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Control of the pike-whitefish tapeworm in Central Canada

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INTRODUCTION

Value of whitefish

Commercial catches of whitefish, *Coregonus clupeaformis*, in the provinces of Manitoba, Saskatchewan, Alberta and in the Northwest Territories together amount to 12-15 million pounds annually, worth about $2 million to the fishermen and $5 million as marketed. It is one of the most valuable of the freshwater food fishes.

Marketing difficulty

Most of the Canadian fish production is exported, and nearly 90 per cent of the whitefish goes to the United States. Its importation is under scrutiny by the Pure Food and Drug Administration and must conform to standards for quality. Unfortunately some lakes in Central Canada produce whitefish too heavily infested with intermediate stages of the tapeworm *Triaenophorus crassus* to meet the quality standards. Refusals of admission led to considerable losses for Canadian shippers, and international relations were not helped by the absence of some quality control before the fish were exported from Canada.

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[1] A paper prepared for the Seventh Pacific Science Congress, New Zealand, 1949.

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Inspection and research

Following several years of friction over the whitefish situation, the Prairie Provinces Fisheries Investigation Committee was formed jointly by the Dominion Government and the governments of the three provinces, and in 1943 advocated a Canadian inspection of all whitefish produced for export from those provinces. This inspection came into practice in the following year.

The Committee also pointed out the necessity of more research with the objective of breaking the life cycle of the parasite and effecting a cure more basic than inspection. The Central Fisheries Research Station was established in 1944 with this objective as one of its chief functions.

LIFE HISTORY OF *TRIAENOPHORUS CRASSUS*

Although some earlier work on the tapeworm *T. crassus* had been done, most of the credit for recent researches on its life history must go to Dr. R. B. Miller who conducted his investigations for the Alberta Department of Lands and Mines and for the University of Alberta.

Adult tapeworms live in the intestines of pike, *Esox lucius*, and in the spring they die after having produced many eggs which hatch in the water into small ciliated coracidia. A young worm may be swallowed by a water flea, *Cyclops bicuspidatus*, and, if the water flea is eaten by a whitefish about 10 days later, the parasite penetrates the fish's stomach wall and lodges in the flesh, usually above the ribs. Here it lies within a sac, and, with its waste products, forms an object of aesthetic distaste to a prospective human consumer. If within 3 years the whitefish is taken as food by a pike the worm is released from its cyst and attaches itself to the inside of the pike's upper intestine and grows to maturity. The pike is the only known host of adult T. crassus, but several coregonines and related fishes may harbor the second intermediate stage.

QUALITY CONTROL

Lake surveys

The degree of parasitization of whitefish varies in different lakes, so one of the first steps in quality control was to survey the whitefish in each lake. About 200 surveys were made in the first year of operation, i. e. to the end of 1945, by provincial personnel, and analyses of all the reports by a federal whitefish inspector showed that if about 3 million pounds of the poorer quality whitefish were removed from production the overall picture would be consideraby brightened. The provinces accordingly closed the poorer lakes, and the volume of rejections by the United States showed a gratifying shrinkage.

Whitefish inspection

The surveying of lakes of origin has not completely eliminated the production of nonacceptable whitefish, however, so in the near future all shipments of whitefish will be inspected before they leave Canada.

The testing of a fish for worm content involves its complete destruction insofar as its ordinary form and market value are concerned, so satisfactory tests using a minimum of fish were desired. From arbitrary standards used in earlier testing, statistical methods have now been developed employing sequential analysis with a maximum of confidence in the inspection and a minimum of time and samples.

Candling

Candling is the term applied to the process of viewing a whitefish or its fillet by transillumination, the same as in egg inspection. It has been applied only on a small scale, because the tapeworm makes a shadow in the flesh only when close to the surface, so that deeper cysts cannot be detected. Worms which can be thus seen are taken out by a knife or forceps, and the fillet may then pass inspection. The experimental testing of various colours and intensities of lights at the University of Alberta and elsewhere and the testing of X-ray equipment at the Pacific Fisheries Experimental Station, have not found a satisfactory method of candling whitefish.

