desirable to anglers. However, some kinds, especially those that infest the gills, may do considerable damage to the fish and may cause heavy losses in hatchery ponds.

The life cycle of the "gill louse" (Salmincola edwardsii)(Fig. 4 and 5) of brook trout is simple. The young hatch from eggs carried by the female. They swim freely until they can become attached to a fish host where they develop into adults in about thirty days. The young die if they do not succeed in attaching themselves within a few days. An adult female produces eggs which hatch in approximately one month; thus the life cycle is completed in about two and one-half months. Bass and bluegills may be infested with a very small species of gill lice.

Although gill lice may do great damage to brook trout in hatcheries, they seldom cause trouble in streams or lakes. Hatchery ponds concentrate many fish in a small area of slowly running water, so the young gill louse has ample opportunity to find a host. In natural streams, trout are less concentrated and the flow of the water is swifter, making it more difficult for the young gill louse to find a suitable host.

The control of this parasite in hatcheries is accomplished in two ways. Free-swimming stages contaminating the water supply may be removed by the installation of sand filters where the water enters the hatchery grounds. Infested fish may be freed from gill lice by transferring them for three months to "curing ponds" in which they are constantly bathed in a 1.2 to 2 per cent solution of salt (NaCl). This solution kills the free-swimming young stages, and the older gill lice die normally and fall from the fish.

Another control method, considered the most economical in the long run, is to destroy all infested trout and restock with trout that are free of disease. Before restocking, all the ponds are emptied of water, cleaned, and allowed to remain in a dormant condition for three months. The source of water must also be freed from infected fish before re-stocking. The species of gill louse found on trout in Michigan lives only on the brook trout; rainbow and brown trout are immune to it.

Gill lice were known on native brook trout before hatcheries were built, but planting of infested fish has spread this parasite throughout the entire state.

Another type of "fish louse" (*Argulus*) is a tiny, flat, disc-shaped crustacean that roams freely over the body of fishes, sometimes going from one fish to another. Ordinarily these parasites are no more harmful to fish than are fleas to a dog, but if the fish is weakened by other conditions they may contribute to its death. *Argulus* leaves the fish three times a year to breed, thus the fish is free of infestation at such intervals.

Argulus has been found on the walleye, yellow perch, rock bass, black bass, bullhead, crappie, calico bass, whitefish, burbot, dogfish, pike, and large suckers.

Many minnows and the smaller surface fish are fond of eating the younger stages of the "fish louse" and thus may aid in controlling these parasites.

Fungus (*Saprolegnia*): Fungus, or water mold, appears as a tuft of fine white threads which radiate out from the body of the infected fish to a distance of one-third of an inch or more. When the water is dirty or muddy, particles of dirt and mud may adhere to the growth and give it a grayish or brownish appearance.

When fish are injured, perhaps by external parasites, by careless anglers, or by spawning activity, the wounds provide openings for attack by bacteria and fungus. One zoöspore, the tiny seed of the fungus, is sufficient to initiate an extensive growth. A heavy infection may cause death of the fish.

Fungus is not confined to living fish, but also may be seen growing on animal matter or dead animals which have been in the water for some time.

Commercial bait dealers occasionally lose many minnows due to excessive growth of fungus. The fungus may be caused by rough handling, poor condition or overcrowding of fish, containers having rough walls or sharp projections that injure the fish, etc. Malachite Green lustrous crystal (Malachite Green-Oxalate), zinc-free, is a chemical that is specific for fungus if used according to the following directions: To aid in combating fungus infections on minnows, three and eight-tenths (3.8) grams of Malachite Green-Oxalate, zinc-free, are mixed with ten (10) gallons of water (a 1-10,000 dilution) and the minnows dipped into the solution and held there for two (2) to three (3) seconds, then placed in flowing fresh water. At fish hatcheries, trout are usually treated for one to two minutes at the same concentration with no danger of loss, but minnows are unable to withstand a prolonged exposure to this chemical. To insure that the chemical will completely reach and cover each fish, care should be exercised not to dip too many fish at one time. In treating fish with chemicals it should be remembered that fish can withstand longer treatments at lower temperatures than they can at higher temperatures and the operator must vary the immersion time accordingly. In treating for fungus with Malachite Green the success of the treatment is indicated by the color of the fungus when the fish is returned to clear water. The fungus should retain the green dye. Several treatments a week may be necessary to keep the fungus in check.

