

# THE CANADIAN FISH CULTURIST

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A Bulletin of Information and Opinion  
as to Fish Culture in Canada

November  
1946

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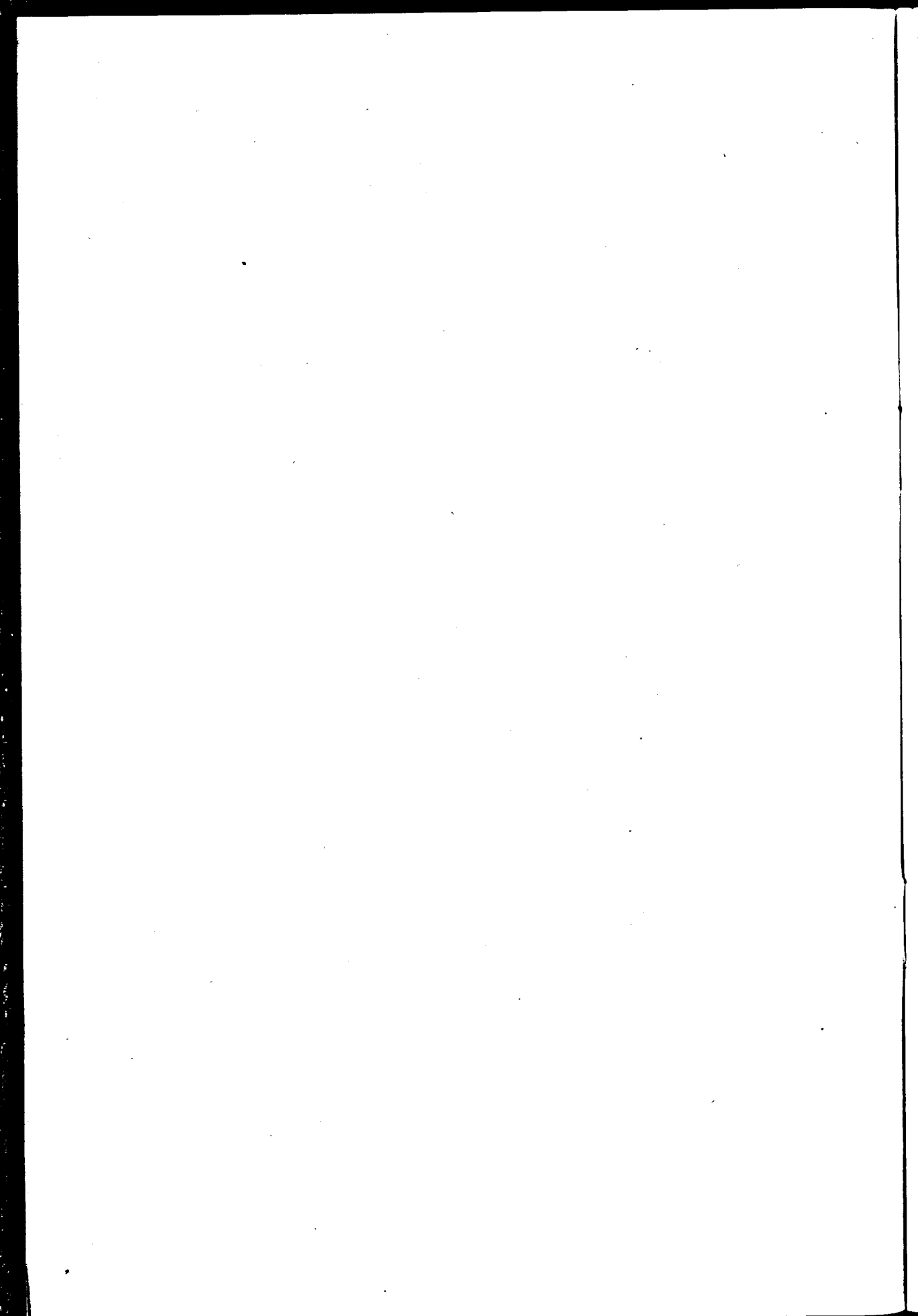
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## ANNOUNCEMENT

The Canadian Fish Culturist is being published by the federal Department of Fisheries to serve as a medium through which information and comment regarding Canadian fish culture and studies bearing upon it may be made more generally available. It is an outgrowth of discussions which had gone on for some time between various people interested in this field in Canada. Sharing in the discussions were a number of people associated with public fish culture services, both federal and provincial, as well as scientists whose work bears on fish cultural questions directly or indirectly. All felt it desirable that some means be created for the readier exchange of information and opinion in the Dominion, and the publication of a fish culture bulletin was proposed. It was also generally agreed that the term 'fish culture,' as definitive of the field to be covered by such a paper, should be interpreted in its broad sense and not as referring only to any single branch or aspect of the subject.

As it turned out, there was no fish cultural organization or group which was in a position to carry the bulletin proposal further. In these circumstances the Department of Fisheries has undertaken to meet the costs of publication and to handle the details in connection with issuing a bulletin of this kind.

During the discussions a number of the participating people from different parts of Canada, some of them concerned with one phase of fish culture in their own work, some with another, undertook to contribute articles to the bulletin. Several offered to prepare, from time to time, abstracts from foreign journals which would call attention to experiments carried on elsewhere that have practical application to Canadian fish culture problems. At the outset, The Canadian Fish Culturist is necessarily dependent upon these volunteers for material for its pages but it is hoped that others engaged in fish cultural operations or related studies in Canada will take the present announcement as an invitation to contribute articles—articles giving accounts of modifications and improvements in fish cultural techniques and equipment, scientific reports on Canadian experiments in lake or stream management, and so on. The frequency of publication will be governed by the volume of material which is made available by those interested. For the time being, no definite schedule of publication has been set.

Manuscripts and letters of discussion should be addressed: The Canadian Fish Culturist, c/o Department of Fisheries, Ottawa. Necessary photographs (glossy print finish) and charts or diagrams should accompany manuscripts but it is desired to avoid the use of non-essential illustrations.

Correspondents who may wish to discuss articles which have been published in The Canadian Fish Culturist will find space available for this purpose in subsequent issues. One of the purposes of the bulletin is to provide a forum for free expression of opinion.

In the areas of fact and opinion alike, the responsibility for statements made in articles or letters will rest entirely with the writers. Publication of any particular material will not necessarily imply that the department shares the views which may be expressed. In issuing *The Canadian Fish Culturist* the Department of Fisheries is acting only as an instrument for assisting in the circulation of information and opinion among people in the fish culture field.

The bulletin is not intended for unrestricted distribution among the public generally but for circulation among people concerned with fish cultural questions—fish hatchery staffs, fish and game associations, fisheries investigators, and so on. This first issue is being sent to a number of people in these groups. No doubt some others have been missed. Their names may be added to the mailing list on request. A limited number of copies of the present issue remain on hand and the department will be glad to fill requests for them while the supply lasts.

## SUCCESSFUL INTRODUCTION OF FISH IN A LARGE SALINE LAKE

BY D. S. RAWSON<sup>1</sup>

An investigation of the physical and biological conditions in saline lakes of Saskatchewan<sup>2</sup> was begun in 1938 by the writer and Mr. J. E. Moore. One of the primary aims of this survey was to determine the fish cultural possibilities of these lakes. By 1940 the studies had reached a stage where it was desirable to begin experiments in fish culture to test the conclusions arising from the survey.

The first of these tests was conducted on Redberry Lake, a large body of water about 40 miles northwest of Saskatoon. This lake was producing no fish although it was observed to have a fair supply of potential fish food. Its salinity of 15,000 parts per million approaches the maximum which can be tolerated by freshwater fish. Whitefish, *Coregonus clupeaformis*, and pike-perch (pickerel), *Stizostedion vitreum*, were introduced under controlled conditions and their progress was observed in succeeding years. Both species thrived in the lake which now produces from more than 20 tons of whitefish annually. It is felt that the details of this experiment should now be recorded.

### PHYSICAL, CHEMICAL AND BIOLOGICAL CONDITIONS

Redberry Lake has an area of 27 square miles, a mean depth of 37 feet and a maximum of 75 feet. It is thus large enough to produce important quantities of fish and of sufficient depth to be in no danger of immediate drying up. Stony islands and reefs appear in the lake, suggesting the presence of suitable grounds for lake spawning fish.

The present salinity of the lake water is 15,000 parts per million or less than half that of the sea. Since the lake has no outflow, continued increase in salinity is to be expected. In the drought between 1931 and 1939 it increased by about 20 per cent. Before that time and since, the increase was much slower. It is probable that, unless a severe drought occurs, the lake will not become too saline for fish in the next 15 or 20 years.

Temperatures and dissolved oxygen in Redberry were found to be much like those in Waskesiu Lake, a typical whitefish lake in the Prince Albert Park area to the north. High salinity in Redberry resulted in the persistence of low bottom temperatures throughout the summer.

The bottom fauna is composed mostly of midge larvae and freshwater shrimps of the genera *Gammarus* and *Hyaella*. Small numbers of insect larvae, caddis, mayfly and dragonfly, are found in the near shore area. The

<sup>1</sup> Professor of Biology, University of Saskatchewan, Saskatoon.

<sup>2</sup> The Saline Lakes of Saskatchewan, Canadian Journal of Research, D, 22. 1944.

average weight of these animals is four pounds per acre. This is not a heavy population but of the same order as that in larger lakes where whitefish are produced in large quantities. The plankton (microscopic plants and animals) is also present in moderate quantity.

Three species of small fish were found in the lake. The fathead minnow, the nine-spined and the five-spined sticklebacks. These were very small and largely confined to the shallow water where they were fed upon by pelicans which nest at the lake. Careful inquiry produced no evidence of previous population by larger fish.

#### METHOD OF INTRODUCTION

A preliminary test was made to determine the suitability of the water for hatching whitefish eggs. In November, 1939, a large sample of Redberry Lake water was sent to the University of Toronto where J. E. Moore and Dr. K. G. Fisher tested it with whitefish eggs from Lake Erie. The saline water appeared to have no deleterious effect on fertilization and the eggs developed to produce normal fry.

Planting was begun in 1940 with the introduction of 500,000 whitefish fry. In 1941, a similar number of whitefish and 100,000 pickerel were introduced. Before making further plantings tests were made of the survival of these fry. To do this whitefish and pike-perch fry were placed in large screened cribs anchored in a protected bay. The pickerel fry escaped through the smallest screen available at the time and thus were not measured. The whitefish fry survived and made good progress. From an average length of one-half inch when planted on May 5 they grew in one month to a full inch. Plankton collected from the lake was added at irregular intervals to supplement that natural food within the crib. The size of a single specimen recovered from the lake early in June suggests that growth in the crib was somewhat slower than that of fry released in the lake.

Having demonstrated that the fry were surviving, further planting was recommended. In 1943, 500,000 and in 1944, 1,000,000 whitefish fry were introduced. Pike-perch were available only in 1941 but planting of this species is to be resumed in 1946. In January, 1946, it was discovered that small numbers of five-year-old tullibee were present in the lake. It is presumed that these were accidentally mixed with the whitefish eggs or fry in the Qu'Appelle hatchery in 1941. It is probable that these will do no great damage but unfortunate that an inferior fish has been introduced.

#### RESULTS

Both whitefish and pike-perch have survived and continue to make rapid growth. Their progress has been observed by sampling, in 1942, 1944, 1945 and 1946. In August, 1942, three settings made with small mesh gill net took 19 whitefish (10 one-year-old and 9 two-year-old) and 8 pike-perch. In October, 1944, three sets took 79 whitefish and 9 pickerel. The four-year-old

whitefish were from 16 to 18.5 inches in length and weighed 3 to 4 pounds (Figure 1). This represents a rate of growth twice that of the same species in Lake Winnipeg or the Great Lakes. The three-year-old pickerel were mostly from 15 to 18 inches and weighed 1.5 to 2.5 pounds. It was suggested that the lake could be opened for commercial fishing and this was done in January, 1945. In October, 1945, a sample of five-year-old whitefish averaged 19 inches and 4.5 pounds.

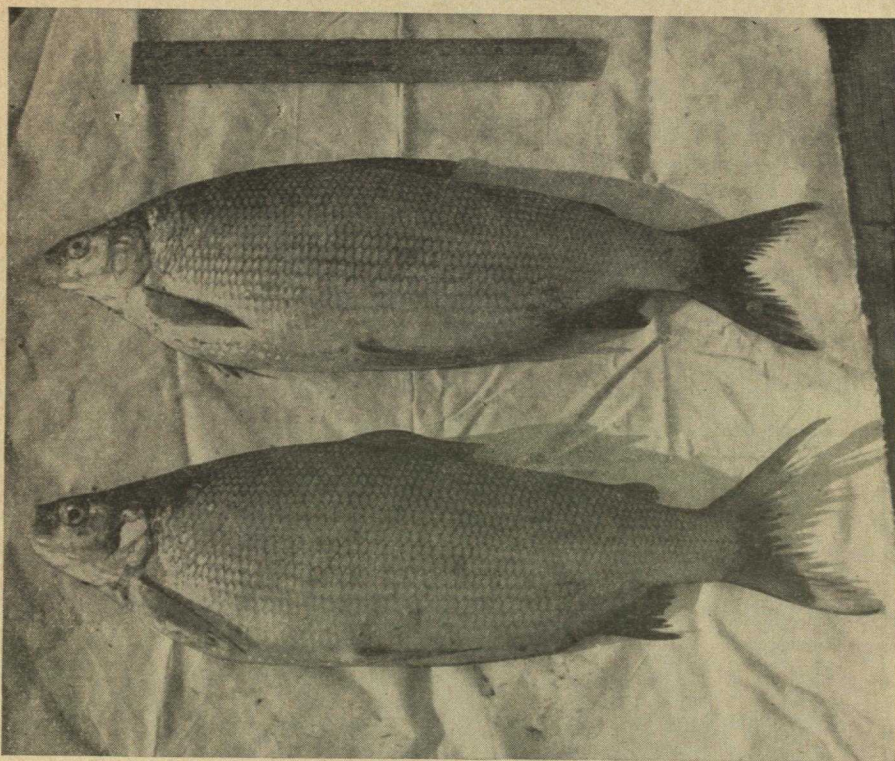


FIG. 1. Four-year-old whitefish from Redberry Lake,  $18\frac{1}{2}$  inches long and weighing four pounds.

The whitefish and pike-perch are both fat and of excellent quality. One pike-perch taken in 1944 had a curved spine and withered tail. We have no reason to associate this abnormality with the high salinity of the lake water.

The whitefish were mature in their fourth year and those caught in January, 1945, showed evidence of having spawned normally. In order to demonstrate whether natural spawning is occurring it is proposed that no whitefish be planted in 1946 and that planting be continued on alternate years until satisfactory evidence is obtained as to whether natural spawning is adequate to maintain the stock.

The pike-perch were mature in their third year but male specimens taken in October, 1944, had not spawned. The testes were still large and milt

could be freely expressed from them. It is suggested that, in the absence of inflowing streams, the pike-perch may not find suitable spawning grounds and continued planting may be necessary.

The mature whitefish had fed mostly on the large shrimp *Gammarus* and to a lesser extent on the smaller shrimp *Hyaella*. Young whitefish had eaten mostly water fleas of the genus *Daphnia*. The stomachs of the pike-perch contained nine-spined sticklebacks and a few large shrimps.

#### COMMERCIAL CATCH

A nominal limit of 20,000 pounds of whitefish was set for the first fishing season, opening on January 1, 1945. This was reached in a few days and before operations could be suspended a catch of about 40,000 pounds had been taken. In addition to this a considerable quantity of fish was taken under domestic licence.

In the second season, January, 1946, the catch was again taken in a brief period. Commercial fishermen took 55,300 pounds and the domestic catch was estimated at 10,000 pounds. This annual catch of 65,000 pounds amounts to about four pounds per acre. This is not unusual for a lake of this size but, in view of the rather limited bottom fauna of Redberry Lake, there is some doubt whether it could sustain so heavy a yield. Production in the next few years will be watched with interest.

#### MANAGEMENT OF THE LAKE

1. It has been suggested that there should be no whitefish planting in 1946 and only in alternate years thereafter until evidence is obtained as to the adequacy of natural reproduction.
2. In view of the somewhat limited food supply it is suggested that the annual limit be set at 25,000 or 30,000 pounds exclusive of the domestic catch.
3. Annual plantings of pike-perch are strongly urged. This is a very desirable game fish and it has shown itself capable of thriving in the lake.
4. Under no circumstances should the introduction of pike be allowed. The whitefish are now free from the cysts of the tapeworm *Triaenophorus*, the adult of which lives in the intestine of the pike. This parasite has been a great nuisance in other lakes of the province and it should not be allowed in this area.

#### SUMMARY

Redberry Lake, in Central Saskatchewan, with a salinity nearly half that of the sea, was chosen in 1939 for test introduction of whitefish and pike-perch (pickerel). It has been shown that both species will thrive in the lake which is now producing 40,000 to 60,000 pounds of whitefish per year. Recommendations for the future management include tests of the adequacy of natural reproduction of whitefish, action in building up the pickerel population and measures to conserve the quality and quantity of the whitefish.

## RESTORATION OF AN ABUNDANT TROUT POPULATION BY POISONING INTRODUCED YELLOW PERCH AND RESTOCKING

BY JAMES CATT<sup>1</sup> AND A. W. H. NEEDLER<sup>2</sup>

Enemies or competitors may be responsible for a scarcity of speckled trout or other game fish and their control has been attempted by various means, among which is the poisoning of the entire fish population by copper sulphate or derris root. This technique has met with varying degrees of success but its value under favourable conditions has been demonstrated. The case of MacFadden's Lake in New Brunswick is presented as one in which an abundant population of trout was apparently brought to a low ebb by the introduction of yellow perch which became dominant, and in which the fish population was successfully destroyed by poisoning with derris root and an abundant trout population re-established by stocking with small fingerlings. The history of the lake also shows an interesting relationship between the abundance of the trout and their size.

*MacFadden's Lake.* The lake is a hill-top lake in Albert County, New Brunswick, at an altitude close to 1,000 feet. It has a normal area of about 50 acres and a maximum depth of about 11 feet. There are no large tributaries, the lake being fed by seepage and springs, none of the small spring feeders being large enough during the dry season to harbour fish. With such a small inflow the level of the lake is readily controlled and the maintenance of a screen at the outlet is relatively easy. The lake is drained by a small precipitous stream into Crooked Creek which in its narrow steep valley now has a self-supporting population of rainbow trout.

*Early History.* MacFadden's Lake has been controlled by the Albert Fishing Club since the latter part of the nineteenth century. The club's earliest records over 60 years ago show an abundance of trout. They were apparently of small average size, two typical one-day catches by small parties totalling 300 trout weighing 66 pounds in all. With continued intensive fishing the numbers caught decreased but fishing remained attractive because of the presence of an increasing proportion of larger trout, weights over a pound being common. The introduction of rainbow trout fingerlings in 1900 did not result in the capture of this species in the lake but some escaped and became established in Crooked Creek into which the lake drains. Eels and some cyprinids were apparently present from the beginning. Smelts were introduced intentionally as forage at an early period and some cyprinids possibly also introduced accidentally as live bait.

*Introduction of Yellow Perch.* Yellow perch were probably introduced as live bait, the first record of their occurrence being in 1936 after the lake had

<sup>1</sup> District Supervisor of Fish Culture, Saint John, N.B., Federal Department of Fisheries.

<sup>2</sup> Director, Atlantic Fisheries Biological Station (Fisheries Research Board of Canada), St. Andrews, N.B.

been fished for more than 50 years. Entries in the club records in 1937 indicate that considerable numbers of large yellow perch were present then and were regarded as being responsible for poorer trout fishing than formerly. The reduction of the trout population resulted in the diversion of the fishing effort more and more to a neighbouring lake controlled by the club. In 1938, the club asked the Dominion Department of Fisheries how best to remove the perch and was advised to poison with derris root. Detailed advice and supervision were given by the Fish Culture Branch throughout the subsequent poisoning and use was made of the research of Dr. M. W. Smith, of the Fisheries Research Board, on this subject.

*The Poisoning.* In the autumn of 1938 the outlet of the lake was deepened to lower the level as far as possible and the lake was surveyed in the succeeding winter when at the resulting low level. With an area of 11.3 acres and a maximum depth of 6 feet the lake contained an estimated 144,000,000 pounds of water. In July, 1939, the lake was poisoned with 175 pounds of derris root (5 per cent rotenone). To assure even distribution of the poison the lake was divided into several sections in each of which the weight of water was calculated and the proportionate weight of derris root distributed. For the most part derris root was put in bags from which it was worked by hand as they were towed back and forth across the lake from row-boats.

Immediately before the poisoning enough stop-logs were placed in the dam to retain the water five feet higher than the low level at which the poisoning was done. As a result the volume was multiplied many times and the poison greatly diluted before the water could overflow into the outlet and thence into Crooked Creek. In this way damage to the rainbow and speckled trout populations there was apparently prevented. The dam has remained an effective barrier against the upstream migration of fish other than eels and a screen has been maintained to prevent the downstream migration of trout.

*Results of the Poisoning.* Large numbers of yellow perch, estimated at over 20,000, were killed as well as hundreds of eels of all sizes, many small cyprinids, and some smelts. Only about a dozen trout were found, most of them very small, and only one about 11 inches long, showing how scarce they had become. The destruction of fish was apparently complete as no species except trout which were introduced, or eels which would have access to the lake in spite of screening, have since been observed. The dead fish were left in the lake to provide nutrient materials.

No detailed quantitative determinations were made of the effects of the poisoning on trout food. It is known, however, that gastropods were destroyed in large numbers by lowering the level of the lake but that enough survived to re-establish an abundant gastropod population. A considerable hatching of chironomid larvae was observed on the day following the poisoning and various insect larvae and small crustacea have been observed in abundance since. Although the cyprinids and smelts are gone, the high population of

trout and their rapid growth in their first year after introduction indicates a relatively abundant food supply.

*Restocking with Speckled Trout.* In each of 1940, 1941 and 1942, 5,000 fingerlings which had been fed about six weeks were introduced. No fishing was permitted until 1942 and some protection was afforded against fish-eating birds. In 1941 many fish were seen breaking all over the lake in the late summer and a few caught as samples were from 10 to 11 inches long, indicating a rapid growth. In 1942, catches were limited to 350 to 400 trout, all those kept being between three-quarters and one pound in weight, fat and well-flavoured. In that year, in addition to the introduction of the last batch of 5,000 fingerlings, some small naturally-spawned trout were observed. No further plantings have been made, natural reproduction apparently being sufficient to maintain an abundant trout population.