Size selection

In some lakes, but not as a general rule, whitefish of specific size ranges--for instance, all whitefish over 4 pounds in weight--would pass inspection. The sorting out of such fish, and the elimination of the undesirable fraction of the catch, have presented administrative difficulties that would make this method generally inapplicable.

Area or depth selection

In some lakes the whitefish population is obviously not homogeneous, because extensive differences in whitefish infestation exist in different areas or at different depths in the lake. Broadly speaking, whitefish from shallow parts are of inferior quality to those from deep portions of a lake, and this principle has been applied in the management of a few waters.

Break life cycle

The surveying of lakes for overall quality, inspection on the way to market, candling, and selective fishing are only temporary expedients in the elimination of poor quality in whitefish. Full use of all production capacity should be the aim, and this cannot be attained unless the tapeworm is severely reduced or eliminated in the lake itself. This can be effected only by breaking the life cycle.

CONTROL POINTS IN LIFE CYCLE OF TAPEWORM

Destruction of coracidia

Only for a few days after hatching from the egg does the young tapeworm lead an existence apart from some host. This fact led Miller to test various agents for their possible toxic effect upon free-living coracidia. It was discovered that acidulation of water to a point more acid than normally found in natural lakes caused failure in the worms osmotic control, with the result that it swelled up and burst. A practical demonstration of this, using several tons of sulphuric acid in a lake, showed natural waters and bottom sediments to be so strongly buffered that the acid's effect was extremely temporary and the coracidia suffered no serious harm.

The search for coracidiacides has continued. Several have proved efficient in dilute concentrations, but are still too expensive for extensive application.

Destruction of water fleas

The first intermediate host of the pike-whitefish tapeworm, the microcrustacean C. bicuspidatus, is so cosmopolitan that its eradication or control has been regarded as one of the larger impossibilities of the whole programme, and has not been attempted.

Destruction of secondary intermediate hosts

The second intermediate stage of T. crassus has been found not only in whitefish but also in lake trout, Cristivomer namaycush, Arctic grayling, Thymallus signifer, inconuu, Stenodus leucichthys mackenzii, round whitefish, Prosopium cylindraceum, Oregon whitefish, P. oregoni, and various species of cisco or tullibee, leucichthys. In most of these the tapeworm is believed to be an accidental or occasional parasite. In tullibee, however, it flourishes with success.

(a) Tullibee

That the tullibee has proved such a successful host is perhaps attributable to two reasons. In the first place, tullibee feed upon plankton all their lives, not just when young or only incidentally as do the other secondary intermediate hosts. They, then, are almost certain to receive a fresh dose of Triaenophorus every spring when the water fleas, their food, are infected. Secondly, tullibee do not generally grow to the large size attained by whitefish, and so serve as suitable food for pike all their life. The belief that T. crassus would be more aptly named the pike-tullibee tapeworm is strengthened in the fact that in lakes containing C. bicuspidatus, pike, whitefish and no tullibee, the whitefish are free of the tapeworm. Tullibee must be present as a tapeworm reservoir, the overflow from which may infest the whitefish.

This has led the Alberta government to sponsor an intensive fishery for tullibee in Lesser Slave Lake, where mink ranchers have created a great demand for fish for feed. In but a few years this 60-mile lake was producing 4½ million pounds of tullibee annually. This exploitation removed practically all the older fish, and the fishery became dependent upon 2-year-olds whose growth rate had increased remarkably. More significantly, the decline in infestation with Triaenophorus was so great in the tullibee that its effect was soon reflected in the quality of whitefish. These, from having been of poor quality, improved so much that they were highly approved for export.

The province of Saskatchewan has taken steps towards tullibee control in a demonstration lake. And in Manitoba consideration is being given towards ways and means of exploiting tullibee in Lake Winnipeg, the seventh largest lake in North America.

Destruction of adult host

Pike, the only host of the adult stage of *T. crassus*, offer interesting possibilities of control. Being piscivorous and solitary of habit they are usually not as abundant as the foraging tullibee. They have no great commercial value, and are heartily disliked by fishermen because of their destructive action upon nets. On the other hand, they are one of the world's most successful fishes in penetrating and maintaining themselves in the north temperate zone, and thus must rank as worthy adversaries in attempts to reduce their abundance.