It is advisable to treat new supplies of minnows before they are released into the holding tanks. Heavy growths of fungus are difficult to treat successfully and usually result in the death of the fish.

Ulcer Disease: The appearance of ulcers or sores on fish may be caused by the action of bacteria or from an injury. If the latter cause is apparent, no specific disease is involved, although bacteria may produce an infection. In Michigan ulcers caused by disease are found most frequently on trout and northern pike. Those found on northern pike may vary from a white, swollen area denuded of scales to reddened, ugly open sores filled with pus. The ulcer may be two inches or more in diameter, located anywhere on the body of the fish. The exact cause of this disease is not known at the present time, but it greatly resembles a disease of pike reported from Canada by G. B. Reed and G. C. Toner, who found as the causative organism a bacterium (*Proteus hydrophilus*) that also causes the "red-leg disease" in frogs.

Ulcers on trout may be caused by two different organisms. One, the same organism that causes ulcers in northern pike, results in an open sore and does not involve the muscle tissue except at the surface of the ulcer. The other disease, called "furunculosis" is of importance in fish hatcheries.

Furunculosis differs from ulcer disease in that it is caused by a different bacterium (*Bacterium salmonicida*), one which is carried in the blood stream of the fish. The ulcers begin deep in the flesh and progress towards the surface of the body, at first forming blisters beneath the skin and finally breaking through to make ulcers. However, death may occur before the external ulcers are evident, the bacteria causing internal hemorrhages (Fig. 6). The disease is very infectious and is transmitted from one fish to another through the water.

Until recently, no cure or suppressive treatment was known and the only method of combatting the disease was to destroy all fish, thoroughly disinfect the ponds, and begin anew.

In 1946, Drs. J. S. Gutsell and S. F. Snieszko of the U. S. Fish and Wildlife Service, experimented with various sulfa drugs in the treatment of furunculosis and found that one, sulfamerazine, effected a cure. In Michigan trout hatcheries, effective control is obtained by administering 16 grams of sulfamerazine per 100 pounds of food daily for a period of four days, followed by 8 grams per 100 pounds daily for an additional 10 days. A sharp reduction of mortality is noted within four days after the treatment is begun. It should be pointed out that fish can be killed by overdosage of sulfamerazine and that this drug has not been demonstrated to be of any value in treating other ailments of fish.

Lymphocystis: Lymphocystis is a disease that produces groups of numerous jelly-like tumors or warts on the body and fins of a fish (Fig. 7). The warts are composed of cells of gigantic size, surrounded by a thick cell membrane. The lymphocystis cells are thought to be stimulated to gigantic growth by the action of a virus within the cells. The disease is reported to be highly infectious among the individuals of the species of fish in which it occurs, but it does not necessarily kill the fish. It is harmless to humans in properly cooked fish.

In Michigan, lymphocystis is frequently found on walleyes in Saginaw Bay, and more rarely in Lake Michigan and other lakes and streams.

Lampreys: Lampreys or "lamprey-eels" are one of the few external fish parasites large enough to be easily seen. They are of a grayish color, have an eel-like appearance, and may be more than ten inches long. They have seven gill openings on each side of the throat and have a sucking oral disk instead of a mouth with true jaws. A number of small thorn-like teeth are located in the center of the disk. The lamprey attaches itself to fish by means of the sucking disk, which is used like a vacuum cup, and rasps away the skin with its thorn-like teeth so that it may feed on the blood and body juices of its host. Lampreys undoubtedly have a detrimental effect on fish, since they bleed the fish while they are attached to it and leave large, ulcerous wounds. The appearance of lampreys on fish and the sight of the sores which they leave is not exactly appetizing but the food value of such fish usually is not impaired. Most fish recover completely, as evidenced by specimens bearing old lamprey scars.

Michigan waters support five species of lampreys but only three of them are parasitic. The five species can be identified readily by the use of the following key, modified from Hubbs and Lagler (1941):

I. Dorsal fin never divided into two distinct fins.

- A. Teeth and buccal (mouth) funnel degenerate. Non-parasitic.
  ....Michigan Brook Lamprey (*Ichthyomyzon fossor*).
- B. Teeth and buccal (mouth) funnel well developed. Parasitic.
  1. Teeth all unicuspid (with single point) ..... Silver Lamprey (*I. unicuspis*).
  2. Teeth at least in part bicuspid (with two points) .. Chestnut Lamprey (*I. castaneus*).