*Decline in Size of Trout.* The trout caught in 1941 and 1942 indicated a rapid growth which could occur only with an abundance of food. In 1943, with an agreed limit of only 24 fish per club member, about 125 fish were taken up to one pound in weight and in good condition, but members reported that the large fish were not as plentiful as in 1942, many more small ones being in evidence. In June, 1944, when the lake was examined by the writers, a great abundance of trout was found between  $8\frac{1}{2}$  and  $9\frac{1}{2}$  inches in length with a scarcity of larger individuals, which was confirmed by the experience of the club members. The larger trout also appeared to be in relatively poor condition. Thus, the lake appeared to have returned to its original condition as shown by the earliest club records; namely, an abundance of relatively small trout. This had occurred in the absence of enemy or competitor fish with an apparently abundant food supply, some protection from fish-eating birds and a fishing effort controlled at a low level. It seems reasonable to suppose that the trout population had again reached the equilibrium level to be expected with a low take by angling, and that now, as 60 years ago, intensive angling would result in decreased number and increased size.

*The Future of the Lake.* The club is currently experimenting with fertilization in the hope of increasing the size of the trout without seriously reducing their numbers. Results will be followed with interest. Will fertilization result in increasing size more than abundance, or will the long-term result be an increase in abundance and a trout population reaching equilibrium at about the same size as formerly? An effort is being made to follow changes in the size and abundance of the trout, estimating numbers by marking a known number of trout and then recording what proportion of the trout caught are marked.

*Success of Poisoning.* The poisoning of MacFadden's Lake resulted in the successful removal of enemies and competitors and an abundance of speckled trout was restored by the introduction of small fingerlings. The value of poisoning as a means of removing enemies and competitors is clearly demonstrated under the conditions which the lake affords. These include

small area and depths and lack of any tributaries which in the dry season could harbour fish. It is also pointed out that at MacFadden's Lake it was possible to lower the level and so reduce the volume of the water that the poison was diluted many times before the water could overflow when the stop-logs in the dam were replaced. Under such conditions, and where enemies or competitors have been responsible for reducing populations, poisoning and subsequent restocking offer good prospects of re-establishing trout angling.

*Acknowledgments.* The writers wish to express their appreciation of the enterprise shown by the Albert Fishing Club, and their thanks for access to the club's records.

## THE EFFECTS OF AMMONIUM NITRATE FERTILIZER IN TROUT REARING PONDS

BY R. B. MILLER<sup>1</sup>

The spectacular results obtained from the fertilization of warm water ponds in the southern United States has led to a demand for similar work in our colder Canadian waters. The enormous quantities of inorganic fertilizer needed to treat natural bodies of water make the expense of such an undertaking prohibitive. However, smaller bodies of water, such as trout rearing ponds, can, perhaps, be treated economically. Accordingly the trout rearing ponds located at Pincher Creek, Alberta, were selected for a controlled experiment in fertilization. These ponds are supplied by water pumped from Pincher Creek; the water is hard, alkaline (pH, 8.16), but low in nitrogen, as shown by the following analysis:

|                               |             |
|-------------------------------|-------------|
| Nitrogen as free ammonia..... | 0.03 p.p.m. |
| Nitrogen as nitrate.....      | 0.97 p.p.m. |
| Nitrogen organic.....         | 0.48 p.p.m. |
| <hr/>                         |             |
| Total nitrogen.....           | 1.48 p.p.m. |

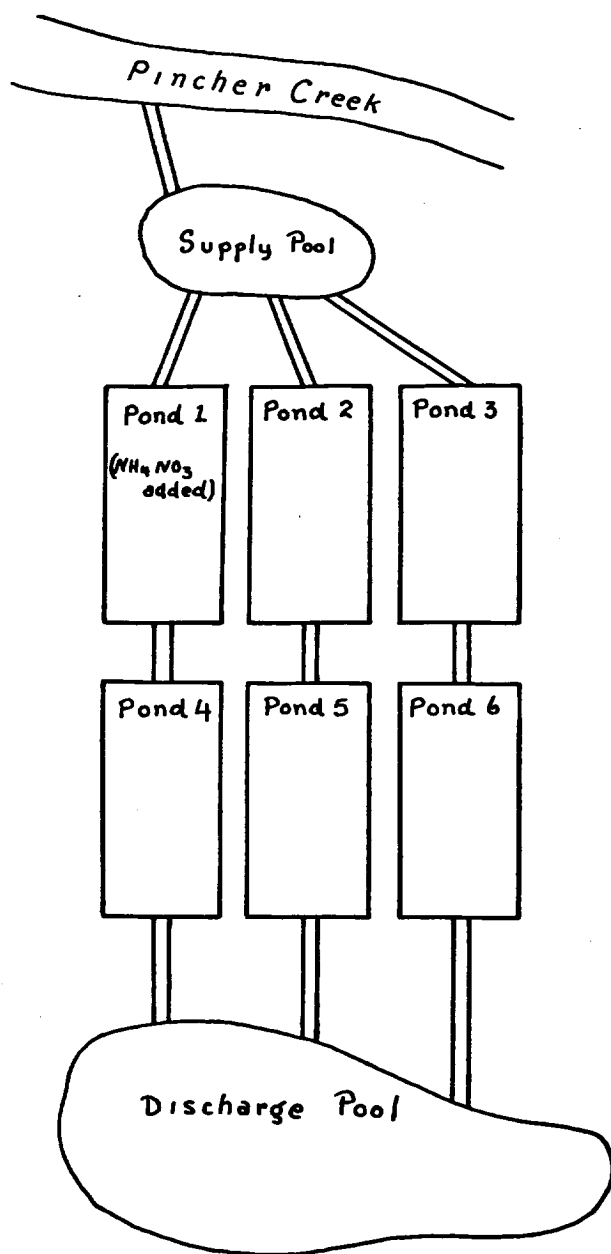
Swingle and Smith (1939) showed that for best alga growth a nitrogen: phosphorus: potassium: lime ratio of 4 : 1 : 1 : 8 was required. Maximum alga growth was achieved when the nitrogen was 4 p.p.m. and the others in the above proportion.

The fertilizer available for the Pincher Creek experiment was Nitraprills, a product of the Alberta Nitrogen Products Limited, which is 97 per cent ammonium nitrate. Two tons of this product were donated for the experiment by this company through permission of the Allied War Supplies Corporation. It was decided, in view of Swingle and Smith's findings, reported above, to use this fertilizer to raise the nitrogen content of one of the Pincher Creek ponds to 4 p.p.m. and determine if the fish in this pond grew better than their fellows in the other ponds.

### METHODS

A diagram of the six Pincher Creek ponds is shown in Figure 1. Pond 1 was selected for the experiment and Pond 2 for the control. Each pond was 50 feet long, 20 feet wide at the top, seven feet wide at the bottom, with an average depth of three feet. This gives a content of approximately 2,025 cubic feet or 127,000 pounds of water. Nitraprills yields nearly 34 per cent nitrogen. Therefore, to bring one pond from 1.48 p.p.m. of nitrogen to 4 p.p.m. required the addition of approximately one pound of Nitraprills. The rate of flow through the pond was such that the water changed a little over four times daily. Accordingly it was decided to add five pounds of Nitraprills daily to Pond 1.

<sup>1</sup> Associate Professor, Department of Zoology, University of Alberta, Edmonton.



The experiment began on August 3 when each of the six ponds contained 15,000 one hundred day-old rainbow trout.

Five pounds of Nitraprills were added to Pond 1 daily until November 19.

The temperature, dissolved oxygen and pH of Ponds 1 and 2 were determined weekly.

A plankton sample was taken with a silk tow net in Ponds 1 and 2 every two weeks.

One hundred trout were taken from each of Ponds 1 and 2 every two weeks and weighed. Ten or more fish were taken from each sample of a hundred fish and preserved for measuring.

Bottom samples and an additional sample of fish were taken from each of Ponds 1, 2 and 4 on November 27.

Analyses of the nitrogen content of Ponds 1, 2 and 4 were made at intervals throughout the experiment.

The fish in the ponds were fed daily a mixture of liver and cereal. All ponds received the same amount of food.

### RESULTS

Temperature, oxygen and pH showed no significant differences in Ponds 1 and 2 from August 3 to November 27.

The total nitrogen in the experimental pond did not differ from that in the control pond. Adding the Nitraprills had no measurable effect on the nitrogen content of Pond 1.

The planktonic algae in Ponds 1 and 2 showed no differences either in quantity or species. The filamentous alga, *Spirogyra*, however, developed abundantly in all of the ponds except in Pond 1; the *Spirogyra* present in the experimental pond at the beginning of the experiment was killed by the fertilizer.

The bottom fauna of the ponds was almost entirely chironomid larvae. These appeared to respond to the fertilizer. Thus in the experimental pond there were, by November 27, 560 chironomid larvae per square foot with a live weight of 6.4 grams, compared to 384 per square foot with a live weight of 2.0 grams in the central pond.

The fish grew slowly and at the same rate in both ponds. The average weights (100 fish per sample) and average total lengths (10-36 fish per sample) are shown in Table 1.

TABLE I  
COMPARISON OF THE GROWTH OF RAINBOW TROUT FRY IN  
EXPERIMENTAL AND CONTROL PONDS

|              | Average weight in grams |         | Average total length (mm.) |         |
|--------------|-------------------------|---------|----------------------------|---------|
|              | ← Experimental          | control | ← Experimental             | control |
| Aug. 13..... | 0.51                    | 0.56    | 35.07                      | 36.01   |
| 27.....      | 0.58                    | 0.46    | 42.55                      | 41.55   |
| Sept. 9..... | 0.59                    | 0.69    | 40.91                      | 44.82   |
| 23.....      | 0.80                    | 0.74    | 47.07                      | 48.15   |
| Oct. 9.....  | 0.74                    | 0.97    | 50.01                      | 50.08   |
| 27.....      | 0.90                    | 0.87    | 50.14                      | 50.53   |
| Nov. 27..... | —                       | —       | 51.0                       | 46.54   |

There is obviously no consistent difference in growth between the fish in the experimental and control ponds.

### DISCUSSION

Since the addition of Nitraprills failed to increase the total nitrogen content of the pond, it is not surprising that increased growth of the fish did not occur. The question of what happened to the nitrogen now arises. The Nitraprills all dissolved very soon after each application, so it obviously got into the water. The answer was found in Pond 4, immediately below Pond 1, and in the discharge pool below the ponds (Fig. 1). Both Pond 4 and this discharge pool receive water which has first passed through Pond 1. Analyses of the water in Pond 4 showed it to contain 4.80 p.p.m. of nitrogen on October 4 and 3.90 p.p.m. on November 19. On the same dates the discharge pool contained 2.00 and 3.50 p.p.m. of nitrogen. Evidently the rate of flow through the ponds (54 gallons per minute in Pond 1) was sufficiently fast to carry away the Nitraprills before it influenced the water. The effects of the fertilizer therefore accumulated in the ponds below. Thirty fish taken from Pond 4 during late October and November (the same stock as in Ponds 1 and 2) were approximately 6 per cent longer than in the other ponds. The figures are as shown in Table 2.

TABLE II  
COMPARISON OF AVERAGE LENGTH (MM.) OF FISH FROM PONDS 1, 2 AND 4 IN  
LATE OCTOBER AND NOVEMBER

|                           | Pond 1 | Pond 2 | Pond 4 |
|---------------------------|--------|--------|--------|
| Number fish examined..... | 25     | 47     | 30     |
| Average length (mm.)..... | 50.5   | 49.6   | 53.4   |

A richer growth of filamentous algae was also observed in Pond 4 and in the discharge pool below the ponds.

### CONCLUSIONS

1. Under the conditions of the experiment, the addition of ammonium nitrate to a trout-rearing pond has no significant effect in growth of the trout.
2. Where the water in a pond changes as often as four times daily the fertilizer is apparently borne away before it can exert much effect.
3. An exception to (2) above is the effect noted on the filamentous alga, *Spirogyra*, which was killed in the experimental pond.
4. The fertilizer showed up in the pond below the experimental pond where the nitrogen content of the water was raised from 1.48 to 4.80 p.p.m. This increased nitrogen content stimulated a more luxuriant alga growth and apparently was responsible for a small increase in growth of the trout.

5. The use of a nitrogen fertilizer in rearing ponds with running water appears to result in such small benefit as to be impractical. The same difficulties may be anticipated in any attempts to fertilize natural trout streams.

#### ACKNOWLEDGMENTS

The Nitraprills used in the experiment was donated by the Alberta Nitrogen Products Limited, to which company we are very grateful. The work was carried out by members of the Fisheries Branch of the Alberta Department of Lands and Mines; I am especially indebted to Mr. H. B. Watkins, superintendent, and to Mr. H. V. Dempsey, formerly an inspector in the branch.

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## THE OCCURRENCE OF A MICROSPORIDIAN IN A NEW HOST<sup>1</sup>

BY E. H. MARCHANT<sup>2</sup> AND F. S. SCHIFFMAN<sup>3</sup>

*Abstract:* A Microsporidian parasitizing a new host, *Mallotus villosus*, inhabiting Newfoundland coastal waters and locally known as "Caplin,"<sup>4</sup> has been identified as belonging to the genus *Glugea*. Cyst and spore morphology are described and its relation to known species discussed.

### *Introduction*

The material, used in the preparation of this paper, consisted of infected fish tissue and individual cysts from the Newfoundland "Caplin," collected and preserved in January and July, 1941, and June, 1942. It was forwarded recently by Dr. W. Templeman, Director, Government Laboratory, St. John's, Newfoundland, to the Institute of Parasitology for examination. The infection is found by the authors to be caused by one of the Microsporidia, belonging to the genus *Glugea*.

### *Material and Methods*

The spores were studied with the aid of an oil immersion objective (97X) and an ocular (10X) and the generic characteristics were determined both by the use of Gram's iodine solution, and Delafield's haematoxylin solution.

Cysts, with the covering peritoneal layer, were sectioned and stained with Delafield's haematoxylin, then studied by the use of an oil immersion objective (97X) and an ocular (10X). In order to show the relation of the cyst to the peritoneal layer, a drawing was made with the aid of a Zeiss drawing prism, using an objective (3X) and ocular (10X).

### *Glugea* sp.

*Host:* This Microsporidian is found in both the male and female smelt, *Mallotus villosus*, but, as far as the writers could learn, it has not been observed in any other fish living in the same waters.

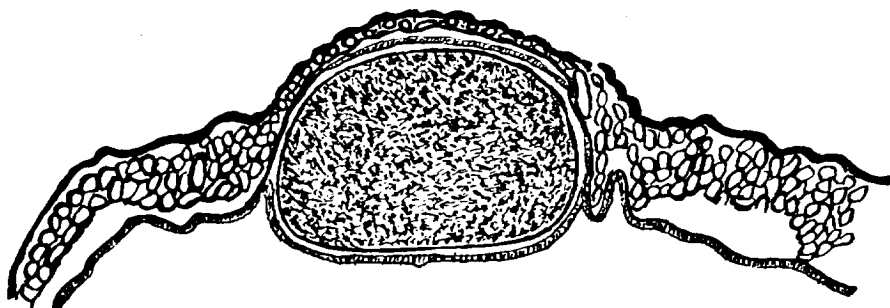
*Habitat:* The cysts, containing the spores, are usually found in the body cavity, lying immediately beneath the pigmented peritoneum, and surrounded by adipose tissue, but apparently without tissue attachment to either the peritoneum or to the muscles of the body wall (Fig. 4). In some cases they have also been found in the ovarian tissue of the female.

<sup>1</sup> Contribution from the Institute of Parasitology, Macdonald College, Quebec, with financial assistance from the National Research Council, awarded through the National Committee on Fish Culture.

<sup>2</sup> Postgraduate student.

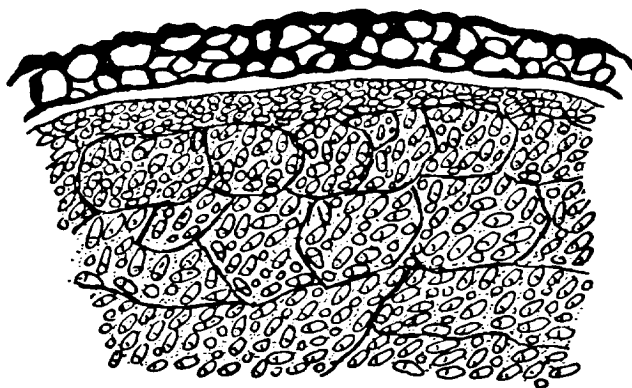
<sup>3</sup> Postgraduate student.

<sup>4</sup> On Canada's Atlantic coast the spelling "Capelin" is frequently used. (Ed.).

FIG. 4. *Section of Preserved Cyst*

*Locality:* Infected fish are found in the waters of the east, west and south coasts of the Island of Newfoundland.

*Cysts:* The cysts, having a distinct membrane, are oval in shape, white in colour and contain immense numbers of spores; the mature ones occupying the central portion and immature ones, the peripheral region of the cyst (Fig. 3). They are small and vary in size, the length being 1.25 to 2.0 mm., and breadth, 1.00 to 1.90 mm. Wherever three or four cysts are lying closely together, the surface is flattened whereas the surface of the individual cysts is round.

FIG. 3. *Portion of the Section of Preserved Cyst*

*Spores:* The spores are oval in shape, being more rounded at one end than at the other. At the larger extremity is located the aniodinophilous vacuole (Fig. 1), which in some spores contains a metachromatic granule (Fig. 2). Neither a polar capsule nor filament are discernible, although the deeply staining area above the vacuole may suggest their position. The spore membrane is a single piece.

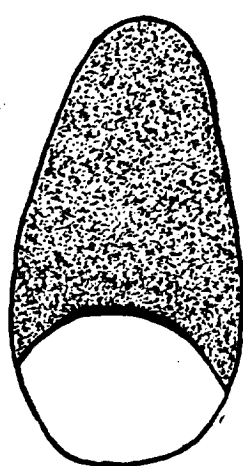


FIG. 1

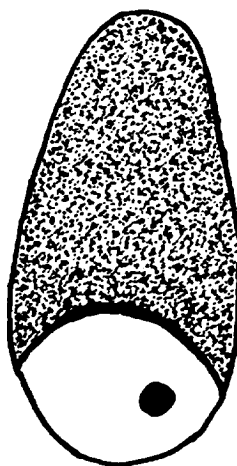


FIG. 2

FIG. 1. *Preserved Spore*

FIG. 2. *Preserved Spore showing Metachromatic Granule within the Vacuole*

Kudo (3) states that spores, preserved more than a year, when subjected to pressure, were caused to extrude their filaments. Although our spores had been preserved for a longer period, a repetition of his experiment promised to be of interest. However, no extrusion through the use of pressure or various reagents, including perhydrol (1), could be effected.

Dimension of spores: length  $6.00$  to  $6.7\mu$ , breadth  $3.00\mu$ .

### Discussion

The classification, used in the study of this Microsporidian, was that of Leger and Hesse (4), based, as it is, on the morphology of the spore, with the slight modification as indicated by Kudo (3).

The present Microsporidian appears to be larger than any other species of *Glugea*, so far reported. The largest yet described is  $4.6$  to  $5.4\mu$  in length, and named *Glugea hertwigi* by Weissenberg (6). This, our form most closely resembles, but it may require the erection of a new species, since none of our spores was smaller than  $6\mu$  in length.

Schrader (5) describes a Microsporidian which Kudo considers to be *Glugea hertwigi*, having a length of  $4.00$  to  $4.50\mu$  and breadth of  $2.00$  to  $2.50\mu$ , and parasitic in the smelt, *Osmerus mordax*, inhabiting North American waters. It is therefore smaller than Weissenberg's European species, and considerably smaller than our American form. This discrepancy in size suggests a species certainly different from that described by Schrader; all the more so, since our measurements were made on preserved while those of Schrader's were based on fresh material.

Schrader's *Glugea* is specific to the smelt, and is absent even in the Salmonidae. Dr. Templeman states that the Newfoundland form has not been observed in any other fish in the same region. The two forms also show a resemblance in the occurrence of cysts in the ovarian tissue of their respective hosts.

While Schrader indicates a heavy infection of smelt on the coast of Maine, Dr. Templeman informs us that the infection is light on the Newfoundland coasts (affecting up to 20 per cent of the fish) and does not constitute an economic problem.

### Summary

With exception of spore size, the Microsporidian, *Glugea* sp., found in *Mallotus villosus*, in the coastal waters of Newfoundland, most closely resembles *Glugea hertwigi*, but definite specific classification must await further study of other stages in the life cycle.

### Acknowledgments

The writers are indebted to Dr. T. W. M. Cameron, for his suggestion of and interest in this study, and to Dr. W. Templeman, for his transmission of the material and all his information relative to it.

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# THE CANADIAN FISH CULTURIST

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## NOTES ON DEVELOPMENT OF FISH CULTURE IN CANADA

By J. A. Rodd<sup>1</sup>

Fish Culture had its beginning in Canada under the direction of the late Richard Nettle, Superintendent of Fisheries for Lower Canada, with the artificial fertilization and hatching of speckled trout eggs collected in 1857 and Atlantic salmon eggs collected in 1858. The parent trout were taken in the Jacques Cartier River and Lac Beauport, and the salmon in the Jacques Cartier.

The experiments and operations under Mr. Nettle's directions were continued into the early sixties.

Fish Culture as a Dominion Government service was initiated with Confederation in 1867, as in that year the then Department of Marine and Fisheries contributed to the expenses of the late Samuel Wilmot in collecting and hatching the eggs of salmon taken in Wilmot's Creek at Newcastle, Lake Ontario. In the following year, 1868, the first federal hatchery was built and equipped at Newcastle. Mr. Wilmot previously had collected and hatched salmon eggs in spring water in his cellar in 1865 and 1866. In 1868 he was appointed a fishery officer with instructions to apply himself more particularly to fish culture. In 1869 he was reimbursed for expenses incurred in his early experiments. In 1876 he was appointed Superintendent of Fish Culture for Canada, the first to hold that position, which he retained until 1895.

The Newcastle establishment consisted of a hatching house and a reception house. The former was about 64 feet long and 24 feet wide, strongly roofed, with a stone masonry wall 7 feet deep, and so embanked with earth as to form an underground cellar impervious to frost. This cellar housed the hatching troughs, which were of wood and extended longitudinally nearly the whole length of the apartment. They were 12 inches wide and 6 inches deep, and laid on a slight decline to facilitate the flow of water through them. They were fed from a water-tight tank at the head, which was in turn supplied from a canal dug alongside the main stream, from a small dam across it, which gave a head for the canal and also turned the salmon into the tail race below, leading them into a reception house adjoining, where they were kept until ripe. Above the cellar were an office and other apartments.

There was a great deal of public interest in the possibilities of fish culture and several lots of salmon eggs from the Newcastle hatchery were sold at the rate of \$40 a thousand. With such high prices it is not surprising that a considerable number of private hatcheries were established.