(a) Manipulation of water levels

Pike spawn in the spring, usually in May and June, in grassy shallows immediately after the ice goes out. These shallows, often in bays or along marshy creeks, become warm quite rapidly under the spring sunshine, and pike eggs hatch in about 10 days. Miller has suggested the possibility of raising the lake level in early spring by a dam at the outlet, allowing the pike to spawn, and then to destroy the eggs before they hatch be exposing them to a sudden lowering of the water. Unfortunately, spring water levels are usually so high, and normal lake outlets so restricted and not permitting of sudden reductions in lake levels, that no suitable situation has presented itself to investigators for test.

(b) Poisoning

The use of poisons in fish cultural operations has met with some success. Some form of derris root (rotenone) has been employed mostly, for the complete or partial elimination of fish populations.

In Alberta rotenone was distributed at selected localities about a lake where there were believed to be congregations of pike. Although solitary hunters, pike do come to favoured places for spawning, and usually seek shallow, weedy places as feeding and sunning stations. Miller effected a considerable reduction in pike by spot poisoning, and brought about some improvement of quality in tullibee. But enough pike escaped with their lives to carry on the tapeworm cycle, and the improvement in tullibee quality (applicable to whitefish) was not complete enough to term the experiment an unqualified success.

The complete poisoning of a lake for the elimination of all fish, with screening to prevent reentry, and the planting of whitefish eggs or parasite-free fish, could logically give good results. But the practicality of poisoning large lakes and maintaining barriers rules this out of the question from the viewpoint of cost.

Techniques in malarial mosquito control have been developed which are based upon spreading poison upon vegetation before an expected flooding, and enough poison remains after high water and the influx of breeding stock to make the submerged vegetation lethal to young mosquitoes. A possibility exists of adapting this to pike control. Favorite grassy spawning grounds could be poisoned in the autumn when the water was at low level. The ideal poison would be one which clung to the vegetation and lost little potency overwinter, so that when the area was submerged in the spring all pike eggs and fry would be destroyed when they came in contact with the poisoned grass.

(c) Trapping

Pike often travel out of a lake for their spawning migration. This takes them through narrow channels into connecting lakes or bays or up or down tributary streams. Stationary traps in operation each spring would intercept a large proportion of the adult fish, and they could be removed from the lake. Owing to difficult travelling conditions in most areas at break-up time, most traps would require a resident operator. In Manitoba a wood and wire trap was operated in a small stream used by pike in the spring, and 10,000 pounds were caught and marketed in two weeks.

(d) Netting

Netting of pike may be accomplished under the stimulus of commercial fishing, i. e. for direct profit, or under various guises, such as catching them to feed fur animals. They are not a fish preferred by the net fisherman under ordinary circumstances, so it is unlikely if any great reduction in their numbers can be accomplished without special inducement.

Saskatchewan has made some effort to take pike with special crews employed for the purpose, but it is doubtful if enough were caught--although the total was several thousand pounds--to bring about any change in the quality of whitefish in the lake.

For 4 years a pike-netting demonstration has been operated on a small lake in Northern Manitoba, and certain conclusions are now evident.

THE HEMING LAKE EXPERIMENT

Heming Lake

To test the efficiency of netting pike as a method of reducing whitefish infestation, a small lake was selected in 1945 and subjected to fishing each spring and early summer. Heming Lake contained a population of whitefish heavily parasitized by Triaenophorus: its small size of 588 acres offered reasonable hope of control by a small field party; it was towards the headwater of a drainage system, so that tributaries were few and small; it was unexploited by other fishermen, so that experimental operations represented total fishing effort; it was located on a railway; there were a limited number of marshy bays for the use of pike. In addition, a small cabin was made available through the courtesy of the trapper.