II. Two distinct dorsal fins.

- A. Teeth radiating in all directions from center of funnel. Ranging in length up to 40 inches; seldom less than 14 inches (as a spawning adult). Parasitic.
  ....Sea Lamprey (*Petromyzon marinus*).
- B. Teeth not radiating from center, but in several groups. Ranging in length up to 15 inches. Non-parasitic.
  ....American Brook Lamprey (*Entosphenus lamottenii*).

The lampreys average from 4 to 15 inches in length, except the sea lamprey, Petromyzon marinus, mature specimens of which measure from 15 to 30 inches long in the Great Lakes.

The sea lamprey (Fig. 8 and 9) migrated to the Great Lakes and tributary waters from the Atlantic Ocean. Although its migration has taken many years, it is now reported as far west as Lake Superior. Niagara Falls was a very effective barrier to its progress until canals built to aid shipping also provided for the sea lamprey's continued migration.

At the present time, commercial fishermen of the Great Lakes report that a large number of fish in their catch show wounds (Fig. 10) and scars caused by the sea lamprey, and directly relate the decline of lake trout and whitefish catches to the increasing abundance of this parasite. No direct proof of such a relationship has yet been established but the fact that they prey upon fish and are increasing inabundance makes the problem a serious one. States bordering the Great Lakes, the U. S. Fish and Wildlife Service, and Canada are now working together in an attempt to find a suitable means of control. Further information concerning the sea lamprey may be found in other reports of the Michigan Institute for Fisheries Research.

Leeches: Certain leeches or "bloodsuckers" attack fishes, but do little damage unless present in large numbers. They usually have a greenish or brownish color, are from one-quarter of an inch to an inch long, and may be found in the mouth, on the gills, fins or body of bluegills, perch, and many other fishes (Fig. 11).

Other Afflictions Visible Externally: Sometimes the angler is startled by catching a fish with a backbone bent so crooked that swimming would seem impossible (Fig. 12), or perhaps with the lower jaw twisted far to one side or shortened so much that it appears to be completely lacking. These and many other deformities seen every year by anglers may be the result of injuries inflicted by anglers, other predators, or other fish. Disease may cause variations in fish anatomy, such as shortening of the spinal column by the softening and squeezing together of the vertebrae with subsequent hardening caused by arthritis. Unfavorable environmental conditions while the fish are yet embryos within the egg may alter normal development to produce spine curvature and other deformities. At trout hatcheries, trout with two or three heads (Fig. 13 and 14), siamese twins, and other monstrosities are occasionally hatched, but usually live no more than a few days. Figure 15 is a photograph of siamese twins that lived for six months. At this time the smaller twin died and the entire specimen was preserved for reference and study.

Deformed fish may be unsightly to the angler but they are as palatable as normal fish and should not be discarded as worthless. Abnormalities, such as goiter (Fig. 16), in hatchery fish may be caused by improper diet or a water supply lacking certain essential elements. These ailments are rarely seen in wild fish.

Fish are the main course on the menu of some animals and an occasional delicacy to others. If these predators were always successful in their attempts to catch fish, this section would not have been written. However, their aim is not always true and the escaped fish sometimes bear marks and wounds which may eventually cause death. Many times the wounds heal and scars are left that are characteristic of the animal that inflicted the wound.

The turtle makes triangular wounds which are usually fatal because the wound is deep and penetrates into the body cavity. The seriousness of the injury is somewhat dependent on the size of the turtle and the location of the wound. The tail of a fish may be completely amputated by a turtle without causing death of the victim.

Snakes seize and hold the fish crosswise, their teeth making a series of parallel punctures in vertical rows along the side of the fish.

Mink leave a horseshoe-shaped pattern of punctures in the side of the fish, the mark of their characteristic tooth arrangement.

The fish-eating birds leave marks that are most easily identified because each species attacks in its own manner and the difference in the size of the bill also aids in identifying the predator. The great blue heron spears fish, either with its bill closed or slightly open, so that the two halves act as forceps. The lightning-fast thrust is aimed at the region of the dorsal fin, and occasionally at the head if the fish is large. The pair of marks made when the great blue heron picks up the fish and manipulates it for swallowing are of much larger size than those made by the American bittern or by the green heron.