In 1866 a Mr. Fletcher, of New Hampshire, collected salmon eggs in the Miramichi River, N. B., for stocking the Merrimac River, New Hampshire. A hatchery was also erected in 1868 at North Esk, on the North-West Miramichi, N. B., by Livingston Stone, of Boston, and John Goodfellow, of North Esk, on the condition that half of the fish produced would be turned alive into the river and the balance would be their property.

A private salmon hatchery was erected by the late John Holliday on the Moisie River, Que., in 1859, and was continued by the Holliday family for over 50 years.

<sup>1</sup>Director of Fish Culture, Federal Department of Fisheries, Ottawa.

David Brown and others operated a trout hatchery at Galt, Ontario. Some of the earlier fish farms are still operating in Ontario, and there are a considerable number in the United States.

Mr. Wilmot was not only enthusiastic but was most ingenious and rapidly extended his experiments to the hatching of the more important food fishes of the eastern rivers and lakes; namely, the Atlantic salmon, salmon trout, whitefish, and pickerel. He was at least one of the first, and he claimed to have been the first, in 1868-9, to have hatched whitefish eggs successfully. Salmon trout eggs were collected in 1869 and were successfully hatched in 1871-72, speckled or sea-trout in 1876-77, pickerel in 1881, Pacific salmon in 1884, and lobster in 1891. Black bass were retained and reproduced in ponds at the Newcastle hatchery in 1872.

As is usual with all new ventures or undertakings, the apparatus used and methods followed by the pioneers were changed as greater experience was gained.

In his earlier experiments Mr. Wilmot endeavoured to follow nature as closely as possible in taking and fertilizing the eggs, and one of his methods was to strip the fish under water. The wet method of fertilization was practised and the eggs of the female were stripped into as large a body of pure water as could be conveniently arranged for the purpose, and to this the milt was afterwards added.

In 1870 Mr. Wilmot endeavoured to get still closer to nature and arranged in the creek a spawning bed of gravel, where he hoped that the fish would spawn and the eggs be fertilized in the natural way. The spawning bed was composed of gravel placed on a wire grating, and it was planned on the principle that in the act of spawning the gravel would be more or less displaced by the fish and the fertilized eggs would drop through the gravel and the wire grating on to an endless canvas apron on rollers, from which by turning a crank the eggs could be deposited in a pan or trough as desired. This apparatus was enclosed in a building 66 feet long, 15 feet wide, and 12 feet deep. The water supply was regulated by gates and taken from the main creek. This plan appears to have been followed for only one season. For the first years the eggs of both salmon and whitefish were carried, during the hatching season, on grills made of double rows of glass rods in a small wooden frame sufficiently close together for the eggs to rest on the rods without falling through. The glass grills were soon replaced by finely perforated zinc pans and trays made with a wooden frame and bottom of woven wire cloth. These pans and trays were subsequently replaced by the trays—made out of one piece of perforated tin or zinc pressed into the exact size and shape desired—and the wire trays and baskets that are now used. Rectangular earthenware platters were used for a time in some of the Atlantic salmon hatcheries, but were inconvenient and cumbersome and were replaced as they became defaced or were broken. In the early days the zinc and wire trays were covered to a depth of half an inch with well washed and screened gravel which simulated natural conditions in the streams and prevented the eggs from coming in direct contact with the metal of the trays. The gravel, on account of its tendency to collect sediment, made it difficult to keep the eggs clean and after due experience was dispensed with; a thorough coating of asphaltum varnish was found to be equally efficient, and much more easily kept clean.

In the experiments with whitefish eggs, glass grills and trays were used, but when the first large whitefish hatchery was built at Sandwich on the Detroit River it was equipped with troughs 12 feet long by 12 inches wide, and 10 inches in depth, and divided into a series of compartments 15 inches long. Eight, ten or more hatching trays, one upon the other, were placed in each compartment. Between each compartment in the trough there was a space of three inches, by which means the water could be made to flow either upwards or downwards through the eggs at pleasure, by reversing the troughs end for end upon the

staging which supported them. This narrow space of three inches, having a hole and plug at the bottom, was also used to draw off the water and sediment from each compartment without interfering with the one adjoining. The troughs were placed one after the other lengthwise of the room, and connected by short pieces of rubber hose let into the ends of each.

The trays and troughs were soon replaced by an invention of Mr. Wilmot's which in 1876 he patented in Canada and the United States under the name of "Wilmot's Combined Fish Egg Incubator and Self Picker of Eggs". As first patented the device retained the eggs in tin or metal receptacles, but in 1881 these receptacles were replaced in the Sandwich hatchery by glass jars, which in various forms are now in general use for hatching whitefish and other semi-buoyant eggs.

In 1872 Mr. Wilmot was awarded a First Class medal by the Acclimatization Society of France for "his achievements in the work of Pisciculture", and in 1883 a complete working section of the system of hatching in vogue in Canada at the time was put in operation at the Great International Fisheries Exhibition in London, where it carried off the highest award, namely, the Gold Medal and Diploma for the best and most complete fish breeding establishment in the exhibition.

The following awards were also won by the Canadian exhibit:--

Young salmon hatched out from eggs brought from Canada and grown to the "parr" stage from four to six inches long in the breeding troughs during the time of the exhibition—Gold Medal and Diploma

Model of salt-water pond as used in Canada, for retaining parent salmon from June till ripe for spawning—Silver Medal and Diploma

Live fish and egg carriers—Bronze Medal and Diploma.

As previously stated, during his earlier experiments Mr. Wilmot endeavoured to follow nature as closely as possible, and placed the eggs of the fish as they were stripped in as large a body of pure water as could be conveniently arranged, afterwards adding the milt of the male fish. In later experiments he found that by using a smaller quantity of water with the eggs a larger number were fertilized, and in 1871 he dispensed with the water almost entirely and employed what is known as the "dry method" of fertilization, which about that time was adopted by most fish culturists and has since been followed.

For many years following its inception the Canadian fish cultural service gave almost its whole attention to the propagation of the more important food fishes such as Atlantic salmon, whitefish, salmon trout, pickerel and Pacific salmon, but, with the more general use of the automobile and the construction of highways, waters that were previously remote have come within reach of a greatly increased number of anglers and the toll taken by them of the different species of game fish has increased to such an extent that the propagation of speckled, rainbow, cutthroat and Kamloops trout has received more and more attention to meet the popular demand and the more intensive angling.

Also, for many years the greater part of the hatchery output was distributed in the free swimming stage after the food sac was absorbed as the early establishments were not located with a view to rearing beyond the fry stage. The facilities available at the various hatcheries for feeding and rearing fish have since been developed and most of the annual production is now distributed in the "fingerling" and older stages after they have been fed for some time. New ideas regarding equipment are thoroughly investigated and all apparatus and utensils that are found to have a useful place in fish culture are standardized as they are perfected.

The acclimatization of some of the more important food and game fish in waters to which they were not indigenous has been successfully accomplished. The small-mouthed black bass, speckled, rainbow and brown trout have been established in selected areas where they provide a greater variety as well as sport at seasons of the year when little, if any, was previously obtainable.

#### **Equipment:**

One of the greatest advances in the way of equipment for increasing production is the circular rearing pond. Circular ponds are saucer-like in shape, sloping in depth from the margin to the outlet at the centre. The water, preferably under considerable pressure, enters at a tangent near the outer margin and makes several circuits of the pond before it escapes through the outlet pipe at the centre. There is a nearly uniform circulation through the pond, the fish are evenly distributed instead of being crowded at either end and there is nothing against which they can jump to injure themselves, as they sometimes do in the longitudinal pond. Consequently, a circular pond will carry several times the number of fish that can be held in a longitudinal pond with the same volume of flow. It may, however, be very difficult and even impracticable to keep circular ponds operating through prolonged periods of extremely cold weather or during heavy falls of snow.

#### **Nutrition:**

With the exception of the water supply, no single factor is of more importance in determining the success or failure of a hatchery than the daily diet of the fish. If healthy, vigorous fish are to be produced, they must have well balanced, nutritious and palatable food, and it is not an easy matter to determine what food, or combination of foods, will give the best results under average conditions. The fish culturist has not a great variety of foods at his disposal, and any ration must be reasonable in cost and in ample supply at all times.

Approximately 100 feeding experiments have been carried on annually for several years at the hatcheries operated by the Department of Fisheries in the Maritime Provinces. These experiments have been handicapped, and in a good many instances were of short duration, because of the general shortages of food during the war years. While some rations gave encouraging returns, general results to date have not been conclusive in regard to any single diet at all hatcheries, beyond showing that meats alone are not a complete or economical food for fish older than fry.

#### **Improvement of Stock:**

It is a well known fact that continuous and careful selection is essential to the development of high class live stock and field crops. As the situation is similar with hatchery fish, selective breeding has been practised for many years. At first, mass or group selection was followed in the Canadian service, all the eggs from a group of selected fish (the progeny of a selected group) being mixed, and the fry, fingerlings and yearlings therefrom being further selected on the basis of rapid growth, early maturity and large size. Latterly, selected pairs are mated, their eggs, and, during the early stages, their progeny, segregated and subjected to careful and periodical selection on the basis of percentage survival, rapid growth, early maturity, large size, colouration and general appearance. The eggs from low yielders are transferred to the general stock and only the best individuals of the lots in which percentage survival is highest are retained for brood stock. The results are most gratifying in the way of rapid growth, average size, short spawning season and egg production, and should prove equally satisfactory in increasing percentage survival, as only the most vigorous individuals are mated. The average egg production per female has been increased several times as well as the average growth of the fish, particularly during the first two years. There is no lack of evidence of the possibilities of careful selective breeding.

Hatchery production of speckled trout eggs is ample to meet the present needs, but, before this point was reached, on one occasion at the Antigonish hatchery in the autumn of their first year one lot of fingerlings, the progeny of selective breeding, was almost seven times the weight of a lot of the same number and age, the progeny of wild fish, although both lots were retained under similar conditions and fed in the same way.

#### **Acclimatization:**

A greater variety of angling or longer angling season has been obtained by the establishing of such non-indigenous species as small-mouthed black bass, rainbow trout and brown trout in carefully selected speckled trout areas.

As is intimated in the opening paragraphs, the late Samuel Wilmot was the father of fish culture in Canada as a Federal Government service. When he retired in 1895 the service was directed by Dr. E. E. Prince, F.R.S., until Lieutenant-Colonel F. H. Cunningham was appointed Superintendent of Fish Culture in 1904 and he in turn was succeeded by the writer in 1911\*.

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While this article refers only to development in the federal service, most of the provinces also administer fish cultural services which in some cases have been considerably expanded in recent years.

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\* Since this article was written Mr. Rodd has retired after 46 years in the public service, which he entered in 1901.

## FISH CULTURAL PROBLEMS INVOLVED IN THE CONSERVATION OF ANADROMOUS FISH WITH PARTICULAR REFERENCE TO SALMON ON THE SKEENA RIVER, BRITISH COLUMBIA

BY A. L. PRITCHARD<sup>1</sup>

Within recent years on the Pacific coast of British Columbia programmes have been outlined to investigate the salmon populations of the two largest rivers, the Fraser and the Skeena, with a view to obtaining basic information for management or conservation so that eventually there may result maximum production for use, yet a guarantee of the runs for perpetuity. Although hatcheries and hatchery practices are not included in these investigations, all phases are directly concerned with fish production and thus are fish-cultural in the broad sense outlined by the editor of this journal in the introduction to the first issue. In the final analysis fish culture embraces everything which concerns production of fish in the same way as agriculture includes anything which involves the production from soil.

In 1944, the first year of the Skeena River investigation, a general survey of the fishery and the river system was carried out to familiarize the investigators with the country and the problems which might be encountered in salmon culture in the area. During the following winter consideration was given to the factors affecting production and possible remedies for those causing adverse results. The results of the analyses and deliberations were depicted graphically as in the following diagram.

(Diagram on the following page)

For a clear understanding of the interpretation and possible application of the diagram, a general outline of the life histories of the Pacific Salmons is helpful and desirable. All five species, the sockeye, (*Oncorhynchus nerka*), coho, (*O. kisutch*), spring, (*O. tshawytscha*), pink, (*O. gorbuscha*) and chum, (*O. keta*) are anadromous, i.e., though they spend part of their life in the sea, they migrate up the rivers into fresh water to spawn. Their life histories are fundamentally similar, differing mainly in the amount of time which each spends in the two environments and in the distances which they run up the river system for spawning. The sockeye usually seek the farthest tributaries above lakes to deposit their eggs in the autumn. When the fry hatch and emerge from the gravel in the spring, they drop down into the lake and spend a year or more there before migrating seaward. The ocean life varies from one or to four years. Coho salmon spawn in almost any stream whether it is above or below a lake. The young, when hatched, almost invariably remain one year in the rivers before going to sea. Nearly 98 per cent, have an ocean life of two years. Springs usually frequent the larger swifter tributaries. While many have the same history as the cohoes, over 75 per cent. drop down to the sea as fry as soon they are free swimming. The sea life lasts from two to six years. Pinks and chums as a general rule enter rivers close to the sea. In both species, the young leave for salt water as fry. The pinks remain in the ocean for two years while the chum may stay from three to five.

<sup>1</sup>Senior Biologist, Pacific Biological Station (Fisheries Research Board of Canada), Nanaimo, B. C.

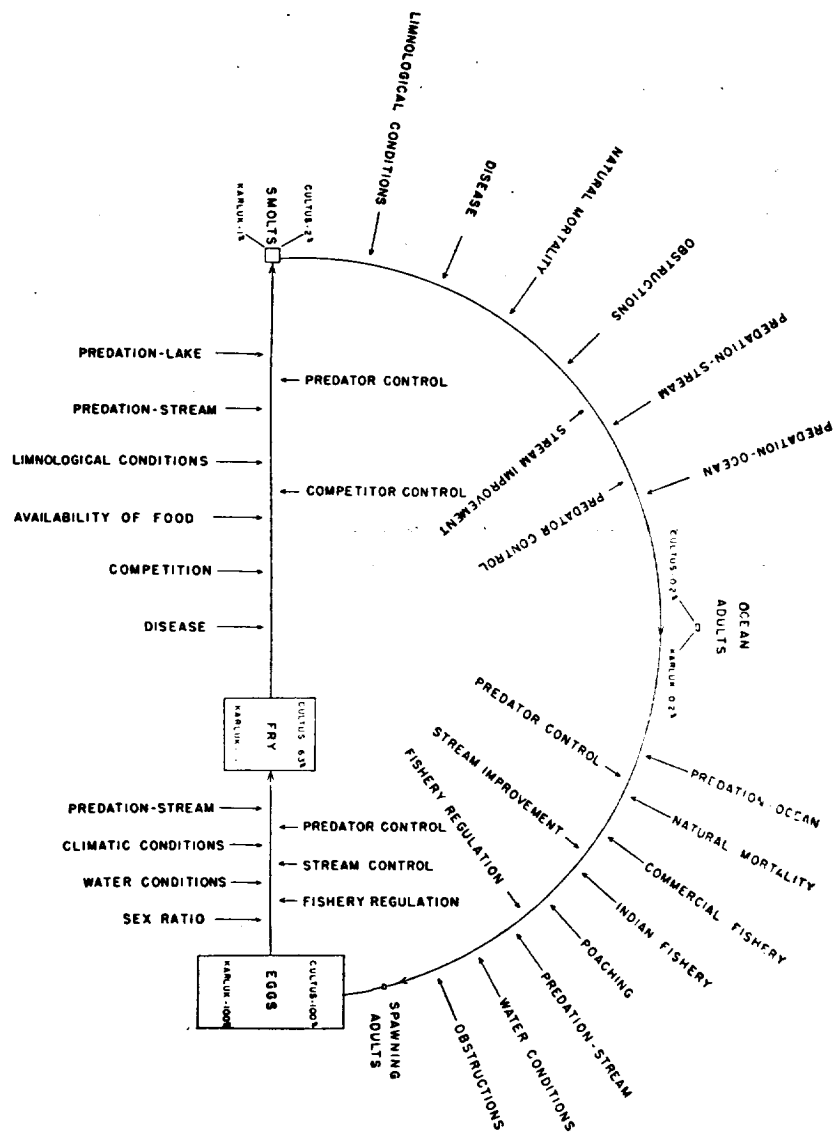


Diagram showing relative losses occurring in various stages of the life history of the sockeye salmon, the factors causing them and possible remedies.

In such circumstances a diagram constructed for sockeye to show the factors affecting production will be generally applicable to the coho, spring, pink and chum. Each species will be subject to similar influences in the ocean and in the river system to the extent to which they occupy it. In other words, specific diagrams for the coho, spring, pink and chum would merely be modified and simplified presentations of that for the sockeye.

The diagram presented has been constructed on the basis of present knowledge to portray for the sockeye salmon:

1. The losses occurring during the life cycle and their extent in the various stages of the life history.
2. The factors which may affect production in four stages, viz., (a) from egg deposition until fry migration from the stream (ca. 6 months); (b) during the lake residence (usually 1 year); (c) from the time of leaving the lake until the fish reach the ocean, have matured, and are about to return to spawn (ca. 1-3 years); and (d) during the time of return from the ocean to the spawning beds (2 to 4 months).
3. Remedies which might be applied in these arbitrary stages to counteract adverse factors.
4. **The complexity of the natural relationships in the life cycle of the sockeye which make conservation not simply a matter of adjusting one factor but of establishing a sound balance between many.**

#### LOSSES, THE PERIOD OF THEIR OCCURRENCE AND EXTENT

The rectangles in the diagram have been drawn to scale (areas proportional to number of eggs, fry, etc.) to depict the average results obtained in Dr. Foerster's investigation of the natural propagation of sockeye salmon at Cultus Lake, B.C. The approximate percentage returns at the various stages are printed in. As an example, if one commences at the lower right-hand corner with 4,000 eggs, the product of 2 fish (1 male and 1 female), in general there will result 2,520 fry (63%), 80 smolts or yearlings (2%), 8 ocean adults (.2%), and a varying return of spawning adults which depends on the action of the factors recorded outside the line.

The results of a similar test at Karluk, Alaska, are also recorded. The sizes of the rectangles have not been designed to give a proportional representation of *these* figures although by chance the one for the ocean adults accomplishes this. The returns from 4,000 eggs would be 40 yearlings and sea adults. It is evident that survival to the yearling stage is lower than at Cultus Lake but improved survival from yearling to adult produces the same ultimate number of "ocean salmon".

From the point of view of potential production, on the basis of available eggs the greatest loss at Cultus Lake occurs during the one year's lake residence (61%). For easy reference and comparison the losses in the various stages on the basis of total possible egg deposition may be recorded as follows:

|                                     | <i>Cultus Lake</i> | <i>Karluk</i> |
|-------------------------------------|--------------------|---------------|
| Stage 1 (eggs to fry)               | 37.0%              | 99.0%         |
| Stage 2 (lake residence)            | 61.0%              |               |
| Stage 3 (migrants to ocean adults)  | 1.8%               | .8%           |
| Stage 4 (ocean to spawning grounds) | Varying            | .1%           |

(Maintained by agreement on a 50:50 ratio between catch and escapement)

## FACTORS AFFECTING PRODUCTION AND POSSIBLE REMEDIES

### Stage 1 — Eggs to Fry

*Climatic conditions and water conditions.* These two factors are closely bound together. If, when the salmon run, the rainfall is small and the weather dry, the water in the creeks will be low and the spawning ground limited. If there is considerable rainfall, the creeks will be high and more gravel will be available. This additional area does not necessarily mean higher returns from increased spawning, since, at a later date, the level may drop, leaving the redds exposed. Loss in such cases need not be complete since seepage may allow sufficient dampness to permit the eggs to incubate. The water level in the spring, however, would have to reach the same height or the fry could not escape from the exposed gravel.

If the eggs are merely being kept damp through seepage, cold weather without sufficient snow cover will make freezing easier. The extent to which such a situation actually occurs is not known but it has been proven to exist on occasion.

Such things as mine tailings, other commercial effluents, sawdust, etc., may be deleterious to fish life either by killing the spawners or by coating beds with sludge, silt, etc., and cutting off the oxygen supply.

High water and the resulting freshet conditions of heavy current after the eggs are deposited, will in extreme cases do damage through eroding the nests and washing out the eggs, but perhaps more often will carry dirt and silt into the crevices between the gravel particles and stones thus cutting off the oxygen.

Obviously, since climate cannot be regulated, the remedy for such conditions lies in stream control and improvement. The removal of debris and the reinforcement of banks to keep the water flowing in one channel over fairly regular beds without any blockage would undoubtedly help. Control of the amount of water at flood stages through the use of dams has been suggested but general application has been avoided in view of the cost. The dumping of deleterious products can be prohibited.

*Predation in the stream* may arise from bears, etc., removing the spawning adults, or other fish and birds eating the eggs. Predator control which involves the elimination, removal, or at least the control of the enemies, is the evident remedy. Any measures must, however, be taken with caution because the removal of one predator may release another with far worse consequences to the desired fish.

*Sex ratio.* A slight variation from the generally accepted ratio of one male to one female on the spawning beds is not necessarily harmful. It is known that one male will serve more than one female. If, however, the difference becomes extreme, some of the eggs will not be fertilized and thus will not develop.

It appears that the main cause for the discrepancy in sex ratio lies in the selectivity of the fishing gear used by commercial fishermen and Indians. For instance, it is known that gill nets will catch more males from the later runs when the humps are on their backs and the hooked noses are further developed. If the conditions were really deemed serious, fishery regulation would have to be invoked to control the situation, e.g. closing of the fishing, increasing mesh size, etc.

## Stage 2 — Lake Residence

During the time of residence in the nursery lake, the losses in numbers will depend on all the factors listed. The incidence of *disease*, although not common in nature, could cause damage. *Limnological conditions* such as the chemical content of water, the depth, the type of bottom, etc., will undoubtedly determine the amount of food which can be produced and thus the crop of fish which can live and grow, just as the type and nature of the soil determines in large measure the yield on any farm. It is possible that a lake may be heavily populated with other species such as squawfish (*Ptychocheilus oregonensis*) which will *prey* heavily on the young salmon. On the other hand, species such as whitefish (*Prosopium williamsoni*) may not eat the salmon but may *compete* for the same food at certain stages.

It is generally accepted that the location, morphometry, physiography, and water conditions in any lake determine its productivity. Under natural conditions this productivity has a maximum limit which will not be surpassed unless changes such as fertilization give rise to better conditions. This type of experiment has not shown exceptional promise up to the present. To raise salmon production, therefore, it would seem logical to experiment with the removal of the *predators* which eat them or the *competitors* which rob them. The experiments by Dr. Foerster at Cultus Lake on the elimination of predators hold out good hope of success for such trials.