Heming Lake is situated in the province of Manitoba at approximately 54° 53' N. lat. and 101° 7' W. long. It is 18 miles south of the town of Sherridon, is 3 miles in length and from one-quarter to one-half mile in width, and lies in the headwaters of the Grass River, a tributary of Nelson River which flows into Hudson

Bay. There are 8 main bays with muskeg shores and muck bottom, depths of water up to 6 feet, and with a fringe of emergent and considerable submerged vegetation. The remainder of the lake has little vegetation, has shores of igneous rock and sand, and a bottom of inorganic silt covered with decayed organic matter. Depths do not exceed 16 feet, the water is acid and brownish, and visibility is about 6 feet. Heming Lake is ice-covered for 6 or 7 months each year.

There are two main tributary streams. One is deep and slow moving, passing through a grassy muskeg where it enters the lake; it is here that most of the pike gather to spawn. The other is rapid and shallow, does not attract pike, and runs of fish are effectively blocked by a beaver dam 5 feet in height. The outlet stream flows to another lake about 2 miles distant, has 4 rapids, but offers no serious barrier to the passage of fish. The outlet of Heming Lake was screened in 1945, but the wire netting rusted away within a few months. Subsequently, beavers erected a dam below the outlet, so that most fish are blocked from coming up to Heming Lake.

Netting operations

Intensive netting for pike, using gill nets of various sized meshes about the lake shore, and hoop nets[3] at the mouth of the

3 Each net was provided with four oak hoops; the first two were 5 feet in diameter, and the last two were 4 feet. There were two tunnels and two 20-foot wings seamed in 9 thread rope. Wings were made of from 12 to 15 thread seaming twine, and around the hoops of about 36 thread twine. From the first hoop to the first tunnel it was 4-inch mesh, to the second tunnel it was $3\frac{1}{4}$-inch mesh, and the pot was between $2\frac{1}{4}$- and $2\frac{1}{2}$-inch mesh. The pot was closed with a draw rope, but greater convenience in emptying the pot was obtained by using a dip net through a laced slit in the side of the pot. Each hoop net was tarred. No leads were used.

favorite spawning stream, has been conducted in May and June each year from 1945 to 1948. Hoop nets proved relatively inefficient at other locations. Whitefish were taken in gill nets in the main body of the lake, and could be caught at all seasons of the year.

Pike

(a) Catch

The catch of pike in Heming Lake varied during the different years partly as a reflection of the total effort expended in their capture. About 2 pounds per acre were removed each year, and this was accomplished with least effort when the project was started in 1945. In no year subsequent to 1945 were pike taken as easily by hoop nets at the spawning stream in May and June, but the decrease was not regular (Table I).

The years 1945 and 1948 brought similar spring break-ups of the ice and fishing results are more comparable between them than under fishing conditions in the intervening years. From the last week in May until the middle of June weekly catches were about half those of the immediately previous week, and fishing in 1948 produced about half the return for the same effort that it did in 1945 (Table II). This rate of decline did not persist past the spawning season. It may be concluded that Heming Lake had a pike population in 1945 at least twice that of 1948, and the yield in the years between indicated the reduction had been even greater.

(b) Biology

The netting programme brought about a reduction in the average size of pike, presumably by removing larger fish more efficiently than smaller ones. Four-fifths of the pike caught were over 18 inches in length in 1945, but only about one-half exceeded this size in later years (Table I). This reduction of larger pike is important, because they are better able to consume whitefish and propagate the tapeworm.

In the spring pike up to 1 pound ate mostly trout perch, Percopsis omiscomaycus, in the neighborhood of the spawning stream, as trout perch were also making a spawning migration. Elsewhere in the lake they fed upon other small fishes also. In the early autumn and winter larger pike depended upon whitefish for their food, as well as other fishes of larger size.

Spawning occurred in the grassy edges of one of the tributary streams, became general when the water temperature reached 40° F., usually in the latter part of May, and was concluded by the time the water was 45° F., early in June in most years. The water temperature in the shallow flooded areas sometimes was 10° higher than in the stream itself, and the lake proper was still covered with ice.

Pike became mature at the beginning of their third year of life, and some were about 12 inches in length. These were too small to be caught effectively by the hoop nets. Female pike produced from 4,000 to 7,800 eggs per pound weight of fish, and on a body weight basis the greatest yields were from 5 and 6 year old fish weighing 2 to 3 pounds.