The bittern, or marsh-pump (thunder-pumper), usually spears the fish, leaving neat, rounded holes deep in the flesh of the back between the head and dorsal fin.

The kingfish rarely spears fish, but uses its bill as forceps, the force of its plunge from above wedging the fish in its bill. As it flies away with the fish, it moves the fish one way or another to balance it, thus making characteristic marks on the body of its prey. Occasionally, a fish too large to be swallowed will be caught and subsequently released, carrying on its body the characteristic marks of the kingfisher bill.

Fresh lamprey marks are easily identified by their circular or oval outline and the shallow pit rasped in the flesh.

INTERNAL PARASITES AND DISEASES

Liver Cysts (Neascus sp.): Certain liver cysts (as well as cysts around the heart and in the kidneys) are close relatives of the external "black-spot" cysts. Although their life cycle is nearly the same (involving snail, fish, and bird), they may be more detrimental to the fish since they infect vital organs. Fish may sometimes carry great numbers of these worms apparently without detrimental effects, but severely adverse environmental conditions may cause such fish to be less resistant than normal individuals and losses among them may be heavy.

Like "black-spot," liver cysts (and related cysts) need offer no cause for concern over the edibility of properly cooked fish.

Yellow Grub (Clinostomum marginatum): The fish in many lakes of eastern North America are often considered unfit for food because of small "yellow grubs" found in the flesh, especially about the head and in the region of the backbone (Fig. 17). Yellow perch, large- and small-mouthed black bass, and bluegills are most often affected. This yellow worm is not always buried deep in the muscle tissue but occasionally appears just beneath the skin, especially in the region of the throat, where it can be seen easily from the exterior. The "yellow grub" is the larval stage of a parasitic worm that spends its adult life in the throat and mouth of the great blue heron. The life cycle (Fig. 18) of this worm, essentially the same as that of "black-spot," is as follows:

A fish parasitized by yellow grubs is eaten by a great blue heron. The flesh of the fish is digested, leaving the grub or larva, which then crawls to the throat and mouth of the bird. There it maintains its location by means of two suction cups. It matures and lays eggs which are washed out of the heron's mouth when the latter dips its bill into the water. The eggs hatch in the water into free-swimming larvae that penetrate certain species of snails. In the snail, each larva multiplies in numbers a thousand-fold (or more) and when a certain stage of development is reached, the progeny leave the snail and are free-swimming again. When they contact certain species of fish, they burrow into the flesh and become the yellow grub.

This worm does not leave the fish in winter as is commonly supposed by sportsmen. Although growth is retarded in fish parasitized by certain parasites, no such effect has been reported for the yellow grub.

Tapeworms: Adult tapeworms (Cestodes), which occur as adults in the intestine of the fish host, are flat, ribbon-like, whitish worms composed of many segments. The head, or scolex, is very tiny and is usually imbedded in the wall of the intestine of the host. The long (one to several inches or more), segmented body lies free in the cavity of the intestine. New segments are constantly being formed in the head region, thus constantly increasing the length of the worm. As the segments grow larger, both male and female reproductive organs are developed in each one so that each segment is actually a complete individual capable of producing fertilized eggs. As the segments become ripe and produce eggs, they are eventually detached from the body of the worm. Segments of some tapeworms discharge the eggs into the intestine while still part of the worm, while others hold the eggs until they become separated from the chain and are voided from the fish into the water.

Ordinarily, the tapeworms seen in fish are small and the segments are difficult to distinguish. When they contract they may appear to be cylindrical and thus may be confused with round worms. However, the tapeworm is elastic and can be stretched out while the round worm has a definite length and cannot be further elongated without rupturing the body.

Broad Tapeworm (*Diphyllobothrium latum*): The broad tapeworm is present in North America in four areas, namely (1) northern Minnesota, around Long, Burntside, Vermillion, and Devils Track lakes; (2) southeastern

Manitoba, around the southern portion of Lake Winnipeg, and including the City of Winnipeg; (3) the Lake Nipigon district of Ontario; (4) the Portage Lake district in the Upper Peninsula of Michigan.

The only fishes in which it has been found in North America are the northern pike (Esox lucius), the walleye (Stizostedion vitreum), the sauger (Stizostedion canadense), and the yellow perch (Perca flavescens). Persons can become infected only be eating the fishes uncooked. The infective larvae of the broad tapeworm can be identified only by an expert and may easily be confused with many other larvae that are infective to gulls, ducks, and certain mammals.