## Stage 3 — Migrant to Ocean Adult

While the young salmon are migrating to sea, they will be mainly affected by *water conditions* in the rivers and *obstructions*. If the rivers are low, some may be held in pools and backwaters. Obstructions are not generally considered to be serious in the case of young small fish but they could be impassable or of a type which would kill the migrants, e.g. turbines, dams, water diversions. There may be *natural mortality* and *disease* in the rivers but more important will be *predation* by fish, birds and other enemies. Once the salmon are in the ocean, *natural mortality* and *predation* will operate. Some of the latter may be from other fish, from sea lions, from seals, etc.

It is evident that natural mortality and disease will be hard to control effectively. The water conditions in the stream can be remedied to a great extent by removing obstructions, screening irrigation ditches, etc., thus making a safe medium of travel for the fish to the sea. Predator control might be tried in both the river and the ocean.

## Stage 4 — Ocean to Spawning Grounds

While the mature salmon are returning from the sea to the spawning grounds, they will of course be affected by *predation* in both the ocean and the streams, *natural mortality*, *water conditions*, and *obstructions* such as log jams and falls. In addition the numbers will be reduced by *fishing*—commercial and Indian—and by *poaching*.

Predator control on such things as hair seals will provide some relief. Streams can be improved by the installation of fishways where necessary, the removal of serious jams and other measures. The adverse effects of legal and illegal fishing can only be removed by regulation and strict enforcement.

## THE COMPLEXITY OF THE PROBLEM

Several definitions may be given for conservation. Where a large industry is involved, economic scientists must accept the fact that it involves maintaining the population of fish in such a condition that its future is guaranteed yet maximum production for use is obtained. Such a definition makes very difficult the duties of the officer charged with regulation and management. It makes equally difficult the task of the scientist or fish culturist who has to suggest sound remedies after outlining the conditions.

The chart has shown the number of factors which can play a part at all stages of the life history. Conditions may be anything but constant. A good escapement might be completely nullified by climatic conditions beyond control. It thus appears that the only reasonable approach is to study the effect of as many as possible of the influences, control those which can be controlled, and base judgement and predictions for the future on average conditions and behaviour.

With a full appreciation of the complexity of the situation and with the knowledge that no one factor such as obstructions was critical on the Skeena as on the Fraser, the Skeena River investigation has been organized to cover the broad general lines of fish culture rather than to concentrate on localized specific problems. In 1945, after the first survey, the programme was subdivided in sections and in these divisions the particular investigator could carry out more intensive work in a particular field. In some instances, e.g. statistics, it was first necessary to assess the reliability of the information already available and then to set down a sound method for future collection. In others, such as lake surveys where no data were accumulated, definite standard procedures had to be chosen and outlined from the work completed elsewhere in the field of limnology with a view to gathering pertinent information in a similar manner in each body of water so that the results obtained in one lake might be safely compared with those from others. In 1946, a further step was taken in stressing the work at Lakelse Lake, an area of reasonable size and accessibility, in the expectation that a more complete explanation of conditions therein would serve to elucidate similar occurrences elsewhere.

This approach to the solution, the general followed by the more particular, should give information on which sound management policies can be based. Repeated observation of the whole system should reveal facts pertinent to stream improvement and control. Lake surveys should show what factors are operating in the nursery areas to benefit or limit production of salmon. The effects of predation and competition can be checked in selected areas. Tagging and marking programmes indicate general behaviour, the effect of obstruction and stream conditions on migration, and the exploitation by the commercial and Indian fishery. More or less specific examinations of selected predators such as hair seals should reveal the damage done. At the same time the trend of the fishery and its present status is being outlined and closely watched through statistical studies.

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## SOME INFORMATION ON THE MINIMUM ADULT STOCK OF FISH NEEDED TO PROVIDE ADEQUATE NATURAL SPAWNING

BY W. A. KENNEDY<sup>1</sup>

During a survey of Tathlina and Kakisa lakes, North-West Territories, which was made jointly by the Fisheries Research Board of Canada and the Department of Fisheries, between July 28 and August 9, 1946, a situation was discovered which bears on the question of the minimum stock of adult fish necessary to provide adequate spawning.

Both these lakes are expansions of the Kakisa River, with Tathlina Lake the farther upstream. Tathlina Lake is approximately 220 square miles in area with a firm sandy-mud bottom, and a remarkably uniform depth of five feet. Kakisa Lake is approximately 130 square miles in area, with the same type of bottom and a maximum depth of 24 feet.

Prior to 1943, Indians who occasionally went to Tathlina Lake found fish plentiful there. In the spring of 1943, dead fish were observed in quantities on the shores of Tathlina Lake and the lack of fish has completely discouraged Indians from camping there since then. A winter kill such as apparently took place seems to be an unusual occurrence in Tathlina Lake. The northern pike, *Esox lucius*, in the muskeg waters which adjoin Tathlina Lake, and the few in the lake itself, had apparently not been affected by the winter of 1942-43. However, in the case of the doré, *Stizostedion vitreum*, whitefish, *Coregonus clupeaformis*, northern suckers, *Catostomus catostomus*, common suckers, *Catostomus commersonii*, and burbot, *Lota lota*, although young fish which must have been hatched since the winter of 1942-43 were present, no adults which could have provided the spawn from which those young were hatched were taken (except that two mature common suckers were taken). The data regarding these last five species indicate that adequate spawning has resulted from a negligible number of adult fish. The evidence is most conclusive in the case of the doré.

No mature doré were taken in four net-nights with 5½-inch mesh and five net-nights with 4¾-inch mesh (these were gill nets each 100 yards long and 30 meshes deep). When these same nets were fished in Kakisa Lake a few days later, the availability was such that the above effort would have taken approximately 170.

One fish in its second year, 6 in their third year and 18 in their fourth year were taken in 1½- and 2½-inch gill nets, and these fish must have been produced by mature fish which were alive in the springs of 1945, 1944, and 1943, respectively. One other, a fish in its fifth year, which must have survived the winter of 1942-43, was taken. When the same small mesh nets were fished in Kakisa Lake a few days later, they caught 3 fish in their fourth year and none younger, although the same effort in Tathlina Lake would have taken approximately 2 in their second year, 12 in their third year and 33 in their fourth year.

It might be argued that adult doré could have been present in quantities in different parts of Tathlina Lake from those in which nets were set. The remarkably constant depths and type of bottom which were found makes this unlikely. It is possible that the limited soundings taken could have missed "holes" which were several square miles in area. However, on a windy day considerable quantities of

<sup>1</sup>Associate Biologist, Central Fisheries Research Station (Fisheries Research Board of Canada), Winnipeg, Man.

bottom material are held in suspension in the water; these settle out quickly when the water is undisturbed, so that over the period of time during which the lake has existed such holes must have been filled. There was a limited area of rocky bottom in one part of the lake which was not fished, but since its area is less than one per cent of the total, even if adult doré were as available there as in Kakisa Lake, they could be considered as present in negligible numbers in the lake as a whole. Although the Kakisa River above Tathlina Lake is deeper than the lake itself, it is not a typical doré habitat, and the Indian family which lives a short distance up the river catch mainly suckers and northern pike. Since the river between Tathlina and Kakisa lakes drops 175 feet in 20 miles, with many rapids and one falls, it is unlikely that doré move from lake to lake extensively.

It cannot be argued that there might have been doré present which were too large to be taken in the small mesh nets and too small to be taken in the large mesh nets since they are so frequently caught by their teeth that any given size is taken in any size of mesh. For instance, the largest doré taken in Kakisa Lake was caught in small mesh net. It is also unlikely that behaviour differences account for large catches of adult fish in Kakisa Lake compared with nil in Tathlina Lake, since the lakes are so similar to one another. Tathlina Lake supplies most of the water which enters Kakisa Lake, their bottoms are composed of similar material, and their temperatures were practically the same at the time of the investigations. Again it is unlikely that adult fish were present in quantity in early 1943, 1944 and 1945 but had vanished by the middle of 1946. There seems to be no alternative to the conclusion that only a few mature fish produced the young fish which were present in 1946.

There is some justification for considering that the catch per unit of effort did not necessarily represent the relative abundance of small fish in the two lakes. Big fish were caught in the small mesh nets in Kakisa Lake, which must have decreased the chances of catching small fish. Also, whereas in Tathlina Lake the nets practically reached from surface to bottom, they did not do so in Kakisa Lake, and although the same conditions prevailed when small mesh nets were set inshore, as they generally were, the deeper parts of the lake were not adequately sampled. In spite of this it seems probable that small fish were more abundant in Tathlina Lake than in Kakisa Lake, although not necessarily 16 times as abundant as the relative availabilities would indicate.

It is clear that the hypothesis that a very few adult doré have provided an abundance of young is highly probable. The concentration of adult fish was probably much lower than could be profitably brought about by commercial fishing. The resulting young are probably numerous enough to fully utilize the food available. It should be noticed that competition and predation from older fish of all species must have been negligible.

## BLACK SPOT DISEASE OF BASS

### PART 1. DISTRIBUTION OF THE DISEASE<sup>1</sup>

BY FRANÇOIS DE S. LAÇHANCE<sup>2</sup>

All fresh-water fish, commercial or otherwise, are known to harbour many parasites in a large variety of forms. Fish may act as first or second intermediate host or as the final host for these parasites. Practically every organ may be attacked at one time or another during the life of the fish. The importance of these parasites varies considerably according to their site in the host, the number present, and in the disease which they cause.

Of these parasitic conditions, one of the most obvious is a black spot occurring on the skin or in the flesh of many different species of fish. These black spots are caused by the encystment of larval stages of certain flat-worms belonging to the class Trematoda, the adults of which occur in the digestive tract of fish-eating birds or mammals. However, these encysted larvae or "metacercariae" do not all belong to a single species of trematode. They may occur, also, in non-pigmented as well as pigmented cysts. The pigment, when it occurs, is due to the host's body reaction which produces pigment cells surrounding the encysted larvae.

The life histories of these parasites are similar to each other. In brief, three hosts are required—a snail, a fish, and a fish-eating bird or mammal. The eggs, which are laid by the adult parasite in the intestine of their host, pass out into water. There they are either ingested by a fresh-water snail or they develop further, giving rise to a miracidium, which leaves the egg after hatching and penetrates into a snail. In both cases, the miracidium invades the digestive gland or liver of the snail, after which it metamorphoses into a sporocyst which eventually gives rise to hundreds of free-living cercariae. These cercariae leave the body of the snail and penetrate into certain species of fresh-water fish. After entering this second intermediate host, each cercaria changes into a metacercaria, encysting as soon as it reaches its final location. Sooner or later, pigment is usually laid down around the formed cyst, giving the well known appearance of black spot.

When fish are infected with trematode larvae, their movements may be impaired greatly, even to the extent that some of them will not eat and so become emaciated. Under these conditions, it is noted that they are easily caught by the fish-eating bird in which development to the adult stage takes place, thus completing their life cycle. This cycle goes on as long as the required intermediate hosts are present, thus spreading disease to more and more fish and, no doubt, new localities each year.

The black spots which occur in different fresh-water fish have been shown to be caused by various species of trematodes. At least two groups of trematodes have been demonstrated to parasitize fish, the strigeids and the heterophyids. The strigeids appear to have a very rigid host specificity according to Dubois (4), while Cameron (1, 2) has shown that the heterophyids have very little host specificity. The life histories of certain heterophyids in Canada have been worked out, but so far of none of the strigeids.

One of the most important of these parasites is the species which is found in fish of the family Centrarchidae. This cyst, found under the scales, at the base

<sup>1</sup>Contribution from the Institute of Parasitology, Macdonald College, Quebec, with financial assistance from the National Research Council.

<sup>2</sup>Junior Research Assistant.

of the fins (particularly the caudal fin) and in the flesh itself, is very easily seen with the naked eye, being the size of an ordinary pin's head; it is particularly obvious when the fish is skinned as is often done. It is very unpleasant to open or skin a fair-size bass and find it speckled with these black spots and for this reason many people have lost their interest in fishing for bass and even more people will not eat it, even though it is still quite edible, provided it is cooked properly. So far as is known, this parasite occurs in its larval stage only in bass and closely related fish.

The first mention of this parasite is the description by Huges (5) who described the metacercaria as *Neascus ambloplitis*. The metacercaria was found encysted in 25 out of 29 rock bass (*Ambloplitis rupestris* Rafinesque) taken from Douglas Lake, Michigan, during the summer of 1926. Several specimens of small-mouth black bass (*Micropterus domolieu* Lacepede,) revealed the presence of black spots and a brief study of the cysts suggested that the parasites belonged to the same species as those found in *A. rupestris*. Following the classification of Dubois (3), the original *Neascus ambloplitis* is now designated as *Uvilifer ambloplitis*; *Crassiphiala ambloplitis* (Hughes, 1927) Hunter, 1933, as it was first described, is now regarded as a synonym.

In the United States it was shown that this trematode passes its adult stage in the digestive tract of fledgling or adult kingfishers (*Streptoceryle alcyon*) (Preble and Harwood, 9). There, the adult parasite lays eggs which are passed in an undeveloped stage to the outside with the droppings of the host. These eggs, which develop only in water, give rise to the first free larval stage known as a miracidium. In order to develop further, the larva must penetrate either one or two species of ramshorn snails, *Helisoma trivolvis* (Say) or *H. campanulatum* (Say), in the United States, while here in Canada, the snail host has been found to be *H. anceps* (Menke).

After five or six weeks, the second free larval stage of the parasite (known as the cercaria) escapes from the snail and penetrates any species of bass where it encysts (metacercaria) in several parts of the body, particularly between the fin rays, mouth cavity and myotomes. During encystment, black pigment is laid down around the cyst by the host tissue reaction causing the characteristic and well known black spot appearance after 18 to 24 days. The metacercarial stage of the trematode has been recorded previously from small-mouth and rock bass only. However, during the present survey the writer found it also in sunfish (*Lepomis gibbosus*). The writer has also been able to infect this fish experimentally with this parasite.

The adult parasite has been found in the kingfisher by members of this Institute, but there is no evidence yet that this is the only source of black spot infection in bass here.

### Distribution of Black Spot of Bass

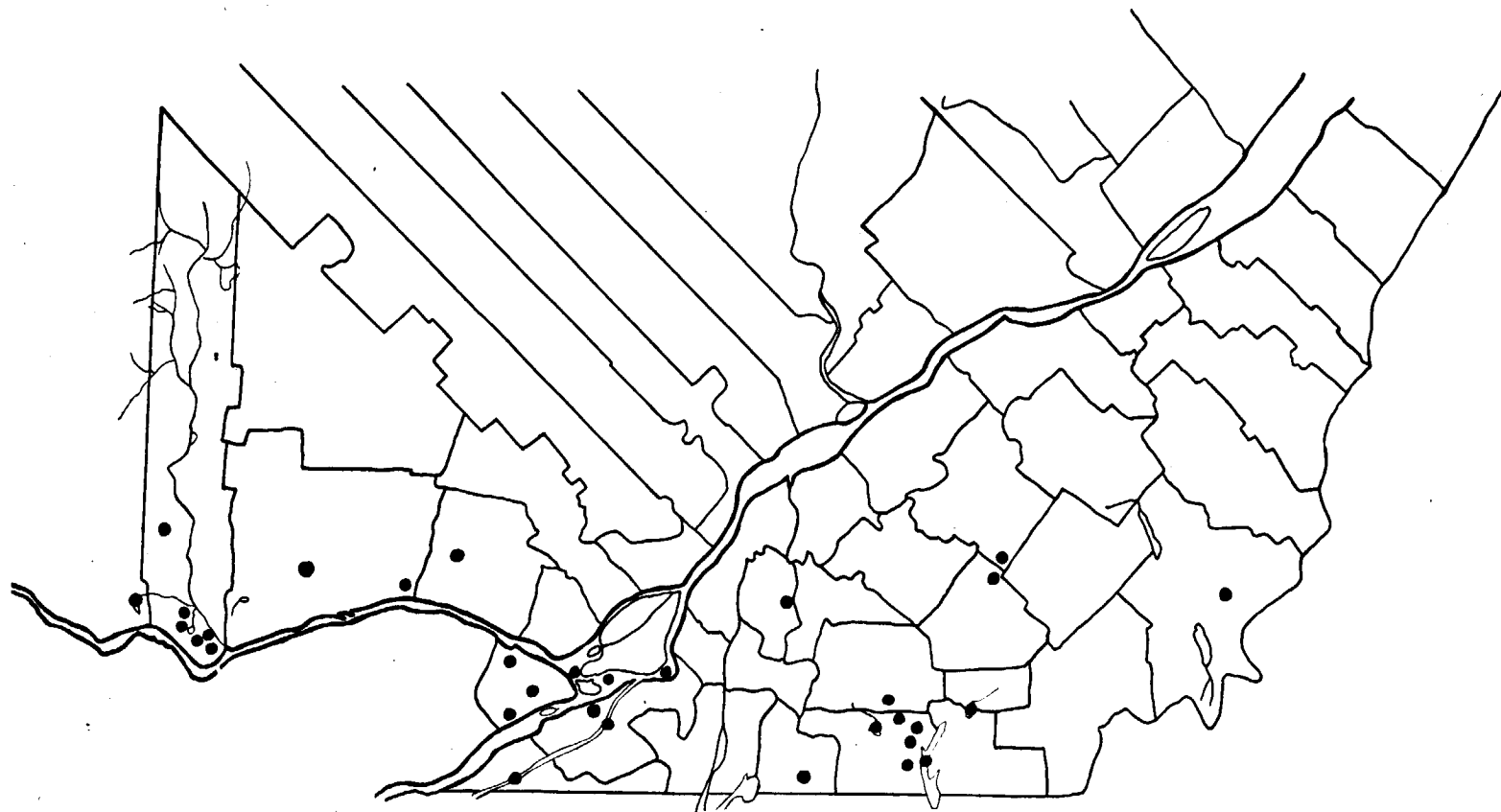
The small-mouth black bass is found in large areas of Quebec, although it is more widely distributed throughout Ontario. From the Georgian Bay across the Kewartha system, through the Rideau chain to the St. Lawrence, is the principal distribution belt, though it is found in great abundance, also, in Lakes Huron and Ontario. North of the Georgian Bay it usually occurs in small and isolated areas.

Approximately 130 lakes and streams in the Province of Quebec are on record as containing small-mouth black bass. Sixty-five of these were visited and in 32 black spot was discovered. The waters visited are recorded here under the headings of counties and townships and the presence or absence of the disease indicated. While the disease has not been recorded from the others, there is no reason to believe it is absent or will remain absent from many of them.

| COUNTY     | TOWNSHIP      | LAKE OR STREAM                                     | Black | spot | present |
|------------|---------------|----------------------------------------------------|-------|------|---------|
| Pontiac    | Onslow        | <i>Lac la Pêche (Wilson)</i>                       |       |      |         |
| Gatineau   | Masham        | <i>Gauvreau</i>                                    | "     | "    | absent  |
|            |               | <i>Brown's Lake</i>                                | "     | "    | present |
|            |               | <i>Cameron Lake</i>                                | "     | "    | "       |
|            | Hull          | <i>Johnston -</i>                                  | "     | "    | absent  |
|            |               | <i>Harrington</i>                                  | "     | "    | present |
|            |               | <i>Meach</i>                                       | "     | "    | "       |
|            | Eardley       | <i>Philippe</i>                                    | "     | "    | "       |
|            | Low           | <i>Bernard</i>                                     | "     | "    | "       |
| Papineau   | Mulgrave      | <i>Blanche Lake</i><br><i>(or La Blanche)</i>      | "     | "    | "       |
|            | Petite Nation | <i>Papineau Lake</i>                               | "     | "    | "       |
| Argenteuil | Harrington    | <i>Macdonald Lake</i>                              | "     | "    | "       |
|            |               | <i>Long Lake</i>                                   | "     | "    | absent  |
| Arthabaska | Tingwick      | <i>Richmond</i>                                    | "     | "    | present |
|            | Warwick       | <i>Riv. des Rosieres</i>                           | "     | "    | "       |
| Wolfe      | Weedon        | <i>L. Louise or</i><br><i>Weedon</i>               | "     | "    | absent  |
|            | Dudswell      | <i>Silver or Mirror</i>                            | "     | "    | "       |
|            | Shipton       | <i>Nicolet River</i>                               | "     | "    | present |
|            | Stratford     | <i>Lake Brochet</i>                                | "     | "    | "       |
|            |               | <i>Lake Aylmer at</i><br><i>Disraeli</i>           | "     | "    | absent  |
| Richmond   | Brompton      | <i>Brompton Lake</i>                               | "     | "    | "       |
| Frontenac  | Winslow       | <i>Lac aux Isles</i>                               | "     | "    | "       |
|            | Lambton       | <i>Lambton Lake</i><br><i>Lac a Richard</i>        | "     | "    | "       |
|            | Stratford     | <i>Lac des Ours</i>                                | "     | "    | "       |
|            | Coleraine     | <i>Lac St. Francis</i><br><i>(Small and Large)</i> | "     | "    | "       |
|            | Gayhurst      | <i>Lac Drolet</i>                                  | "     | "    | present |
|            |               | <i>Three Mile Lake</i>                             | "     | "    | absent  |
|            | Ditchfield    | <i>Lac Megantic</i>                                | "     | "    | "       |
|            |               | <i>Spider Lake</i>                                 | "     | "    | "       |
|            |               | <i>Egg Pond</i>                                    | "     | "    | "       |
|            | Clinton       | <i>Rush Lake</i>                                   | "     | "    | "       |
| Compton    | Lingwick      | <i>Moffat</i><br><i>McGill</i>                     | "     | "    | "       |
|            |               |                                                    | "     | "    | "       |
| Stanstead  | Magog         | <i>Magog Lake</i>                                  | "     | "    | present |
|            |               | <i>Magog River</i>                                 | "     | "    | "       |
|            | Barnston      | <i>Lyster</i>                                      | "     | "    | absent  |

| COUNTY          | TOWNSHIP                 | LAKE OR STREAM                                                                                   |   |   |         |
|-----------------|--------------------------|--------------------------------------------------------------------------------------------------|---|---|---------|
|                 | North Hatley             | <i>Lake Massawippi</i>                                                                           | " | " | absent  |
|                 | Stanstead                | <i>Tomisobia River</i>                                                                           | " | " | "       |
|                 |                          | <i>Crystal Lake</i>                                                                              | " | " | "       |
|                 |                          | <i>Memphremagog</i>                                                                              | " | " | present |
| Sherbrooke      | Orford                   | <i>Fraser Lake</i>                                                                               | " | " | absent  |
|                 |                          | <i>*Seigneurial Lake</i>                                                                         | " | " | "       |
|                 |                          | <i>Mill or Daisy</i>                                                                             | " | " | "       |
| Drummond        | Drummondville            | <i>St. Francis River</i>                                                                         | " | " | absent  |
| Brome           | Brome                    | <i>Brome Lake</i>                                                                                | " | " | present |
|                 | Bolton                   | <i>Lake Orford</i>                                                                               | " | " | absent  |
|                 | Bolton Centre            | <i>Lake Nick</i>                                                                                 | " | " | "       |
|                 |                          | <i>Trouser's Lake</i>                                                                            | " | " | present |
|                 |                          | <i>Trouserleg Lake</i>                                                                           | " | " | absent  |
|                 |                          | <i>Long Pond</i>                                                                                 | " | " | present |
|                 | Sutton                   | <i>Missisquoi River</i>                                                                          | " | " | "       |
| Shefford        | N. Stukely               | <i>Stukely Lake or Bonelli</i>                                                                   | " | " | absent  |
|                 | Shefford                 | <i>Waterloo Lake</i>                                                                             | " | " | "       |
|                 |                          | <i>Libby's Lake</i>                                                                              | " | " | present |
|                 |                          | <i>River No. 2, 1½ mile east of Foster Station at the bridge. Address, Foster, Route 2, Que.</i> | " | " | "       |
| Missisquoi      | Frelighsburg             | <i>Pike River</i>                                                                                | " | " | "       |
|                 |                          | <i>Selby Lake</i>                                                                                | " | " | absent  |
|                 | At Cowansville           | <i>Yamaska River</i>                                                                             | " | " | present |
| Huntington      | At Huntington            | <i>Chateauguay River</i>                                                                         | " | " | "       |
| Vaudreuil       |                          | <i>Coule St. Lazare</i>                                                                          | " | " | "       |
|                 |                          | <i>Riv. St. Jean at Bellevue near Lake</i>                                                       |   |   |         |
|                 |                          | <i>St. Louis</i>                                                                                 | " | " | "       |
|                 |                          | <i>Riv. Raquette</i>                                                                             | " | " | "       |
| Soulanges       |                          | <i>Riv. Beaudette</i>                                                                            | " | " | "       |
| Jacques Cartier |                          | <i>Lake St. Louis</i>                                                                            | " | " | "       |
|                 | At Ste. Anne de Bellevue | <i>Ottawa River</i>                                                                              | " | " | "       |

\*In Mount Bruno area



Partial map of the Province of Quebec showing the distribution of black spot disease of bass in the Eastern Township and north-west Laurentian regions.