In Heming Lake pike attained fork lengths of 8, 13, 17, 19, 21, 24, 30 and 34 inches in their 2nd to 9th years, respectively.

Whitefish

(a) Catch

Only whitefish 13 inches and over in length have been considered with reference to infestation, because none smaller are customarily commercially marketed. The removal of a few hundred each year has apparently made no effect upon their availability in Heming Lake. They are, perhaps, a little smaller now than in 1945.

(b) Infestation

When the lake was first examined in March, 1945, the whitefish average 289.6 cysts of Triaenophorus per 100 pounds of whitefish. This remained unchanged that year, but the following year only about half as many were found (Table 1), and there has been no further improvement in quality based on annual averages of samples. The infestation was cut in half again by the end of the summer of 1947, but only proved to be temporary, not greatly influencing the average for the year. The greatest number of cysts in one fish was 99 in 1945, but has not been less than 17 in any year since then. These heavily parasitized whitefish were exceptional individuals.

The incidence of infestation increased in the fish with each year of age and reached a maximum at age 8 after which there was some decline. The greatest rate of increase in parasitization occurred from age 4 to age 5.

(c) Biology

Age-frequency distribution of 439 whitefish taken in 1945 showed bimodality at 5- and 9-year classes, at average lengths of 13.8 and 15.3 inches, respectively. The 9-year-olds have not continued in importance since then. After the 5th year length and weight increases became slower than in earlier years of life. It was in their 5th year that some whitefish matured, and the remainder did so a year later; in general, males matured a little earlier and lived longer than did females.

In the spring whitefish foraged through Heming Lake, and less than 10 per cent had not been feeding. There were no consistent differences in the food taken by fish of various sizes and at this time of year they had a more varied diet than in the autumn or late winter. Their slow growth is possibly related to the meagre bottom fauna, 0.5 c. c. per sq. ft., but they ate what was available without any marked selectivity. That they must ingest the occasional Cyclops is evident from the parasites they bear, but none were seen during the analyses of whitefish stomachs. Indeed, it is remarkable that they are not even more heavily infested by accidentally consuming parasitized microcrustaceans which were present in the lake in numbers exceeding 6,000 per c.m. in June, 1948, and 43 per cent of these carried procercoids of Triaenophorus.

SUMMARY AND CONCLUSIONS

1. Whitefish, one of the most valuable commercial fishes in Central Canada, sometimes suffers difficulty in marketing owing to the undesirable presence in the flesh of an intermediate stage of the tapeworm Triaenophorus crassus.

2. The life history of the tapeworm is known, and involves a microcrustacean and pike, besides whitefish or tullibee.

3. Quality control has been instituted by surveys of lakes producing whitefish, by inspection of shipments, and by selective fishing.

4. Research into methods of breaking the parasite's life cycle have involved poisoning coracidia and pike, and of intensive netting of tullibee and pike.

5. An account was given of the latter, where pike were attacked upon a basis of knowledge of their habits and those of whitefish, but the pike population could not be reduced by netting to a level low enough to effect more than a 50 per cent improvement in whitefish quality.

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Table 1. Catch of pike in Heming Lake, Manitoba, between 1945 and 1948, and data on whitefish infestation.

	1945	1946	1947	1948
Pike caught, number	563	571	931	705
Pike caught, pounds per acre	2.25	1.8	2.31	1.95
Pike caught, per cent 18 inches in length and over	82	58	48	53
Pike caught, pounds per hoop net per night at spawning stream in May and June	18	3	7	8
Whitefish examined, number	273	125	161	278
Cysts, number per 100 whitefish	528	327	322	353
Cysts, number per 100 pounds of whitefish	290	156	168	196
Cysts, greatest number in one whitefish	99	33	17	32

Table II. Average weekly hoop net catches of pike in the spawning stream at Heming Lake, Manitoba, in pounds per net per night.

	May 22-31	June 1-7	June 8-14	June 15-21	June 22-30
1945	49	27	19	5	
1948	27	13	6	7	4