The fact that the broad tapeworm will develop also in the dog, cat, seal, bear, fox, and mink complicates attempts to control it. It has been shown that even in areas where the larvae of this tapeworm are found in fishes, very few people are infected.

Bass Tapeworm (Proteocephalus ambloplitis): This tapeworm annoys both fish culturists and anglers, because it frequently causes considerable damage to bass by destroying the reproductive organs and causing unsightly "granulations" and adhesions in the body cavity.

The life cycle (Fig. 19) is as follows:

The Adult. - The adult tapeworm occurs in the intestine of the bass. The eggs pass into the water where they are eaten by a small water animal, a non-parasitic copepod, within which they develop into forms known as procercoids (first-larvae).

The Larva. - The procercoid stage exists within the copepod until it is eaten by a young black bass, rock bass, sunfish, bluegill, yellow perch, or pickerel. The parasite is released from the copepod by digestive action in the stomach or intestine of the fish. Once released, it bores through the wall of the alimentary tract into the body cavity and develops into a second larval form known as the plerocercoid, which remains in the body cavity until the host is eaten by a largemouth or smallmouth black bass. It is then released by digestion into the alimentary tract, where it develops into an adult worm and the cycle is completed.

When heavy infestations of larvae occur in the body cavity, a severe inflammation is caused which results in a knotting of the intestines to form a hard ball, which is often noted by fishermen. Damage of another kind results when the larvae penetrate the reproductive organs, sometimes rendering the fish sterile and at other times initiating the growth of large tumors. Unlike the "black-spot" and "yellow grub" which are carried by fish-eating birds, the bass tapeworm can only be spread to unconnected waters by the planting of infected fish.

A conspicuous grub is found in the flesh of ciscoes from certain lakes. This grub is a larval form of another tapeworm (Triaenophorus crassus). When another fish eats a cisco infected with these grubs, the larvae grow into adult tapeworms. The larvae may live in the flesh of ciscoes for three to four years and then either dry up or form calcareous nodules. It has been demonstrated that heavy infections of these larvae retard the growth of the fish host. There is no danger to man of infection by this tapeworm, and they are easily destroyed by normal cooking.

Other Tapeworms: Tapeworms, less harmful than the bass tapeworm, are found in all fishes and have the same general life cycle. An interesting larval tapeworm (Ligula) (Fig. 20) is frequently found lying free in the body cavity of some fishes, often causing a conspicuous distension of the belly. The size of this immature tapeworm is limited only by the size of the fish, and seldom more than one individual is found in a single fish, although as many as 15 were found on one occasion. It may be only two inches long in a minnow and over a yard long in a 20-inch sucker. The adult of this worm is found in certain fish-eating birds.

Roundworms (Nematodes): Threadworms, a kind of round worm, are slender, cylindrical worms varying from microscopic size to half an inch or more in length. They sometimes attack a fish in such large numbers as to cause its death. These worms are easily distinguished from others by their thread- or hair-like shape and by their whip-like movements. They are usually found in the digestive tract and occasionally in the swim bladder. Sometimes they are found encysted in muscles or fat, and at other times they may be attached to the lining of the body cavity. Roundworms live on the blood or vital fluids of the fish host, and some living in the stomach or intestine feed, not upon the host, but upon the partially digested food in the intestinal tract of the latter. They injure the host by tearing the intestinal wall, draining the vitality of the fish, and also by providing wounds where bacteria and protozoa may gain foothold. Fishes become infected when they eat the eggs or infective stage of these worms.

Spiny-headed worms (Acanthocephala), another kind of roundworm, live in the intestines of the host and often occur in great numbers in aquatic vertebrates. In size and shape they are much like threadworms but differ in their movements and structure. They do not have a whip-like motion and they have a prominent proboscis (head end) studded with recurved hooks. The hooks are used by the worms for the purpose of anchoring themselves to the wall of the intestine, which is injured in the process. If enough worms are present, they may cause the death of the host.

During spawning runs of smelt, spiny-headed worms (Fig. 21) are observed in smelt by people dipping this fish.