Although black spot has been found in bass and sunfish in 32 out of the 65 lakes examined, its distribution is probably wider. Kingfishers frequent practically all lakes and the determining factor is probably the snail. Where both bass and suitable species of *Helisoma* occur, black spot is either present or will almost certainly become established in due course.

### SUMMARY

Black spot in bass in Quebec is caused by the metacercarial stage of *Uvilifer ambloplitis*, a trematode parasite of the belted kingfisher.

A survey of 65 lakes and streams in the Eastern Townships and southern Laurentians showed the presence of the disease in 32 of them.

During this survey, black spot was recorded for the first time in nature in the sunfish.

The encysted cercariae (metacercariae) were found at the base and between the rays of the fins, especially the pectoral and caudal, around the eye, in the mouth cavity, and in the myotomes.

In Canada, black spot of bass occurs in several parts of Ontario and its known distribution in Quebec extends from east of Levis county, south-east and south along the United States border, across Montreal Island, along and including the Ottawa River up to Pontiac county.

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# EFFICIENCY OF NATURAL PROPAGATION OF PACIFIC SALMON

BY A. L. PRITCHARD<sup>1</sup>

Within the last two decades, an appreciable amount of information has accrued on the efficiency of natural propagation of at least four of the five species of Pacific salmon in British Columbia, viz., the sockeye (*Oncorhynchus nerka*), the coho (*O. kisutch*), the pink (*O. gorbuscha*), and the chum (*O. keta*). While many of these data have been published in papers dealing with special problems, they have as yet not been gathered together for a composite presentation with a general statement of the factors which may affect production. It is with this idea in view that the present paper has been prepared.

After discussion with Dr. R. E. Foerster<sup>2</sup> and Mr. Ferris Neave<sup>3</sup>, this article is being developed by the writer, who wishes to extend his thanks for the kind permission to use their data available both from published papers and manuscript.

## RESULTS

### Sockeye Salmon

Sockeye salmon normally migrate in the autumn up rivers which arise from a lake source. After spending some time in the lake itself, they move into the tributaries above for spawning. In some instances, e.g. Kitsumgallum Lake, the eggs may be deposited along the beaches especially where seepage occurs. Some, although a relatively small number, spawn in the streams below lakes. The following spring, the fry emerge from the gravel and drop down into the lake where they usually remain for at least one year before going to sea.

To gain some idea of the efficiency of natural propagation for that phase of the life history from the time when the adults enter the lake on their way upstream until the time when the young leave for the ocean, Dr. Foerster initiated his experiment at Cultus Lake on the Fraser River, B. C. In this, through the operation of a standard type picket weir, all adults were counted. From a random sample of females, the average number of eggs per individual was determined. With this figure and the count for the total number of females, the potential egg deposition could be calculated. Each spring the fry, yearling, and two-year-old migrants were assessed at a specially devised screen fence as they made their way to the sea. With this the "efficiency" — the percentage which the return in young fish constituted of the potential egg deposition — was easily calculable.

Full details of these experiments have already been submitted by Dr. Foerster in Bulletin No. 53 of the Biological Board of Canada (Foerster 1936). The pertinent figures are submitted again in Table I.

Table I — Counts for the Determination of the Efficiency of Natural Propagation of Sockeye Salmon at Cultus Lake, B. C.

| Brood Year                     | 1925       | 1927        | 1930       |
|--------------------------------|------------|-------------|------------|
| Number of males                | 1,540      | 26,049      | 4,853      |
| Number of females              | 3,883      | 56,376      | 5,542      |
| Average egg content per female | 4,500      | 4,500       | 4,500      |
| Females released to spawn      | 3,883      | 55,569      | 5,542      |
| Potential egg deposition       | 17,470,000 | 250,000,000 | 24,900,000 |
| Seaward migrants               | 197,563    | 2,637,573   | 788,637    |
| Percent. efficiency            | 1.13       | 1.05        | 3.16       |

<sup>1</sup> Senior Biologist, Pacific Biological Station (Fisheries Research Board of Canada), Nanaimo, B. C.

<sup>2</sup> Director, Pacific Biological Station.

<sup>3</sup> Senior Biologist, Pacific Biological Station.

During the spring of 1946, the number of yearling migrant sockeye leaving Lakelse Lake, a tributary of the Skeena River, B. C., were counted and totalled 557,400. These were the progeny of the parent year of 1944 when the number of adult spawners were estimated as 25,000. By applying to this figure the average sex ratio determined from repeated examinations of the spawning streams (46% males and 54% females), and using the figure of 3,888 (Pritchard and Cameron 1940) for the average eggs per female, the potential egg deposition was about 52,488,000 and the percentage efficiency approximately 1.06.

### Coho Salmon

The coho salmon, in contrast to the sockeye, spawn in almost any river. They may remain below lakes or they may migrate through them to the tributaries above. After hatching, almost 99 per cent. remain in fresh water for one year before migrating to sea.

Experiments to check the natural propagation of this species were initiated by the Fisheries Research Board on two small creeks tributary to the Cowichan River in 1938 and have been continued up to the present. These streams are located near the site of the hatchery about two miles below the lake. Here, each autumn, counts of the adult cohoes are made and the average egg content per female determined. Each spring the fry and yearling migrants are checked. To date the results have not been published in a formal paper but they have been reported each year in the Summary reports by Dr. Carl, Mr. Neave and the writer.

In Table II the information on file is submitted. Further analyses of these data may result in slight changes but these will not be sufficiently large to affect in any way the general conclusions which may now be drawn.

Table II—Potential Egg Depositions and Percentage Returns in Fry from these Egg Depositions (Percentage Efficiency) for Coho Salmon at Oliver and Beadnell Creeks, B. C.

| Brood Year | OLIVER CREEK             |              | BEADNELL CREEK           |              |
|------------|--------------------------|--------------|--------------------------|--------------|
|            | Potential Egg Deposition | % Efficiency | Potential Egg Deposition | % Efficiency |
| 1938       | 330,200                  | 14.4         |                          |              |
| 1939       | 665,300                  | 11.8         | 433,400                  | 40.0         |
| 1940       | 481,700                  | 30.4         | 74,100                   | 30.1         |
| 1941       | 564,900                  | 26.0         |                          |              |
| 1942       | 199,500                  | 25.6         | 78,100                   | 16.3         |
| 1943       | 326,000                  | 15.2         | 354,000                  | 19.5         |
| 1944       | 173,000                  | 22.3         |                          |              |
| 1945       | 249,000                  | 22.2         |                          |              |

### Pink Salmon

As a general rule pink salmon spawn in clear fast coastal streams or in the tributaries of the larger river systems which are near the ocean. They differ from the sockeye and the coho in that the fry leave for the sea as soon as they are free-swimming.

The most extensive experiment on the natural propagation of pink salmon was carried out at McClinton Creek, Masset Inlet, Queen Charlotte Island, B. C., during the period from 1930 to 1941. In 1943 another set of counting fences (adult and fry) was installed in Morrison Creek, a tributary of the Puntledge River, near Courtenay, Vancouver Island, B. C. In this latter area two cycles have been investigated, the first by the writer and the second by Mr. Neave. All the results are included in Table III.

Table III—Potential Egg Depositions and Percentage Returns in Fry from these Egg Depositions (Percentage Efficiency) for Pink Salmon at McClinton Creek, B.C., and Morrison Creek, B. C.

| Brood year | McCLINTON CREEK          |              | MORRISON CREEK           |              |
|------------|--------------------------|--------------|--------------------------|--------------|
|            | Potential Egg Deposition | % Efficiency | Potential Egg Deposition | % Efficiency |
| 1930       | 50,800,000               | 10.6         |                          |              |
| 1932       | 13,240,000               | 17.3         |                          |              |
| 1934       | 139,500,000              | 9.0          |                          |              |
| 1936       | 53,200,000               | 6.9          |                          |              |
| 1938       | 8,500,000                | 23.8         |                          |              |
| 1940       | 26,600,000               | 19.0         |                          |              |
| 1943       |                          |              | 14,400,000               | 4.7          |
| 1945       |                          |              | 11,900,000               | 6.7          |

#### Chum Salmon

In 1945, the Fisheries Research Board of Canada began intensive work on the chum salmon by installing counting weirs at Nile Creek on the east coast of Vancouver Island. In the autumn of that year, 1,498 males and 1,564 females or a total of 3,062 spawning adults were counted into the river. The average number of eggs per female was 2,922 and thus the potential egg deposition 4,570,000. During the spring of 1946 the fry migrants were enumerated at 138,388 or 3.3 *per cent.* of the egg deposition.

#### DISCUSSION

To give a concise and composite picture of the number of experiments which have been conducted and of the results obtained, the percentage efficiencies are listed for each species, area, and brood year in Table IV. In case of sockeye, the percentage efficiency is the percentage relationship between yearling migrants and eggs available for deposition, and for all others, the percentage which the fry constitute of the eggs available for deposition.

Table IV — The Percentage Efficiency of Natural Propagation for Sockeye, Coho, Pink and Chum Salmon as Determined from Experiments conducted by the Fisheries Research Board in British Columbia in the Areas and for the Brood Years indicated.

|            | SOCKEYE                                                               | COHO                                                         | PINK                                                         | CHUM                                                         |
|------------|-----------------------------------------------------------------------|--------------------------------------------------------------|--------------------------------------------------------------|--------------------------------------------------------------|
| Brood Year | % Efficiency                                                          | % Efficiency                                                 | % Efficiency                                                 | % Efficiency                                                 |
|            | $\left\{ \frac{\text{Y'rling mig.}}{\text{Eggs} \times 100} \right\}$ | $\left\{ \frac{\text{Fry} \times 100}{\text{Eggs}} \right\}$ | $\left\{ \frac{\text{Fry} \times 100}{\text{Eggs}} \right\}$ | $\left\{ \frac{\text{Fry} \times 100}{\text{Eggs}} \right\}$ |
|            | <i>Cultus Lake</i>                                                    |                                                              |                                                              |                                                              |
| 1925       | 1.13                                                                  |                                                              |                                                              |                                                              |
| 1927       | 1.05                                                                  |                                                              | <i>McClinton Cr.</i>                                         |                                                              |
| 1930       | 3.16                                                                  |                                                              | 10.6                                                         |                                                              |
| 1932       |                                                                       |                                                              | 17.3                                                         |                                                              |
| 1934       |                                                                       | <i>Oliver Beadnell</i>                                       | 9.0                                                          |                                                              |
| 1936       |                                                                       | <i>Creek Creek</i>                                           | 6.9                                                          |                                                              |
| 1938       |                                                                       | 14.4                                                         | 23.8                                                         |                                                              |
| 1939       |                                                                       | 11.8 40.0                                                    | 19.0                                                         |                                                              |
| 1940       |                                                                       | 30.4 30.1                                                    |                                                              |                                                              |
| 1941       |                                                                       | 26.0                                                         |                                                              |                                                              |
| 1942       |                                                                       | 25.6 16.3                                                    | <i>Morrison Cr.</i>                                          |                                                              |
| 1943       | <i>Lakelse Lake</i>                                                   | 15.2 19.5                                                    | 4.7                                                          |                                                              |
| 1944       | ca. 1.06                                                              | 22.3                                                         |                                                              | <i>Nile Creek</i>                                            |
| 1945       |                                                                       | 22.2                                                         | 6.7                                                          | 3.3                                                          |

Since the returns for sockeye are calculated on the basis of yearling migrants rather than fry, the population would have been exposed to reducing factors for almost a full year longer. It is not unexpected, therefore, that the efficiencies of reproduction for sockeyes are lower in every case than those for all other species with one exception, namely, that for chums at Nile Creek.

In the case of cohoes, pinks and chums, where the percentage efficiencies are calculated on the same basis, not only do they vary in size from species to species in the same year, but also within a given species for streams in close proximity, e.g. Oliver and Beadnell creeks in 1939.

There is a distinct indication that certain areas give better efficiencies for a given species than do others. This is shown by the figures for the pink where the McClinton Creek, Queen Charlotte Islands, efficiencies are consistently much larger than those for Morrison Creek on the east coast of Vancouver Island in southern British Columbia, viz., a range of 6.9 to 23.8 as compared with two figures of 4.7 and 6.7. Further confirmation that conditions in the latter locality may not be so favourable for spawning, hatching, incubation and alevinage is given by the low return of 3.3 per cent. for chums at Nile Creek.

Consideration would indicate and observation would confirm the fact that losses in the stages of the history discussed are due mainly to the effect of the environment, both physical and biological, on the life processes. Amongst the most important causes up to the fry stage might be mentioned:

1. Predation on adult spawning salmon
2. Incomplete spawning
3. Dislodging and destruction of eggs due to superimposition by later runs.
4. Destruction of eggs from erosion of the beds by freshets.
5. Deleterious effects of climate and the resulting environmental conditions on incubation and alevinage.
6. Predation on the fry migrants.

For sockeye which have spent an additional year in the nursery lake may be added:

1. Predation in the lakes
2. Competition with other species for food.
3. Effect of the physical, chemical and limnological conditions in the lake in so far as they affect food production.

To determine the absolute effect of each of the factors, although a long, difficult and tedious task, should be the ultimate goal of a fish culturist. This important aim has not been ignored since even now many continuous records on such things as climate and water conditions are available in the many experiments for correlation with the changes in efficiency already determined. Several investigations have been made of predators in the case of the sockeye, pink and chum, and all indicate that this factor is one of the most serious if not *the* most serious which is encountered. Some study has been made of the other losses from spawning to fry migration and in at least one case (McClinton Creek) at least reasonable figures have been reached for each. There is no denying the fact that much more remains to be done and that the work will be very time-consuming, but there is no other evident way to get a clear picture and thorough understanding of the various problems.

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## STREAM CONTROL AND NEW FISH CULTURAL PROCEDURES ON A SWEDISH RIVER

BOOK REVIEW BY W. PERCY WICKETT<sup>1</sup>

Salmon and Trout in the Kavlinge River (Lax och Laxoring i Kavlingeån), by Ph. Wolf. Published at Lund by C. W. K. Gleerup and printed by Broderna Forssells Boktryckeri, Malmo, 1946. A translation from the Swedish by Alice Backlund is available. 84 pages. 81 photographs. Price Kr. 7.

This first publication by the Swedish Salmon and Trout Association, Malmo, is well worth reading because it records the establishment of uniform administrative control for effective utilization of a watercourse, and new fish cultural procedures and devices. The author point out that the methods employed are subjected to critical examination and development.

**Organization.** The personnel consist of a board of five directors, the auditor, the Research Council of fishery authorities and biologists of Lund University, a field force of 45 members and a fish keeper. A small biological laboratory and six small nursery ponds at Skogsmollan are at the disposal of the association.

**Methods.** Through the property owners' cooperation practically all the essential parts of the stream, 79 miles long, draining an area of 475 square miles and flowing through one of the most densely populated parts of Sweden, have been leased. More than 2,000 leases have been executed. The rearing and planting of young fish, the control of vermin fish and the inspection of pollution are at present considered the most urgent matters.

**River Survey.** The entire river system has been divided into numbered sections, approximately 200 yards long, in which data regarding stream flow, type of bottom, pollution, available food, and present and past fish populations, etc., are gathered. There is no native stock of sea trout or salmon. Only remnants of a stock of brown trout are to be found. These are protected and their environment improved as much as possible.

In some of its lower reaches, the Kavlinge River system is not suitable for salmon and trout. However, it does possess, especially in the upper reaches, large areas that appear unusually suitable. All the small tributaries in both the upper and lower parts constitute an important area for rearing the largest possible number of trout and salmon to the migrant stage. Pollution appears to be on the wane due to the installation of purifying devices for the waste water of factories and towns, and in a few years this danger to the stock should be gone. Ascent barriers practically do not exist. The fish already in the river system—eel, pike, minnow, roach, bream, perch and tench—if proper methods are used, should not limit the improvement of the conditions for salmon and trout. The supply of food for the fish is excellent, consisting of *Gammarus*, *Daphnia*, *Trichoptera*, *Ephemera*, *Plecoptera*, *Chironomidae* and *Simuliidae*.

<sup>1</sup> W. Percy Wickett, Junior Biologist, Pacific Biological Station (Fisheries Research Board of Canada), Nanaimo, B. C.

**Stocking.** The association has thus far reared imported fry in ponds, partly because it considers it best to leave the small brooks for experiments. In the spring, fry are planted in the ponds. These structures, which are built in the stream beds, are emptied in the fall when the young are distributed as widely as possible over the area according to a carefully designed plan. Vermin fish are removed with bow-nets, etc., beginning with stretches to be stocked. All sources of pollution are visited and inspected at intervals by the fish keeper. Oxygen and biological samples are taken and pH values determined. The year after the fish have been planted in the open streams they become the object of sample fishing. This is carried out by angling, either fly or worm, or, when suitable, by nets. All fish are marked by affixing a celluloid tag to the back with a non-corrosive wire loop and released. During seaward migrations, fish are caught for marking in the permanent trapping gear to be found in the main streams (eel-traps). Marking is again carried out during the migration from the sea.

It is intended that the stock of fish will be exploited after it has reached a satisfactory size. When the stock is fished, the financial surplus is to be distributed among the property owners from whom the association has leased the streams. They will thus receive compensation for giving up their fishing rights, which however, when the association took them over, were worthless from the point of view of salmon fishing.

**Use of Small Brooks as Nursery Areas.** Dams and pollution have rendered the larger streams unsuitable for fry. An experiment has been carried out in Humlemada Brook which is approximately two miles long with an average width of two feet. The flea-lobster (*Gammarus pulex*) is very common, but otherwise the bottom fauna is not abundant. In 1944, fry from the nursery pond in the brook were allowed to escape up the stream. In November the ponds were emptied of fish and drained. In the spring of 1945, the 800 yards above the pond site was limed twice. In this section, which varies from eight inches to two feet wide, 302 sea trout were taken. The largest was seven inches long. To stock the larger streams, one-year old fish must be used to minimize predator losses. The brooks of the whole system comprise three times the area of the larger streams and lack predatory fish. The use of the brooks therefore saves the cost of a year's feeding and gives them a good chance of survival.

**Deflectors—Aid for Creating Satisfactory Living Conditions in Running Streams.** Many types were tried out on the Bra River. The most satisfactory was found to be the V-form, point downstream. The Bra River is subject to flash floods, yet is only a trickle in summer. High dams would cause mud deposits to raise the bottom in places formerly deepest, while shallower places would be deepened. Under these new conditions there would be the danger of pike establishing themselves, of water temperatures rising to undesirable heights and of the farming land being flooded. An ideal water level was determined, about one foot, which would be deep enough for the fish and yet not interfere with drainage of farm lands. By always taking as a guide the river's original structure and building deflectors one foot high at the points which are naturally the highest, but not damming up the high parts immediately above, the stream has now as great a depth during periods of slight flow as formerly during times of high water level. The scouring by the water falling over the deflectors creates added depth for some distance below the drop. At high water the deflectors hinder the run-off very little. They will also withstand ice. At the lower end of the "V", a sluice is placed so that run-off may be quickened during freshets and so that silt and detritus may be washed out of the pools. So-called "roofs" have been tried out. A platform of boards below the surface and eight inches from the bottom provides shade and a hiding place.

**Daphnia Ponds.** To provide additional natural food for the period just after the fry are planted the water flea (*Daphnia magna*) has been raised in enclosures

attached to the fish-breeding ponds. A one-foot earth embankment is sufficient for the 25 x 5-foot pond. An embankment across the middle with a sluice in it gives two 12 x 5-foot pits that are on the same level as the fish pond. The one next to the fish pond, the *culture pond*, has a depth of two inches on the side nearest the fish pond and of one foot on the other. The second pit, the *manure pond*, has a depth of one foot throughout. Four inches of horse manure was placed in the manure pond in April. The *Daphnia* cultures which had been raised indoors were set out in the culture pond at the beginning of May. At intervals, during a 20-day growing period, the sluice between the manure and culture ponds was opened for a few hours. Then the sluice between the culture and fish ponds was left open for two days to let the *Daphnia* into the latter. The procedure was repeated until the end of July. Enough *Daphnia* remained in the culture pond to form a new stock. Three such ponds connected to a 1,000-square-yard fry pond should greatly reduce mortality.

**Wrack Organism.** Water fleas cannot be supplied in sufficient quantities to feed larger three-month-old fry. A source of live food, mainly *Orchestia platensis*, has been found in the huge beds of wrack (seaweed) along the coastal beaches. The seaweed is tossed onto a frame 10 x 7 feet covered with 1/2-inch wire netting. The animals fall into a linen bag below. Two men working an eight-hour day collected on the average 300 quarts in July, 250 in August and 125 in September. The animals and seaweed remains were scattered in small quantities in the centre of the fry ponds. The ponds should be at least 50 yards in radius, so that the wrack fleas may be caught before they swim ashore. The seaweed remains, if not too plentiful, have the added effect of fertilizing the ponds. Throughout July, August and September 418 gallons of wrack animals and remains were put into a pond 2,500 square yards in area. Of the 35,000 sea trout fry planted in the spring, 17,181 fish averaging 2.7 inches in length were taken out in December. This is a production of 268 pounds per acre.