The worms are about one-sixteenth of an inch long, and are whitish to yellowish in color. They live normally in the intestine of the fish. However, the anatomy of the proboscis enables the worm to burrow rapidly through tissue, and when the smelt are taken from water and die the worms begin to burrow through the intestinal wall into the body cavity. Some continue from the body cavity into the flesh, and in some cases burrow through to the outside surface of the smelt. Since they are destroyed by normal cooking, fish so infected need not be discarded.

ENVIRONMENTAL FACTORS

Fish may be killed by factors other than disease. Environmental conditions may become altered, either naturally or through pollution, so that they are unable to support fish life. Lowered vitality following spawning, coupled with adverse water conditions, frequently causes losses among bluegills and bass. In rare instances, lightning has been known to kill fish.

Pollution: Pollution will be discussed here in relation to its deleterious effects on fish life. Due to the many kinds of pollutions and the complexity of their actions, no attempt will be made to go into detail. Fish may vary according to species, age, size and weight and individual vitality in their reactions to pollution.

The battle to regulate and prevent the pollution of our lakes and streams has been going on for many years and must necessarily be continued due, in part, to the establishment of new industries with new types of wastes. Many industries have benefited in the elimination of pollution by converting harmful effluents into profitable by-products.

Fish life is affected by two major kinds of water pollution: sewage and industrial wastes. Sewage is usually regulated as a public health measure. It is injurious to the fishes' environment, and fish from waters known to carry sewage are less desirable for the angler's table.

Industrial wastes are the chief pollution menace in relation to fish life. Some of these wastes cause fish mortalities because they remove the oxygen from the water, either by chemical action, as in pollution from coal mines, or by the decomposition of organic matter of which they consist, as in pollution from canneries. In the latter case, the wastes form a sludge which ferments, thus removing oxygen from the water. Some wastes kill fish by toxic or poisonous action. Acids such as nitric, hydrochloric, and sulphuric, from chemical and munitions plants, are toxic to fish.

The following are some of the chemicals that have been demonstrated to be lethal to fish life in the concentrations customarily released into lakes and streams by industries:

Nitric acid: Manufacture of fertilizer, munitions, etc.

Sulphuric acid: Manufacture of munitions, nail and iron works, etc.

Tannic acid: Manufacture of ink and leather.

Hydrochloric acid: Chemical and dye plants.

Ammonium hydroxide: Ammoniacal works.

Ferrous sulphate: Iron and nail works.

Sulphite liquor: Paper pulp manufacture.

Sodium hydroxide: From many industrial processes.

Cyanide salts: Electroplating processes.

Oil well brines and petroleum distillates: Petroleum industry.

It is often difficult to determine the cause of death of fish where pollution is suspected because the specimens usually appear to be normal in respect to anatomy. In some instances, fish dying from lack of oxygen may show redness in the regions of the cheeks and throat, indicating congestion of the blood vessels. Pathological study, which involves the use of detailed and lengthy procedures, may not disclose the cause of death.

Winterkill: (Fig. 22) Ice cover isolates lakes completely from the air and prevents the exchange of oxygen and carbon dioxide, two gases of vital importance to all plant and fish life. Snow cover on the ice effectively prevents sunlight from reaching submerged water plants, so that oxygen production and consumption of carbon dioxide by aquatic vegetation is prevented. Since fish and other water animals constantly use oxygen and give off carbon dioxide, the amount of oxygen in the water is constantly decreasing and the amount of carbon dioxide is increasing. Lakes having much muck or organic debris on the bottom also lose oxygen by constant decomposition, or rotting, of the organic matter. In deeper lakes the water volume is great enough to carry sufficient oxygen to supply the needs of both fish and decomposition throughout the period of isolation. In shallow lakes, however, the oxygen may be entirely depleted during winter, with a resulting mortality of fish.

It may be stated that various species of fish differ considerably in their oxygen requirements, which explains why some species of fish are killed by a partial depletion of oxygen and others are not visibly harmed by it. Carbon dioxide in certain concentrations is deleterious to fish although its exact role in winterkill has not been explained. Why one lake suffers winterkill and another, apparently identical, does not is difficult to explain, unless one understands the many basic differences of lakes, such as number and species of fish present, type of bottom, contour, general depth, proportion of shallow and deep water, source of water supply, etc.