**"Wolf" Trap.** In order to collect all living matter, including fish, that may drift down the streams, the author has designed a self-cleaning trap with 0.3 millimeter mesh able to handle up to 80 cubic feet per second of water and which could be enlarged to handle up to 2,000 cubic feet. Sixteen inches below a 5 1/2-foot dam, a fine screen 10 feet wide is placed at a slight angle away from the pond. Attached to the lower edge of the screen is a large box made of screening. The box has a cleaning door at the side. The force of the falling water keeps the screen clear even when the stream is full of leaves. All solid material and organisms large enough for fish food collect in the box. If the box is made sufficiently large, the device will function without supervision for periods up to two weeks. Fish and fish food are not injured at all. Anyone interested in using this device may obtain additional information by applying to the association.

## POLLUTION STUDIES IN BRITAIN

BY J. R. DYMOND<sup>1</sup>

A good start has been made on the study of pollution as it affects the fisheries in Great Britain.

In 1925 a pollution team responsible to the Director of Fisheries Investigations (Dr. E. S. Russell) and consisting of two chemists, a botanist and a zoologist, was organized. Its purpose was to assess the effects of pollution on the fisheries including those of tidal waters. Arising out of this step by the Ministry of Agriculture and Fisheries, there was formed in 1927 under the Department of Scientific and Industrial Research (DSIR) which is directly responsible to the Privy Council, a Water Pollution Research Board. One of the chief objects of the work of this board has been to help industry to avoid contributing to the pollution of water. From 1929 to 1933 the two teams of investigators joined forces to make a survey of the Tees River to determine the nature and effect of pollution in the river.

In this survey it was found that pollution in the up-river reaches was not serious. Only a few small towns and villages discharged their sewage into the river. A town of 70,000 contributes to the pollution of the middle reaches of the river but without catastrophic results.

A number of large towns on the estuary discharge not only untreated sewage but industrial wastes including wastes from coke ovens in to the water. The salmon fishing has been declining in recent years, although up to 1920 the Tees was a good salmon river. The decline of the salmon led to an argument as to whether it was due to the sewage or the industrial wastes or to other causes. The pollution studies established the fact that cyanide in the wastes from the coke ovens was poisonous to the descending smolts. It has also been determined that coke ovens need not produce cyanide. Whether they do or not depends on the process used for ammonium recovery. Although one of the steel firms has erected coke ovens using a process which should not produce cyanide, their old ones could not be demolished owing to the outbreak of war. The results of these researches give promise, however, that the salmon of the Tees may be restored as soon as economic conditions improve. The results of the pollution studies on the Tees have been published in three reports. Reference to them is as follows:

Department of Scientific and Industrial Research.

Water Pollution Research Technical papers.

Survey of the River Tees

No. 2 Part I Hydrographical

No. 5 Part II Estuary — chemical and biological.

No. 6 Part III Non-tidal reaches — chemical and biological.

Other investigations undertaken have been on the beet sugar and milk industries, where the effects of the wastes have been investigated by the Ministry of Agriculture and Fisheries, and the problem of their elimination or treatment by the Water Pollution Research Board. The results are recorded in the following publications:

<sup>1</sup>Professor of Systematic Zoology, University of Toronto; Director, Royal Ontario Museum of Zoology; Member, Fisheries Research Board of Canada.

Investigation of the River Lark and the Effect of Beet Sugar Pollution, by R. W. Butcher, F. T. K. Pentelow and J. W. A. Woodley. Fisheries Investigations Series 1, Vol. III, No. 3. 1931.

The Purification of Waste Waters from Beet Sugar Factories. Water Pollution Research Technical Paper No. 3.

An Investigation of the Effect of Milk Wastes on the Bristol Avon, by F. T. K. Pentelow, R. W. Butcher and J. Grindley. Fisheries Investigations Series 1, Vol. IV, No. 1, 1938.

The Treatment and Disposal of Waste Waters from Dairies and Milk Product Factories. Water Pollution Research Technical Paper No. 8.

More recent and not yet published work has included the investigation of the effects of metallic wastes on streams and the treatment of effluents from a great variety of industries, many of them set up owing to the war.

These publications may be obtained through H. M. Stationery Office, York House, Kingsway, London, W. C. 2.

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### CORRECTION

In the first issue of the Canadian Fish Culturist (November, 1946) an error occurred in the table, on page 15, comparing the growth rates of rainbow trout in the course of the experiment in fertilization discussed by Dr. R. B. Miller in his article on The Effects of Ammonium Nitrate in Trout Rearing Ponds. As the table was published, the words "Experimental control" appeared, in one case, as a sub-head over columns showing average weight of the fish at different stages of the experiment and, in the other instance, over columns showing average length. Actually, "Experimental" and "Control" should have been printed as distinct sub-heads. The first of the columns relating to average weight, and the first relating to average length, referred to fish in the experimental pond and should have been headed "Experimental". The other two columns referred to growth in the control pond, and "Control" should have been the heading.

OTTAWA  
EDMOND CLOUTIER, C.M.G., B.A., L.P.H.,  
IMPRIMEUR DE SA TRÈS EXCELLENTE MAJESTÉ LE ROI  
CONTRÔLEUR DE LA PAPETERIE  
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# THE CANADIAN FISH CULTURIST

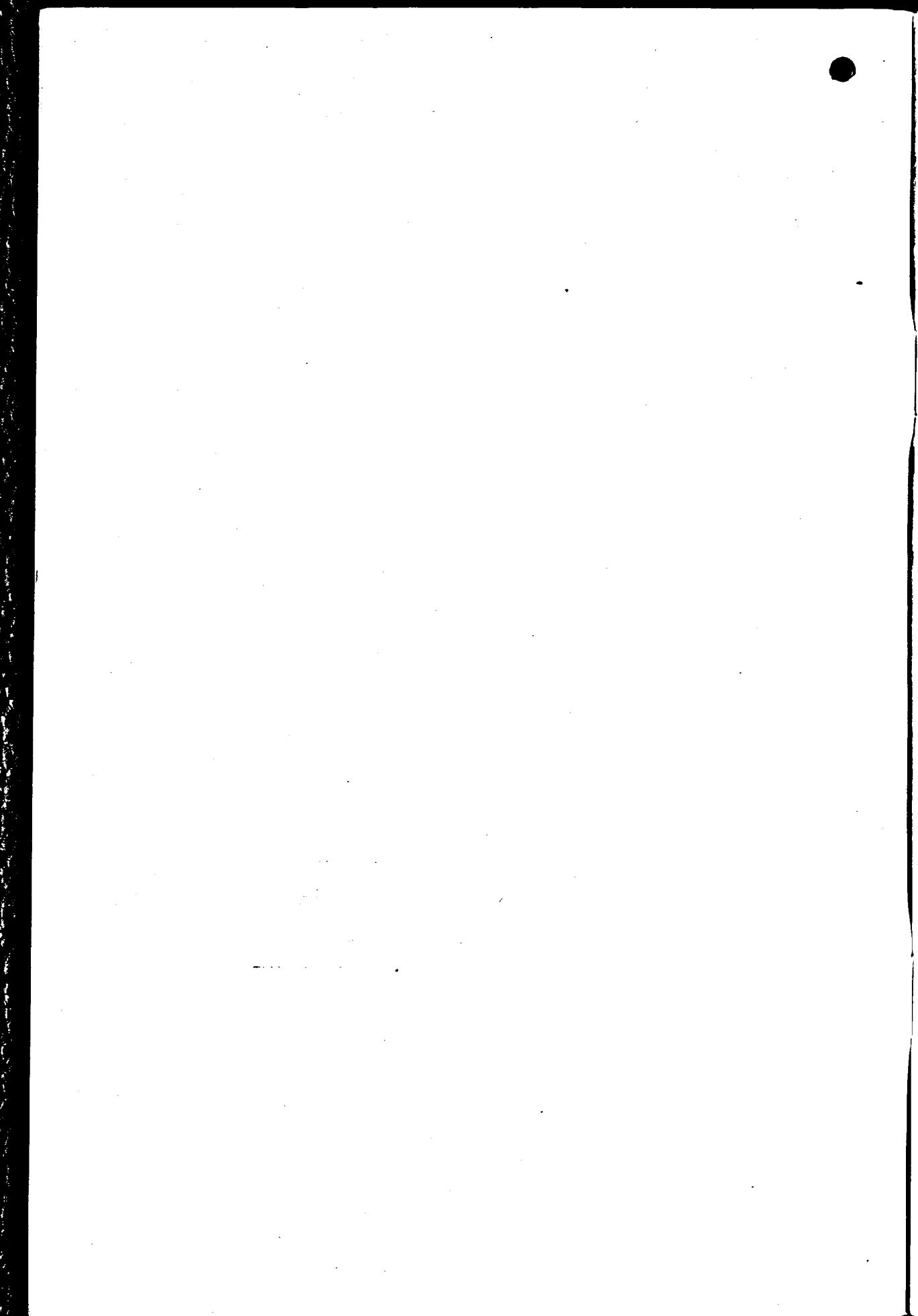
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## ON COUNTING THE TROUT IN A LAKE

By F. R. HAYES<sup>1</sup>

The central problem of freshwater fisheries would seem to be the lack of a good method to count the crop, for we cannot find out, in any easy way, how many fish there are in a lake. Thus it becomes extremely difficult to assess the result of any experiment which may be carried out, whether in the nature of planting young fish, fertilization of the water, destruction of predators, etc. The problem becomes clear if we consider, by contrast to the fish culturist the farmer. If the farmer wants to know how the crops are getting along in a certain field, with a certain treatment, he can simply count the barrels of apples or what not, at the end of the season. What would his difficulties be if he had, instead, to make an inspired guess at his crop, after some careful surveys, reinforced by the latest in statistics, of the composition of the soil, the apparent success of weeds, and the number of small boys raiding his orchard per unit time, (assuming that one small boy can carry away, say, 11.2 lbs. of apples on the average)? Alternatively he might get a somewhat closer estimate by a method involving the destruction of all his trees. If such were the best the farmer could do, we should be safe in assuming that agriculture would not be within 200 years of the position it has reached.

The management of inland fisheries in fact, is, as someone has pointed out, scarcely equal to that of agriculture 200 years ago, mainly because we have still to rely on indirect counts. These may be chemical (phosphorus or nitrogen in the water or soil); leaf size or plant abundance; weight of plankton taken under standard conditions, etc. When we come to direct counts of trout of a size suitable for angling, three methods are in vogue, the first being to poison the lake and count the dead fish, or a representative sample. There are some technical difficulties, the method being applicable only to certain kinds of small lakes, and naturally, not capable of annual repetition. In practice it is applied only to lakes deemed lost to angling, and has given valuable information about some of these.

The second method, and the one most widely practiced and highly regarded, is the creel census. In its full dress form the creel census requires that one or more men be kept permanently on the lake during the angling season, to record the numbers and sizes of all fish caught. If the man is a local lake-side dweller, he generally contributes nothing further to the investigation than the census, and his work becomes rather light after the spring rush of anglers has passed. Thus, on a Nova Scotian lake last summer, the census taker reported less than one trout per day during the summer months. This was a full time job for which he was paid as much as a graduate student would receive on a field party. The cost is clearly so high, for the information obtained, that the technique is hardly likely to come into extensive use. Of course the cost, which is in any case a rather small fraction of the national

<sup>1</sup> *Zoological Laboratory, Dalhousie, and Department of Industry, Province of Nova Scotia.*

budget, will be thoroughly warranted as a means of establishing experimental procedures. The tendency to demoralize a young man by a snap job will perhaps be considered to be no concern of the investigator; what is more serious is that the surrounding community of hard-working farmers tend to look on the whole investigation as a patronage proposition. These are personal difficulties; a scientific one, in the lake under consideration, is that local reports indicate that large numbers of trout are taken in the winter, out of season, when there is a flourishing juvenile sport of angling through the ice.

The picture of the creel census, under difficult conditions, is not reassuring. However, at its best, and at considerable cost, it may give a fair picture of the annual crop of a small lake and, if continued for several years, a fair estimate of the productivity of a lake. In its complete form it requires too great a staff to be economically feasible in large lakes. In such cases the modified census has been substituted, in which no attempt is made to ascertain the total annual catch. Instead, a census is taken over a limited period, and some value, such as pounds of trout caught per fisherman per hour, is arrived at. This forms a basis for comparing different bodies of water, or different seasons, or parts of a season, on the same body of water. Obviously the technique will not provide information on the degree of depletion of the lake by overfishing. As a combination of the complete and the relative creel census methods, it might be possible to approximate something approaching the former, at something like the cost of the latter, by employing census takers on the six or eight week-ends and holidays of the intense spring fishing season. This might cover nine-tenths of the total summer's catch, and could be done by persons engaged on other fisheries work during the week.

A third method of direct fish census begins by the taking of as many fish as possible by angling, marking them, and returning them to the water. After a rest period the lake is re-fished and the proportion of marked fish in the catch used as a basis for calculation of the total population of the area in question. For instance, if 300 fish are marked at the first fishing, and if 2 per cent of the second fishing consists of marked fish, then 2 per cent of the population of the lake is 300 fish; hence the population is 15,000 fish. The method is comparatively inexpensive, since the second round of angling may be carried out by sportsmen, with the experimental anglers of the first round acting as census takers. Also, it does not take up a whole season, and yields some information about the size of the fish and the catch per unit of effort.

There are several sources of error in the method; for instance, some of the marked fish may die as a result of handling, after they have been returned to the water. Again, the census taker is likely to miss an occasional marked fish. Both these errors will result in too high an estimate of the total population. Further, the method assumes that the marked fish will take the hook a second time as readily as the population as a whole; if they fail to do so the estimate will be high. Much more serious, however, is the inherent error if the ratio of marked to unmarked fish is too small. In the example above, fluctuations in the marked fish count will be multiplied fifty fold in the estimate

of total population. If the marked fish had represented 10 per cent of the population instead of 2 per cent, the error would have been ten fold; had they represented 50 per cent the error would have been only two fold, which is the best result possible. It follows that it is desirable to bring the marked group as closely as possible up to 50 per cent of the population of the lake. In practice this is not likely to be attained by angling, although something in the direction of traps might be developed.

For the purpose of examining the difficulties in the method just discussed, a Provincial field party was sent out in the spring of 1947 to make a census of several Nova Scotian lakes in Pictou and Antigonish Counties. There were two university students, both experienced anglers, who engaged local help as necessary. They travelled in a jeep, and were equipped with portable rubber boats and all necessary gear. Initial experiments with barbed hooks showed that the losses amounted to some 30 per cent; on filing off the barbs the loss of fish was reduced to about 1 per cent, hence the barbless hooks were adopted for use. (As compared to this, Westerman (*Mich. Conservation*, 2, no. 12, Dec., 1932) reports trout losses as follows: 3 per cent using an artificial fly, 6 per cent using the barbless hook, and 9 per cent using the barbed hook, baited.)

A few general observations on angling conditions were made.

1. No relation could be observed between weather and angling success, wind, sunlight, and rainfall being equivalent.
2. More fish were caught within 100 feet of shore than farther out in the lake.
3. No difference in fish response could be observed between flies and worms, nor could any one fly be shown to be better than any other.
4. Noise did not appear to interfere with results, as evidenced by the operation of an outboard motor, in the tailrace of which, fish could be caught.
5. Local help was disappointing; it was found suprisingly difficult to engage people who would fish actively, and those who did not do so caught very few fish.
6. The fish appeared to bite in cycles; thus after a disappointing interval nearly everybody scattered over the lake would begin to get bites at once. Whether this phenomenon is associated with a change in some physical condition such as light, was not clear.

The first lake fished was Black Brook Lake, also called Birch Brook Lake. It is about 75 acres in area and reaches a depth of nearly 60 feet. It is locally known as a "natural breeder" with an abundance of small trout but practically no larger ones. All the fish caught ranged between 11 and 20 cm. Two men fished the lake for five and one-half days, a total of 238 trout being marked and put back. The lake was not closed and general angling was in progress at

the same time. Accordingly only a week-end "rest period" was allowed for the marked fish before a creel census was begun, the results of which are given below.

| Date (May)  | Total Catch | Marked Fish | Per cent Marked |
|-------------|-------------|-------------|-----------------|
| 12          | 182         | 3           | 1.6             |
| 13          | 129         | 9           | 7.0             |
| 14          | 201         | 11          | 5.5             |
| 15          | 124         | 2           | 1.6             |
| 16          | 123         | 0           | 0.0             |
| 17          | 108         | 0           | 0.0             |
| 18 (Sunday) | 347         | 9           | 2.6             |
| 19          | 38          | 0           | 0.0             |
| 20          | 32          | 0           | 0.0             |
| 21          | 43          | 0           | 0.0             |
| TOTAL       | 1327        | 34          |                 |

Applying the calculation for determination of fish population to these figures, one would obtain the following result:

$$\frac{1327 \times 238}{34} = 9,289 \text{ trout in the lake.}$$

If we look no farther the estimate appears to be fairly taken. However an inspection of the day to day marked fish, particularly when turned into percentages, as in the right hand column, suggests that most were caught in the early days of fishing, few towards the end. A statistician, Dr. Donald Mainland, has very kindly worked over the results, and drawn the following conclusions:

1. *The proportions of marked fish taken from day to day, differ more than would be expected in random samples of homogenous material.* In applying the Chi square test to show this, the days were grouped as follows, in order to reduce the risk of fallacious results due to the small size of the samples; May 12 and 13, 14, 15 and 16, 17 and 18, 19-21. Chi square = 15.54; degrees of freedom = 4; P is less than 0.01.

2. *Although the successive percentages of marked fish fluctuate, there is a general downward trend, that is to say, the proportion of marked fish was really diminishing.* Linear regression is a test for this trend, in so far as it can be represented by a straight line. Fisher's angular transformation of percentages was applied, and the regression equation for these values was estimated. The downward slope of the regression was found to be significant; P is less than 0.05.

We have gone from practice to theory, and we must now return to practice again to seek an explanation for the diminishing proportion of marked fish. Black Brook Lake has an abundance of trout, which are readily caught. It also has a road along the side. Hence all the angling is from the shore, and this included the initial experimental angling for marking purposes. Thus

the marked fish were thrown back into the areas where angling was carried out. We may think of the general body of fish in the lake as moving about, into and out of the preferred fishing areas. On the other hand the marked fish had at the start only one direction in which they could move, i.e. out of the preferred areas where they were placed. It is to be expected that they would, with time, become uniformly dispersed in the lake, after which they would be moving into and out of the fishing areas in the same numbers. If this interpretation is correct one would expect to get the maximum proportions of marked fish in the early days, gradually diminishing to a constant proportion after complete dispersal. It might be further deduced that the migration of fish throughout is quite rapid; if the marked fish parallel the behaviour of the general population, there is a major readjustment of distribution within a few days. This suggests that the trout are not maintaining "homes" in particular places in the lake. Since most of the marked fish were caught at the start, there is evidently no extended rest period needed to enable them to recover from the hook wound. A rest period is necessary, if at all, to permit uniform dispersal, this being, however, better attained by fishing over the whole lake in a systematic way.

The conclusion from the Black Brook Lake experiment in general is that in the first days the result represented an approximation of the number of fish in the areas frequented by anglers; later it began to approach the population of the whole lake. Thus the total set down, 9,289, has little validity and does not warrant any attempt at interpretation. If experimental errors were eliminated one could proceed from a count, to estimate (given a rough notion of lake volume) how many cubic feet were occupied by one fish. The matter could then be further pursued into the realm of food supply, fish weights, and comparison with other lakes.

While the census taker was at work on Black Brook Lake the party of two spent five days fishing a lake which is rather inaccessible to anglers, McEachearn's Lake (locally called McIsaac Lake), on the Antigonish-Pictou border. The lake has about twice the area of Black Brook Lake but is not so deep. The initial fishing was for five days, and in this instance was carried out from boats which cruised the lake uniformly. Three hundred and ten fish were marked. After a "rest period" of four days (no fishing), the census was begun and carried out for six days, resulting in a catch of 827 trout, of which 6 were marked, thus:

$$\frac{827 \times 310}{6} = 43,000 \text{ trout in the lake.}$$

The figure six for marked fish is so low, in comparison to the total catch that, as mentioned above, the accuracy of the total count is necessarily poor. The area of the lake is about 150 acres or twice that of Black Brook Lake. The McEachearn fish were larger than the Black Brook, ranging from 11 to 24 cm. with a mode of some 18 cm. The 827 trout were arranged in length groups to the nearest cm. and a frequency curve constructed. It turned out that the

18 cm. peak was the only one, indicating either that angling was centering around trout of a single year class, or that conditions of the competition were such that trout could not grow very much larger in the lake.

Scale samples were taken and examined carefully; they were also submitted to workers in fisheries at the University of Michigan. It has not been possible so far, to differentiate year classes or to state the age of the trout. It appears that in order for a summer growth spurt to show clearly on the scale, the water in a particular lake has to become quite warm. Where there is a thermocline, the trout will migrate to the cooler deep water during the summer, where growth will proceed relatively slowly. It would be desirable to follow the procedure which has been tried in Michigan, of marking trout for re-catch, and scale sampling at intervals, so that a norm could be set up. The phenomena of aging of bones, which might be established through X-ray examination, deserves to be investigated as well. Until criteria for age determination become available it is going to be most difficult to assess the results of such experiments as raising the fertility of waters.

The third lake fished was Copper Lake on the Antigonish-Guysborough border. It is somewhat smaller than Black Brook Lake, being about 50 acres, and has similar depth characteristics. It differs from the other lakes in having an abundance of coarse fish, chiefly white and yellow perch and golden shiners, in addition to the ubiquitous eel. The lake was fished uniformly for 12 hours by eight men, who caught and marked 34 trout, the largest being 33 cm. or considerably above the range for the other two lakes. The lake was then observed for 10 weeks during which 68 trout were caught, of which three had marks. Thus the population is calculated as

$$\frac{68 \times 34}{3} = 771 \text{ trout in the lake.}$$

The lake is readily accessible, surrounded by farms, and heavily fished. These factors, together with the predators, and perhaps a smaller area of spawning beds, keeps the population at a much lower level than in the other lakes, but apparently permits a few trout to reach a large size. Attempts to do scale readings on the trout were unsuccessful.

The foregoing remarks may be summarized in two sentences. (1) It appears possible to develop an economical method of lake population census to a degree of accuracy sufficient for general purposes. (2) A major obstacle to the interpretation of any count of population is inability to assess the age of the fish.

## A MANAGEMENT PROGRAM FOR GOLDEYE (*AMPHIODON ALOSOIDES*) IN MANITOBA'S MARSH REGIONS

BY WM. M. SPRULES<sup>1</sup>

There has been an increasing demand for smoked goldeye, (*Amphiodon alosoides*), in recent years as its reputation as a table delicacy has spread throughout the continent. During the same period the commercial catch, which comes almost exclusively from Manitoba, has fallen from over one million pounds annually to less than one half this figure. The resultant scarcity of the product has aroused public interest in the fate of this popular fresh water fish.

Since comparatively little was known concerning the general biology and natural requirements of goldeye an extensive investigation of this species was started during the summer of 1945 as part of the program of the Central Fisheries Research Station, Winnipeg. Part of the investigation has been carried out along a one hundred mile stretch of the Saskatchewan river between Cumberland lake, Saskatchewan, and Cedar lake, Manitoba, which embodies the flat delta region of the river and consists of many square miles of marsh with numerous channels and small, shallow lakes. This area has been developed recently by the Provincial Department of Mines and Natural Resources through construction of dams and subsequent control of water levels and has yielded a rich annual fur crop made up principally of muskrat.

In general these dams are opened twice a year in order to freshen the marshes and build up a suitable water level. This must be done when the water level in the Saskatchewan river is high and occurs immediately after break up in the spring and again in early summer when the spring run-off from the headwaters reaches this region. At these times, especially in the spring, a large number of fish of several species including goldeye enter the marsh and spawn. As soon as the water level in the river drops below that of the marsh the dams are closed and thus act as artificial barriers to the movement of fish back to the river during the summer and winter months. Although some of the adult fish which enter the marsh when the dams are open during the first high water period may leave the marsh during the second high water period it is obvious that the young which develop from the spawn of that year would be unable to escape at that early date and thus would be forced to overwinter in the marsh. Thus an appreciable loss of stock would occur each year if ecological conditions prevailing in these waters during the winter stagnation period proved limiting to the successful survival of fish. Such a condition would be expected since the prolonged period of ice and snow cover found in this latitude, shallow water and large amounts of putrescible matter on the bottom would tend to lead to an oxygen depletion and finally a winter kill of fish and other aquatic organisms.

<sup>1</sup> Associate Biologist, Central Fisheries Research Station (Fisheries Research Board of Canada), Winnipeg, Man.

The results of the investigation showed that such conditions actually existed. Seining operations carried out behind the dams during the summers of 1945 and 1946 showed that large numbers of goldeye averaging  $2\frac{1}{2}$  inches in length began to accumulate at the dams early in August. By the middle of August a short sweep of the seine produced as many as two hundred goldeye in addition to other species. This condition was repeated behind eight of the ten dams visited.

Evidence of a winter kill of fish was obtained at two dams where observations were made in April, 1946, prior to break-up. Fish in an advanced stage of decomposition were seen beneath the ice and floating in the first open water which occurred along the shores of the streams immediately behind the dams. On April 16 a total of fifty-seven dead pike, (*esox lucious*), was observed in the narrow strip of open water along a thirty-yard stretch of one bank. In addition, pickerel or pike perch, (*Stizostedion vitreum*), burbot or marias, (*lota lota*), brook sticklebacks, (*Eucalia inconstans*), and frogs were found dead. Although no evidence of a winter kill of goldeye was observed directly, it is highly probable that they too are unable to survive the severe winter water conditions of the marshes since it has been shown in several instances that pike are able to survive under conditions of low oxygen content which are unsatisfactory for most other species.

A series of water analyses was made between March 3 and 7, 1947, to determine the gas content of these marsh waters under stagnation conditions. It was found that some shallow areas were frozen to the bottom and in others the dissolved oxygen content was completely depleted with concomitant high quantities of carbon dioxide, methane, and hydrogen sulphide gases present. All other tests showed a small amount of dissolved oxygen in the water but this value was close to the critical level for fish. Since oxygen depletion will continue for another four to six weeks in these areas prior to break-up when a fresh oxygen supply will be obtained, it is probable that few fish would survive the winter even in these waters.

In order to establish a practical method of releasing the fish from behind the dams an experimental flushing operation was carried out at one of the dams between September 17 and 20, 1946. A fine mesh wire screen was attached to the dam, stop logs removed from one gate of the dam and a flow directed through the screen. Thus any fish passing over the dam were trapped in the screen and were available for examination. The number of each species was tabulated each hour and flows of different volumes were released for a total of forty hours. During this time a total of 2,260 fish belonging to 14 species was flushed out of the marsh including 474 small goldeyes. An 8-inch flow along one 10-foot gate proved to be the most satisfactory flow from the standpoint of flushing the fish over the dam. Further, it was found that goldeye flushed more readily during the night than during the day and that the greatest movement occurred during the hours of sundown and sunrise.

From these data detailed plans for annually flushing each of the dams in the marsh area during the late summer have been formulated and forwarded

to the Provincial authorities. The period of flushing will differ at each dam dependent on the volume of water maintained by the dam. Since the water areas controlled by each dam are large, and since the volume of flow required to release an appreciable quantity of fish comparatively small, the change in marsh water level brought about by a controlled flushing program would be negligible and amount to only some fraction of an inch. Thus a large quantity of small goldeye as well as other fish can be released from the marsh areas, where ecological conditions become severe during the winter stagnation period, into the Saskatchewan river, where they would be able to travel freely to suitable waters, by creating a small flow of water over the dams at the critical period each year. In addition, with suitable control, such a management program would not have a deleterious effect on other industries, such as muskrat ranching, which are carried on in the same area.

MARCH, 1947

## DO SMALL SALMON TEND TO PRODUCE SMALL SALMON?

BY F. NEAVE AND A. L. PRITCHARD<sup>1</sup>

In the spawning migrations of sockeye, *Oncorhynchus nerka*, spring, *O. tshawytscha*, and coho, *O. kisutch*, salmon there normally occurs a proportion of precociously developed male fish, commonly called "jacks" which are easily recognizable by their small size. Since they are almost immune to capture by standard commercial gear, jack salmon do not constitute a particular asset to the fishery, and because the number of full-sized males reaching the spawning grounds ordinarily appears to be sufficient to fertilize the available eggs, they do not appear essential to efficient propagation.

At times such fish constitute a considerable proportion of a run. For example, the spring salmon migrations in the Cowichan river, Vancouver island, in 1939 and 1942 were estimated to be 58% and 62% jacks respectively. The run of sockeye salmon to Babine lake, Skeena river, in 1947 (ca. 523,000) was 48% jacks. Fishermen and canners frequently ask: "Are jacks capable of fertilizing eggs?" and "Is the jack condition hereditary?". An experiment which was undertaken by Mr. Ferris Neave and Dr. G. C. Carl at the Cowichan Lake Hatchery several years ago was designed to answer these questions.

The species used was the coho. Eggs taken from female fish (3 years old) in December 1938 were divided into two lots, one lot being fertilized with milt from full-sized males (3 years), the other with milt from jacks (2 years). The eggs were incubated and the fry raised under similar conditions in the hatchery troughs and ponds. In October 1939 the surviving fingerlings from the two lots were marked in different ways and liberated in the Cowichan river. The adipose and both ventral fins were removed from the offspring of the three-year-old males and the adipose and dorsal fins from the progeny of the jack males. The young fish were expected to go to sea in the spring of 1940. Those developing into jacks would of course return to fresh water in the autumn of 1940. Fish caught in the sea in 1941 or in fresh water in the fall of that year would be regarded as "normal" three-year fish.

The following table shows the number of fingerlings originally released and the numbers which were subsequently recovered as jacks and as third-year fish.

|                                                      | Offspring of    |            |
|------------------------------------------------------|-----------------|------------|
|                                                      | 3-year<br>males | jack males |
| Number released.....                                 | 23,544          | 8,567      |
| Number recovered in fresh water as jacks (1940)..... | 6               | 3          |
| Number recovered as third-year fish (1941).....      | 31              | 10         |

That jacks are capable of fertilizing the eggs of normal females is of course definitely established by the fact that fry, jacks and normal fish resulted from

<sup>1</sup> Senior Biologists, Pacific Biological Station, (Fisheries Research Board of Canada), Nanaimo, B.C.

the experiment. While the number of recorded captures of marked fish were comparatively small, it is evident that both experiments produced some jacks, while in each case a much greater number was recaptured as third-year fish. The difference between the experiments in this regard cannot be considered significant and thus proves beyond a doubt for the coho that jacks do not tend to reproduce their own type.

Recently Dr. Gunnar Alm, the Swedish scientist, has published data pertinent to this problem in the case of the Atlantic salmon, *Salmo salar*. (Befruktnings-försök med Laxungar samt Laxens Biologi före Utvandringen—Fertilization-Experiments with Salmon-Parr—Kungl. Lantbruksstyrelsen. Nr. 22, 1943). Dr. Alm points out that salmon parr often have ripe milt and if such small males could be used for fertilization in hatchery practice, it would remove the disadvantage of considerable costs in catching and handling large individuals and these fish spared from breeding would be available for the market and natural spawning.

Experiments in wooden troughs and ponds were designed to show how the hatching losses, growth, the smolt stage, maturity and sex ratio differed in salmon resulting from eggs of normal females fertilized by (1) male parr and (2) large adult males. The ripe parr gave relatively large quantities of milt and could be "stripped" several times. Losses during hatching and in subsequent development did not differ. The growth did not differ between the two types although there was variation in each due to factors such as volume and supply of water, stock size, food competition, etc. The time of appearance of the smolt stage did not change and in both had the usual connection with growth rate. The slight differences which do appear in the time of attainment of maturity could not be definitely attributed to the differences in the parents. The sex ratios were about the same in both groups. In conclusion Dr. Alm states: "As any real differences between X-salmon and S-salmon cannot be proved, the use of ripe male parr can be recommended".

## DETERIORATION OF RECENTLY ESTABLISHED TROUT POPULATIONS IN LAKES OF THE CANADIAN ROCKIES

BY D. S. RAWSON<sup>1</sup>

When trout are planted in lakes entirely lacking in fish they frequently make rapid growth and reach a large size in the first few years. This is often followed by a sudden deterioration in the quality of the larger fish and later by a more or less complete recovery. After this recovery the average size of the mature fish is usually much smaller than that at the peak of the first few years' growth and some of the large fish remain in poor condition long after the general recovery has taken place.

It appears that this sequence of rapid growth, deterioration and slow recovery has been observed by fish culturists and others in many localities but it has rarely been reported in more than a casual reference. It is therefore desirable to place on record observations from six lakes of the Canadian Rockies examined by the writer in the years 1936 to 1946. Similar deterioration has been reported in a few other lakes of the region which were not visited in the course of the fisheries survey.

### MALIGNE LAKE

Maligne Lake is the largest in the Jasper region, having an area of 8.5 square miles and a maximum depth of 315 feet. Its altitude is 5,460 feet and being fed by adjacent glaciers, it is heavily silted and extremely cold. The general physical and biological characters of this lake have been described by the writer (Rawson, 1942). Stocking was carried on in the years 1928, 1929, and 1931 with large numbers (an average of about 175,000 per year) of eastern brook trout (*Salvelinus fontinalis*) fry. It was formerly barren of fish and the trout developed rapidly providing excellent fishing from 1932 to 1935. The large fish then deteriorated quickly to a low point in 1937 at which time they were severely emaciated. After that time a gradual recovery occurred but the fish were smaller than those of 1933. An account of the experiment up to 1940 has been published by the writer (1940). It was suggested that the difficulty was not the presence of too many fish but of too many large fish, a population of almost uniform size which could not find suitable food and was unable to adjust itself by cannibalism.

The angling in Maligne Lake was negligible from 1940 to 1944 and it has not been possible to keep a regular check on the condition of the population. All the larger fish taken in a test net in August 1942, by W. C. Cable, were in good condition.

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<sup>1</sup> Professor of Biology, University of Saskatchewan, Saskatoon.

### AMETHYST LAKE

Amethyst Lake is about 15 miles southwest of Jasper in the Tonquin Valley. The area of the lake is about two square miles, maximum depth over 79 feet and altitude 6,450 feet. The water is cold and usually clear though temporary silting occurs. It was stocked in 1932 with 46,000 rainbow trout (*Salmo gairdneri*) fry, in 1933 with 83,000 and in 1934 with 96,000. The fish grew well and in a few years were reproducing naturally.

When the lake was studied in September 1939 the larger fish were thin and lacking in vigour. Some of the fish were still in spawning condition and others carried eggs from the previous year. Fish from 13 to 17 inches in length were 30 per cent lighter than rainbow of the same lengths in Paul Lake near Kamloops. The stock used for planting in Amethyst Lake came from the Kamloops district.

In 1939, Mr. W. C. Cable noted delayed spawning and failure to spawn in Amethyst Lake. In September 1940, he reported the fish to be definitely slim, lacking the depth usually found in lake rainbow.

Studies under the writer's supervision in 1946 show almost complete recovery of condition among the larger fish. Spawning is still much delayed but there is evidence of some increase in the proportion of fish which complete spawning early in the short summer. The fish are now in their third generation. They have the size and colour characteristics of the mountain subspecies *Salmo gairdneri whitehousei* described by Dymond (1932). Preliminary examination of the number of scale rows in the lateral line shows an increase over that of typical rainbow and toward that of the mountain form.

### MARVEL LAKE

Marvel Lake is 20 miles south of Banff at an altitude of 5,900 feet near the foot of Mount Assiniboine. Its area is 450 acres and its maximum depth about 220 feet. Its water is clear and cool though the shallow area near the outlet warms considerably at midsummer. It was stocked in 1927 with 8,000 cutthroat trout (*Salmo clarkii*) fry, with 24,000 in 1928, 16,000 in 1929 and 24,000 in 1930. Growth was rapid and many fish reached 20 inches in length and 3 to 4 pounds in weight. Natural reproduction was reported in 1931 and planting was discontinued.

The first evidence of deterioration was reported in 1932, five years after the initial planting. In 1933 many fish were caught and about one-quarter were emaciated and had soft flesh. The number of fish in poor condition increased in 1934 and 1935. In 1936 a large number of fish were examined by the writer. All the larger fish were thin, most of them were 25 per cent below the normal weight of cutthroats of similar length in the Banff area and some of them were less than half the normal weight. One fish 18 inches long weighed only 19 ounces as compared with the average expected weight of 49 ounces. All this time the smaller fish—less than 13 inches and 1 pound

weight, were in good condition. In 1937 some improvement was made and in 1938 a sample of large trout, obtained through the kindness of Erling Strom, Mount Assiniboine Lodge, was mostly in fair condition. A few were thin and one very thin. In 1941 and 1942 two-thirds of the large fish were in good condition. The remainder were thin but most of them edible. A report in 1944 suggests that all fish are in good condition.

Most of the "poor" fish examined in 1936 had ulcers in the stomach, a few had perforated stomach walls. Larvae of the tapeworm *Diphyllbothrium* were numerous in the pyloric region but no special significance is attached to this observation since similar larvae are often found in healthy fish.

#### EGYPT LAKE

Egypt Lake is 16 miles southwest of Banff, near the Redearth Pass at an altitude of 6,600 feet. It is a small lake, 40 acres in area, with a depth of 100 feet and very clear water. It was stocked in 1930 with 24,000 cutthroat trout fry, 16,000 in 1931, 8,000 in 1932 and 16,000 in 1933. There are few reports of the early progress of these fish. On August 16, 1938 the larger specimens, 14 and 15 inches in length, were mostly thin and from 15 to 20 per cent underweight. Many were unspawned and some had their peritoneal ribs loose from the body wall. The lake is lightly fished because of its inaccessibility. In 1943 and 1944 anglers reported the fish to be in good condition.

#### RAINBOW LAKE

Rainbow Lake is 14 miles northwest of Banff and about two miles east of Sawback Lake. It is small, about 15 acres, and more than 40 feet deep. It lies at the high altitude of 7,400 feet in a little travelled area. It was planted in 1937 with 10,000 rainbow trout fry. There are no plantings recorded in the succeeding years. Examined on September 8, 1943 the fish were still small and quite slender. Their lengths ranged from  $7\frac{3}{4}$  to  $9\frac{3}{4}$  inches and their weights from  $2\frac{1}{2}$  to 5 ounces. The weight of the adults was from 10 to 20 per cent less than that of rainbow of the same size at Paul Lake. Scale examinations showed that they were all of one year class, from the original planting in 1937. They were well coloured, showed definite parr marks and were sexually mature although no evidence of spawning or natural fry could be found. The fry were of the typical rainbow stock imported from Troy, Montana but the fish taken from the lake show some characters of the mountain subspecies *Salmo gairdneri whitehousei*, as in the case of Amethyst Lake described above. Fish from Rainbow Lake, however, show no evidence of increase in the number of scale rows. It may be significant that these fish are those of the original stocking and not from the second and third generations as in Amethyst.

TABLE 1

SUMMARY OF PHYSICAL DATA, INITIAL PLANTING AND HISTORY OF DEGENERATION AND RECOVERY OF TROUT IN SIX LAKES OF THE CANADIAN ROCKIES

| Lake                                                                            | Maligne  | Amethyst | Marvel    | Egypt     | Rainbow | Kananaskis |
|---------------------------------------------------------------------------------|----------|----------|-----------|-----------|---------|------------|
| Area, acres.....                                                                | 5,000    | 1,160    | 450       | 40        | 15      | 1,600      |
| Max. depth feet.....                                                            | 315      | 79       | 220       | 100       | 60      | 280        |
| Shoreline miles.....                                                            | 35       | 8.3      | 6         | 1.3       | 0.6     | 9          |
| Altitude feet.....                                                              | 5,460    | 6,450    | 5,900     | 6,600     | 7,400   | 5,550      |
| Initial Stocking—                                                               |          |          |           |           |         |            |
| Year.....                                                                       | 1928     | 1932     | 1927      | 1930      | 1937    | 1935       |
| Species.....                                                                    | E. Brook | Rainbow  | Cutthroat | Cutthroat | Rainbow | Rainbow    |
| Number.....                                                                     | 175,000  | 46,000   | 8,000     | 24,000    | 10,000  | 75,000     |
| Number per acre.....                                                            | 35       | 40       | 18        | 600       | 660     | 47         |
| Number per mile of shoreline.....                                               | 5,000    | 5,500    | 1,300     | 18,500    | 16,500  | 8,300      |
| Years from planting <sup>1</sup> to first record of deterioration.....          | 7        | 5        | 5         | 6         | —       | —          |
| Years from first <sup>1</sup> deterioration to first record of improvement..... | 5        | 3        | 5         | 4         | —       | —          |
| Years from first <sup>1</sup> improvement to recovery or adjustment.....        | 5        | 4        | 6         | 3         | —       | —          |

<sup>1</sup> These figures are only approximations, derived in many cases from reports of wardens and anglers.

#### UPPER KANANASKIS LAKE

The Kananaskis Lakes are 45 miles south of Banff and about 10 miles outside the Banff Park boundary. They are the headwaters of the Kananaskis River which joins the Bow near Seebe. The Upper Lake is large, 2½ square miles, and 280 feet deep. Its elevation is about 5,550 feet but its level is controlled by a high dam as a reserve for power development. It differs from the lakes described above in having one small fish, the long-nosed dace, *Rhinichthys cataractae* prior to its stocking in July 1935.

Planting with rainbow trout was begun in 1935 when 75,000 fry were introduced. In 1936, 95,000 eyed eggs were planted along the shoreline and in 1940 a further planting of 20,000 fry was made. The fry planted in the lake in 1935 had reached lengths of 6 to 9 inches in August 1936. In 1937 fish 14 and 16 inches long and 1 to 2 pounds in weight were caught. In 1938 they were 18 to 20 inches in length and 3½ to 4 pounds in weight. In 1939 some of the four-year-old fish had reached 22 inches and 5 pounds. After this time the rate of growth fell off although some specimens of 8 and 10 pounds have been reported.

Deterioration of some of the larger fish has been reported but we have been unable to obtain details of the number affected and the degree of emaciation.

## COMPARISON OF THE LAKES

As an aid to the comparison and discussion of these lakes Table 1 has been prepared. This table includes physical data, information as to the initial planting and the subsequent development of the trout population.

The physical characters of the lakes vary widely. Their areas range from 15 acres to  $8\frac{1}{2}$  square miles. Most of them are deep, from 40 to 315 feet. They are at high altitudes, 5,460 to 7,400 feet, which accounts for their low water temperatures, usually 10 to 13°C (50-55·5°F) at midsummer. Silting is severe in Maligne, slight in Amethyst and the others are practically clear. Their locations are such as to make them relatively inaccessible and they are therefore only lightly fished.

The biological features of the lakes are somewhat less varied than their physical characters. With the exception of Upper Kananaskis Lake (where *Rhinichthys* was found) they were barren of fish before planting. The bottom organisms of the deeper water are similar in quality and small in quantity in all these lakes. The fish feed mostly on freshwater shrimps and insects (larval and adult) found in the shallow water near shore. Since the lake basins are deep and "U"-shaped in section, the proportion of shallow water is small and the feeding grounds for fish are only a small fraction of the total area. In the clear lakes an abundance of Entomostraca is often important as food for the trout but it is apparently not suitable for the larger fish.

Fish cultural experience in the six lakes follows a general pattern. Growth was rapid in the first three or four years with the fish reaching a large size and showing good condition. A partial exception to this is Rainbow Lake in which the trout were not large but typical in size and colour pattern of the mountain subspecies *Salmo gairdneri whitehousei*. After five or six years some deterioration was apparent in the larger fish. In some lakes this affected most of the fish and developed rapidly. In others it affected smaller numbers. The large fish became emaciated, weighing from 12 to 50 per cent less than "normal" individuals of the same length. In only one location, Marvel Lake, was there any suggestion of pathological conditions. The fish here had ulcer-like erosions of the stomach lining, some with definite perforations of the stomach wall. In most of the lakes extremely low temperatures were associated with delayed spawning and many females failed to spawn, carrying partly resorbed eggs in the next season. The maximum deterioration occurred about nine years after planting in Maligne and Marvel lakes. The recovery varied in rate and extent but was usually nearly complete after four or five years. The average size of mature fish after the population had recovered, was much smaller than that at the peak of development resulting from the first planting.

## THE CAUSE OF DETERIORATION

An explanation of the deterioration in these lakes was proposed earlier in a study of Maligne Lake (Rawson 1940). It was suggested that there were too many large fish present to find suitable food, and since they were of nearly

uniform size the population failed to adjust itself by cannibalism which occurs in most trout populations. The delayed spawning and failure to spawn in several of the lakes may also be considered as a contributing factor in the poor condition of some of the fish. Difficulty in spawning, however, would have the same effect on the population from year to year and would not account for the deterioration and later recovery. In this connection also it should be noted that in Maligne Lake, where severe degeneration occurred, the eastern brook trout is a fall spawning species capable of living and spawning in low temperatures. Also in Marvel Lake where the most severe deterioration took place, there was no evidence of failure to spawn. It is of interest that deterioration occurred in three populations of cutthroat, two of rainbow and one of eastern brook trout.