Spring-Kill: "Spring-kill" is a mortality that occurs during or just after the spring fish-spawning season. Very heavy losses are frequently reported from lakes having large areas of shoal or shallow water. The combination of low water over the shoals and of very warm days elevates the temperature of such waters to a point that is dangerous to fish life, especially during the spawning period. The warming is seldom sufficient to cause the death of the fish directly, but is enough to decrease resistance of fish to disease, or to hasten the multiplication of disease organisms. Most losses of this type are considered normal and are, in many cases, of benefit to the lake as they help to hold the population of fish down to a level that prevents stunting from over-population.

REMARKS

Control of fish disease in nature is impossible, except in very rare instances. Where it might be possible, it is seldom economically feasible.

The transfer of disease between unconnected bodies of water may be accomplished by various means. Probably the greatest offender is man when he carries fish from one lake or stream to another, either for use as bait or for purposes of stocking. The dissemination of a disease to waters previously free of that disease could be prevented in many cases if the fish were examined before transfer by a competent fish pathologist, and a study made of the history of fish disease in the water from which the fish were to be taken.

Further Identification of Fish Parasites: The diseases and abnormalities discussed in this report are limited to those most frequently observed by the average angler and represent only a small fraction of the total number of diseases that occur in fishes. A complete list and description of all the parasites would require a large volume and be of interest only to the pathologist.

Additional information concerning fish parasites may be obtained by writing to the Pathologist, State Fish Hatchery, Grayling, Michigan, or to the Institute for Fisheries Research, University Museums Annex, Ann Arbor, Michigan. Accurate descriptions of the parasites, including the location in the fish host and the kind of fish host should be included. Specimens of the parasites or parasitized fishes, preserved in alcohol or 10 per cent formalin, should accompany the descriptions whenever possible.

Fresh specimens of fish are preferred and should be submitted whenever possible. Infected fish can be packed for shipment in dry ice or regular ice. However, if there is a possibility of the fish spoiling en route, they should be preserved in alcohol or 10 per cent formalin. Containers of some kind, glass jars, or tin cans, may be used for this purpose, or the fish may be wrapped in several layers of cloth soaked in 10 per cent formalin, then further wrapped in cotton waste or some other substance, with an outside covering of thick paper.

INSTITUTE FOR FISHERIES RESEARCH

Leonard N. Allison
Parasitologist

Approved by A. S. Hazzard

Typed by B. J. Bair

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Captions for Figures

Fig. 1. Black-spot on yellow perch. Lengths of the two perch approximately 4 inches.

Fig. 2. Life cycle of Black-spot of bass. (After Hunter and Hunter. Courtesy of the New York State Conservation Department.)

Fig. 3. "Gyro," Ancyrocephalus sp., a gyrodactylid parasite found on the skin, fins and gills of fish. Note large hooks for anchoring to tissue of fish.

Fig. 4. Gill louse (Salmincola edwardsii). Female showing egg sac. (Courtesy of the New York Conservation Department.)

Fig. 5. Gill louse (Salmincola edwardsii) on gills of brook trout.

Fig. 6. Internal furunculosis in brown trout. Black spots in internal organs are hemorrhages.

Fig. 7. Lymphocystis on walleye.

Fig. 8. Sea lamprey. The adult is 15 to 30 inches in length.

Fig. 9. Sea lamprey. Anterior view with mouth funnel expanded showing arrangement of teeth.

Fig.10. Sea lamprey marks on whitefish collected from Hammond Bay, Lake Huron, June, 1947. The fish were approximately 20 inches in length.

Fig.11. Leeches on tail of yellow perch.

Fig.12. Spinal deformities in yellow perch taken from a Michigan Lake.

Fig.13. Two-headed brook trout sac fry.

Fig.14. Three-headed brook trout sac fry.

Fig.15. Siamese twins, brook trout, six months old.

Fig.16. Goiter in hatchery brook trout caused by faulty diet.

Fig.17. Yellow grubs in flesh of yellow perch. (Courtesy of the New York Conservation Department.)

Fig.18. Life cycle of the yellow grub. (After Hunter and Hunter. Courtesy of the New York Conservation Department.)

Fig.19. Life cycle of the bass tapeworm. (After Hunter and Hunter. Courtesy of the New York Conservation Department.)

Fig.20. Dissection showing Ligula in the body cavity of a fish (Couesius plumbeus). (Courtesy of the New York Conservation Department.)

Fig.21. Proboscis of acanthocephalid worm from smelt.

Fig.22. Winterkill of fish.

Figures with original only which is to be printed.