A similar experience has been reported by P. R. Needham (personal communication, 1945) in Bright Dot Lake of eastern California. Golden trout, one of the rainbow group, were planted in this lake, did well for three years and then deteriorated apparently because of the overpopulation by large fish. Dr. Needham also referred to lakes in Oregon where similar conditions have been encountered.

It should not be inferred that deterioration occurs in trout populations of all barren, high mountain lakes. The experience in Baker Lake 8 miles northeast of Lake Louise, might be contrasted with that in Marvel Lake. Baker Lake is 145 acres in area, 36 feet deep and at the high altitude of 7,330 feet. It was planted in 1931, 1932, and 1933 with cutthroat trout, which grew rapidly and soon reproduced naturally. All fish were fat and in good condition up to 1943. Individuals weighing 3 to 5 pounds were frequently caught. Differences which might account for the absence of deterioration in Baker Lake might be the abundance of the large freshwater shrimp *Gammarus* and the heavier fishing. It is probable that the rich supply of *Gammarus* sustained the large fish until natural reproduction and normal predation (cannibalism) was established.

#### *SUGGESTIONS FOR MANAGEMENT*

The fish cultural procedure which would avoid this deterioration of the large fish would seem to be a graded planting in which a small number of fish would be planted in the first year, a large number in the next and still more in the third year. This might be expected to build up a population with age composition similar to that in a normal population. Such a procedure assumes that overpopulation and severe food competition between the large fish is the cause of their degeneration.

Heavier fishing would also be helpful in reducing the excess of large fish but this is frequently impracticable. The lakes are reached by long trails and most of them can be fished only in a two-day hike or pack-horse trip. In severe cases gill netting of the larger fish would probably be justified. The onset of deterioration soon discourages angling and aggravates the situation. It would therefore be desirable to avoid the overpopulation by the use of graded stocking if this can be done.

The intensity of planting in lakes is commonly expressed in numbers per acre. Mottley in his work on Paul Lake, B.C., prescribed an annual planting of 200 fry per acre and found that with this treatment the lake would provide anglers with from 3 to 12 fish per acre with a total weight of 10 pounds. (Mottley, 1939). It is of interest that Mottley's original estimate of 200,000 fry per year was computed on a basis of 7 miles of shoreline with a highly productive zone 30 feet wide, rather than on the lake area of 1,000 acres. It was indicated above that the deep water of the six high mountain lakes was relatively unproductive and that the shore zone provided most of the insect and amphipod food for the trout. Thus the length of shoreline or better, the area of the productive littoral zone, would be more closely related to the fish carrying capacity of the lake than the total area. This is especially evident in extremely cold, silted lakes such as Lake Louise, Bow Lake in Banff National Park and Maligne Lake in Jasper Park, where the fish are concentrated in shallow water close to shore and are only rarely found in the open water.

In the six lakes under consideration the initial plantings varied from 18 per acre in Marvel to 600 in Egypt and 650 in Rainbow. The last two figures would be obvious overstocking even for more productive lakes at lower altitudes. In the same six lakes the number per mile of shoreline ranged from 1,300 in Marvel to 5,000 in Maligne and 20,000 in Egypt Lake. Mottley's planting in Paul Lake was 30,000 per mile but Paul Lake is warmer and much more productive than these high mountain lakes. The bottom fauna of Paul Lake is more than ten times as heavy as that of Maligne Lake (Rawson, 1942). It is suggested that even the lightest of the plantings in the six lakes was too large and especially so in view of the fact that these were initial plantings in which a high rate of survival might be expected.

The use of graded plantings in barren lakes for the first three years is suggested as a reasonable way to prevent the development of a "top-heavy" population with too many large fish. The basis for such a gradation should be knowledge of the relative numbers in different year classes in normal populations of the same species. Any information as to the predation of older on younger year classes would be helpful and some allowance might be made for the expected intensity of angling. In a preliminary examination of the literature the writer has failed to find any record of the use of graded plantings. Mottley (1940) suggests this procedure for the improvement of lakes in which the normal population was depleted. It would seem to apply more forcibly to lakes planted for the first time.

The scarcity of published data as to the age composition of natural trout populations in lakes formerly barren of fish, suggests that this would be a profitable study. In the absence of such data and of information as to the degree of cannibalism in such lakes we can only suggest a "rule of thumb" gradation based roughly on the known age composition of other fish populations. It is suggested that in barren lakes the ratio of initial to subsequent plantings might be about 1 to 10 to 30. Thus a lake for which a "normal" annual planting might be 30,000 fry, would receive 1,000 in the first year,

10,000 in the second and 30,000 in the third. It is also pointed out that the past plantings in these lakes have tended to be too heavy and that it would be better to plant more sparingly even though the achievement of maximum production might be delayed.

The degeneration of trout populations has a very unfortunate effect on the angling in any district. The fish are poor in appearance, lacking in fight and unsuitable for food. The loss of production for a period of several years in which the fish are unsuitable for angling is also a serious matter.

### SUMMARY

When trout are planted in lakes previously barren of fish they frequently go through stages of rapid growth, sudden deterioration and gradual recovery. This has been observed in six lakes of the Canadian Rockies where rainbow, cutthroat and eastern brook trout have been introduced. It is believed that this difficulty results from overpopulation with large fish and their consequent failure to find suitable food. Since these fish are of nearly uniform size the population is unable to adjust itself by cannibalism. It is suggested that degeneration of this kind might be avoided by making a small initial planting to be followed annually by increased allotments until something resembling a normal population is built up.

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THE ADVERSE EFFECT OF COLD WEATHER UPON THE  
SUCCESSFUL REPRODUCTION OF PICKEREL,  
*STIZOSTEDION VITREUM*, AT HEMING LAKE,  
MANITOBA, IN 1947

BY B. DERBACK<sup>1</sup>

The yellow pickerel or pike perch, *Stizostedion vitreum*, is of great importance in the Prairie Provinces and composes about one-quarter of the total commercial catch. The discovery of the action of various ecological factors affecting pickerel contributes to a better understanding of the management of this fish. The influence of suddenly lowered water temperature upon the success of spawning was apparent at Heming lake, Manitoba, during the spring of 1947.

Heming lake is situated at approximately 54° 53' N. Lat., and 101° 7' W. Long., about 18 miles south of the town of Sherridon. It is 3 miles in length from north to south, from  $\frac{1}{4}$  to  $\frac{1}{2}$  mile in width, and is 588 acres in area. It lies at the headwaters of Grass river which flows into Nelson river at Split lake.

There are 8 main bays with muskeg shores and muck bottom, depths of water up to 6 feet, and with fringes of emergent and considerable submerged vegetation. The remainder of the lake shore is rock and sand, with little aquatic vegetation, and the bottom is mostly inorganic silt covered with decayed organic matter. The water is acid, brownish in colour, and not deeper than 16 feet. The ice broke up on May 27, 1945, and the lake froze over on October 31; in 1946 break-up occurred on May 1, and in 1947 on May 22.

There are two main tributary streams. Heming creek flows in from the south, is marshy, deep, meandering, and arises in a muskeg lake from which fish are blocked by a beaver dam. It is used mostly by spawning jackfish or pike, *Esox lucius*. Northwest creek flows into the northwest corner of Heming lake, and drains a small, shallow lake about  $\frac{1}{4}$  mile distant. A 5-foot beaver dam offers a barrier to the passage of fish where the creek leaves the upper lake. The bottom of Northwest creek is hard, with many stones, and a rapids occurs midway its course. The maximum depth of water in the spring of 1947 was 3 feet, and the rate of flow varied from 0.9 to 4.5 miles per hour. This stream is used mostly by spawning pickerel and suckers, *Catostomus commersonnii*. There are a few other creeks entering Heming lake but they arise in muskeg, and are too small for the passage of fish.

The outlet of the lake, towards the northeast, is about 35 feet in width where it leaves the lake. Former pickerel spawning areas at the outlet have been flooded by the erection of a new beaver dam below, and fish are prevented entry to or exit from Heming lake.

<sup>1</sup> Senior Research Assistant (seasonal), Central Fisheries Research Station (Fisheries Research Board of Canada), Winnipeg, Man.

Hoop nets were set in the mouths of Heming and Northwest creeks on May 10. Pickerel first moved into these creeks on May 14 and 15, respectively. Although no immature pickerel were found to enter these streams, not all of the fish were ready for spawning. The first female pickerel were only mature, and the ripe individuals appeared at Heming creek on May 15 and at Northwest creek on May 20. The males were ripe at their first appearance.

On observing the fish in Northwest creek in the morning and afternoon they were found to be resting in protected bays or behind rocks in the rapids. Random samples of pickerel taken on different days from both creeks, captured by net and by hand, showed a ratio of 4 males to 1 female, and this proportion was general throughout the spawning period.

The first spent female was taken May 19 in Heming creek, and next day pickerel eggs had been deposited in Northwest creek indicating that spawning was in progress. On May 23, in the latter stream, pickerel were observed in the rapids towards evening, and as it became darker a light was used to facilitate seeing the fish; however, they became disturbed.

There seemed to be a correlation between spawning activity and water temperature. A recording thermometer was set in the mouth of Northwest creek, and on May 16 the water temperature was 42° F. The beaver dam at the outlet of the lake above was washed out the following day, the instrument was flooded, and was not reset until May 20. On this date the temperature was 43°, and the first pickerel eggs were observed. A period of cold weather set in on May 25, and lasted until June 1. The water temperature had dropped to 41° by May 28. Thus it was found that 43° was the favourable temperature for pickerel spawning in Northwest creek in 1947.

The pickerel eggs were round and had a diameter of 1.5 to 1.7 mm., as compared with the much larger sucker eggs. When first fertilized they were translucent and slightly pinkish, but when not fertilized they became opaque and grey. They were found imbedded in loose organic material and in the submerged dead grass along the stream, below the rapids, and beneath the sucker eggs that were deposited in the same stream.

At the onset of cold weather on May 25 the pickerel moved out of Northwest creek, back to Heming lake. No fish returned to the creek by June 5, even though the water had warmed up again. It appeared that spawning had not been completed, nor was it resumed. Subsequent fishing in June in deeper waters of the lake yielded some female fish that were reabsorbing their eggs. Also, the cold weather resulted in a very poor hatch of pickerel; so poor, in fact, that repeated seining in July and August failed to reveal a single young fish in localities where they had been caught in previous years.

These observations have been presented as an example of the narrow range of optimum conditions—temperature, in this instance—required to successfully accomplish spawning, and of a failure in one season's reproduction owing to unfavourable natural circumstances.

## BOOK REVIEWS

Fish Production in Lakes as a Guide for Estimating Production in Proposed Reservoirs. By George A. Rounsefell. *Copeia*, 1946, No. 1, April 30.

REVIEW BY R. E. FOERSTER<sup>1</sup>

In an attempt to determine the probable fish-producing capacities of artificial reservoirs being constructed for water-power, water storage, flood control, etc., purposes in various parts of the United States, a comprehensive analysis was made of the available information on fish productivity in lakes in the United States and Canada. A very complete bibliography is given which should be of great value to fish-culturists and fisheries biologists.

In summarizing the information available on total production and/or annual yield it is stated that

"The most obvious characteristic of the yields is the rapid decline in production per acre as the lakes increase in size. The optimistic production estimates of most fishery experts are not borne out; but it is believed that this is owing largely to the fact that such opinions have been based on the production of very small ponds. For instance, the total population falls from 268.5 pounds in ponds of one acre to only 32.3 pounds in lakes of 200 acres. . . .

"The yield per acre of lake is probably correlated with the relative area of fertile shallow water, which is generally much less in proportion to total area in the larger lakes than in the smaller ones, as indicated by the difference in length of shoreline.

"There are various reasons for variation in the yield of lakes of similar size. Some of these differences are related to the physical and chemical conditions of the lake itself, such as depth, temperature, heat budget, and the quantities of various nutrient materials available. Others relate to the populations of fish and other organisms present."

Reference is made to sockeye salmon production records obtained by the Fisheries Research Board of Canada, where when certain predator control experiments were undertaken the removal of the competing and predator species raised the level of maximum productivity very considerably.

Conditions in artificial reservoirs differ in many respects from natural lakes. The water levels are more subject to frequent and extensive fluctuation, the bottoms are more likely to be covered with heavy layers of silt, the deep water usually is confined to one end, causing unnatural temperature stratification. All of these features tend to make the reservoir less productive than natural bodies of water. It seems that only by stocking certain reservoirs and following closely the records of total production or annual yield can reasonably accurate information be obtained for general application.

<sup>1</sup> Director, Pacific Biological Station (Fisheries Research Board of Canada), Nanaimo, B.C.

The problem is likely to be of some significance in the Prairie Provinces of Canada and in British Columbia where storage reservoirs may be built in the near future. If they can be made attractive to the angler or profitable to the commercial fisherman it will be highly advantageous.

#### REVIEW BY A. L. PRITCHARD<sup>1</sup>

Undersökningar över Tillväxt M. M. hos Olika Laxöringformer (Investigations on Growth etc., by Different Forms of Trout) by Gunnar Alm. Kungl. Lantbruksstyrelsen, Meddelanden från Statens undersöknings- och försöksanstalt för sötvattensfisket, N: r 15, 1939—93 pages, 27 text figures, 21 tables and 6 plates, Pr. Kr. 2.50. English summary.

This paper by Dr. Gunnar Alm should be of particular interest to all fish-culturists since it presents data on the possible effects of heredity and environment in determining the characteristics of the several forms of *Salmo trutta* in Swedish waters.

Two varieties are considered in particular, viz.—the large lake trout, *Salmo trutta lacustris* or *ferox*, of the big European lakes, and the small river trout, *Salmo trutta fario*, indigenous to small forest and mountain brooks. The former often attains a weight of 3 to 5 kg., and occasionally as much as 10 to 15 kg. It is silvery with black spots, except at spawning time, and often moves about from place to place. The river trout seldom reaches more than 20 to 30 cm. in length, is brownish green with black and red spots and black and white fin margins, and is of a very stationary nature.

The growth of the river trout is admittedly poor in the home brooks, but when the fish are transferred to other areas, they grow well reaching as much as 40 cm. in length. Fry reared from eggs and transplanted also show similar increased growth. This form, however, apparently does not have the same latent power of growth as the lake trout because, if the progeny of each are reared in the same environment, the river trout will always be smaller. This demonstrates that growth is primarily conditioned by environment (phenotypical in nature) but that genotypical factors are also operative.

Under the conditions of the Swedish experiments, it appears that the nature and relative abundance of the food and the hydrogen ion concentration of the water may be disregarded as factors causing the change in growth. The ponds used had abundant food perhaps better than in the lakes, yet the best growth took place in the lakes. There was, however, no lack of nutriment in any of the three environments investigated, namely, brook, pond and lake. The pH value of the water was 7.3 in the river, about 7.0 in the ponds, and less in the lakes. No connection of importance could be demonstrated between this variation and changes in growth.

The size of the ova may have an effect in the first year but the fish from the small eggs (river trout) will soon grow to practically the same size as those from the large ones (lake trout).

<sup>1</sup> Senior Biologist, Pacific Biological Station (Fisheries Research Board of Canada), Nanaimo, B.C.

One cause for difference in growth and size is the spawning. Early sexual maturity and annual deposition of eggs reduces both.

The length of the growing period and the availability of space exert some control. The most favorable temperature for growth of these trout is 16°C. or 17° C. This is rarely encountered in brooks for any extended period of time. The space factor is important. In Norrbäcken, the river under examination, based on catch estimates, there ought to be in the neighbourhood of 16,600 river trout or 1.3 per sq. m. In the ponds, there were from 0.3 to 3 fish per sq. m. (in the latter case only fry), and in spite of abundant food, growth was invariably better when they were less heavily stocked. In the lakes, where the area per fish was undoubtedly much greater, the fish were considerably larger.

Difference in size of trout in different localities should thus be considered as primarily due to environmental factors. Since, however, river trout mature earlier sexually, and since they stop growing sooner than do lake trout reared under the same conditions, hereditary factors must also play a part. Such things as varying numbers of vertebrae and other differences which are given, indicate that the different populations of trout may logically be regarded as different forms even though their growth is mainly governed by environment. It is not impossible, however, that the racial characteristics now demonstrated may be changed. The present experiments may provide better data for a discussion of the problem.

#### REVIEW BY D. J. MILNE<sup>1</sup>

Reasons for the Occurrence of Stunted Fish Populations with Special Regard to the Perch (Uppkomsten av Småväxta Fiskbestånd Speciellt hos Aborre) by Gunnar Alm. Kungl. Lantbruksstyrelsen, Meddelanden från Statens undersöknings- och försöksanstalt för sötvattenfisket, Nr 25, Stockholm 1946, 146 pages, 23 figures, and 32 tables. Pr. Kr. 3:.. Text in English with summary in Swedish.

This paper includes a comprehensive review of the work done on the native perch populations in approximately thirty Swedish lakes as well as the results of numerous marking and transplanting experiments conducted during the past fifteen years. The primary objective has been to discover the reason for the stunted populations so that recommendations can be made to permit increasing their growth and, hence, their economic use.

Perch occur in both large-sized and stunted populations, the former being typical of the larger lakes examined while the latter are taken mainly in small lakes and tarns. The females grow more and mature later than the males especially after the second or third year of life so that in any one population, a higher percentage of the larger fish are females and of the smaller, males. The actual sex ratio was found to be about equal, but, due to these and other differences, more males are commonly found in the spawning runs. Individuals in the large-sized populations usually have a greater relative weight at any given length and live to an older age than those in the stunted varieties.

<sup>1</sup> Assistant Biologist, Pacific Biological Station (Fisheries Research Board of Canada), Nanaimo, B.C.

Growth in the stunted populations may be fairly good during the first few years only to decrease rapidly and soon cease altogether without necessarily involving death. The reason for this may be either that the population has become too large for the food supply so that the fish remain small and feed on plankton and insect larvae with only a few attaining the size at which they can take small fish to stimulate better growth, or that the environment is unsuitable due to conditions of low temperature limiting the food supplies. The numbers in a year class vary considerably and may sometimes affect the average size of the population.

In the ponds, growth is inversely proportional to the density of the population and directly proportional to the area and water volume. Thus the corrective procedure for stunted populations is to reduce the numbers by fishing or, if the perch are of small size, to try planting predators such as pike and trout. When this is done, the growth and individual size are increased with more perch becoming fish eaters except under conditions of very unfavourable environment.

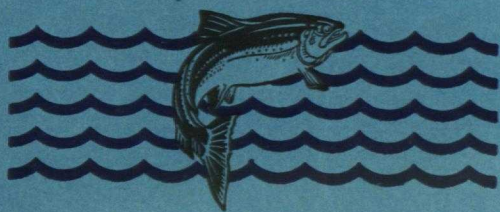
No hereditary bad growth was demonstrable but there are marked individual variations in growth which persist throughout life. Even though all stunted perch, when transplanted to ponds with a more favourable environment, show growth similar to those from the large-sized populations, the best individuals for planting are those in any population which grow best and mature earliest. All perch remain stunted in small dystrophic tarns or quagmires. Apparently therefore the environmental effect overshadows the genetic.

In the same population sexual maturity sets in at a low age for individuals with very good growth but at a higher age for those with poorer growth, and yet the length of the latter may be less than that of the former. In any stunted population reacting to an unfavourable environment maturity appears to occur at a low age.

On the basis of the above work as well as other published studies, the author discusses at length the relationship between environment, heredity, growth, size and sexual maturity.

OTTAWA  
EDMOND CLOUTIER, C.M.G., B.A., L.Ph.,  
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1948

# The Canadian Fish Culturist



A Department of Fisheries Publication

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*A Bulletin of Information and Opinion  
as to Fish Culture in Canada*

VOLUME III

AUGUST  
1948

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Requests for earlier issues of the Canadian Fish Culturist continue to be received. A limited number of copies of the issue for December, 1947, remain on hand and distributions will be made on request until the supply runs out. However, no copies of the issues for November, 1946 and June, 1947 are now available.

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# The Canadian Fish Culturist

*A Department of Fisheries Publication*

*A Bulletin of Information and Opinion  
as to Fish Culture in Canada*

VOLUME III

AUGUST  
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No. 4

## **New Chief of Fish Culture Development**

A contributor to the Canadian Fish Culturist and regarded an authority on British Columbia salmon, Dr. Andrew Lyle Pritchard, has recently been appointed Director of Fish Culture Development in the Department of Fisheries.

Leaving his post of Senior Biologist at the Pacific Fisheries Biological Station at Nanaimo, B.C., Dr. Pritchard comes to Fish Culture Development at a time when its activities are expanded and his duties as Director of Fish Culture Development have been enlarged in comparison to those of his predecessor, J. A. Rodd, who retired a few months ago. In addition to being responsible for administration, production and distribution of the fish hatchery stocks, and the development of cultural practice to make the fisheries more effective in commercial operation and sport fishing, Dr. Pritchard is charged with developing and administering methods of river management, fertilization of waters, control of pollution and fish predators, and control of water obstructions.

Dr. Pritchard has been with the Fisheries Research Board of Canada since 1928. An important part of his work has been his intensive research in connection with the British Columbia salmon species and he has written many scientific papers on his findings. Recently he has been in charge of the Board's Skeena River salmon investigation.

## Improved Trout Angling in a Small Lake After Poisoning Undesirable Fish

by

**M. W. Smith**

*Biologist, Atlantic Biological Station, (Fisheries Research Board of Canada)  
St. Andrews, N.B.*

Not infrequently in Maritime lakes, speckled trout populations, under an increasing angling pressure, decline and undesirable species become dominant. Attempts have been made to restore such lakes as suitable trout habitats by poisoning the competitors and predators of trout. Rotenone, as contained in derris or cubé powders, is an effective fish poison at low concentrations, at which its action is quite selective against fish, while most aquatic invertebrate animals remain unaffected. In the stratified waters of Potter's lake, New Brunswick, where control of undesirable fish by poisoning with derris was attempted by the writer, it was found that an almost complete kill of fish was realized, but, presumably as a result of an inadequate mixing of the poison, a few fish survived, and with reduced competition and predation the progeny of these, especially the yellow perch, soon re-populated the lake. On the other hand, Catt and Needler (1946) report a complete kill of coarse fish, principally yellow perch, by poisoning with derris the unstratified waters of MacFadden's lake, New Brunswick, and the restoration, after stocking, of an abundant trout population. To demonstrate further the utility, under favourable conditions, of poisoning undesirable fish as a method of improving trout angling, results obtained after the treatment of Bill's lake, Charlotte county, New Brunswick, with derris are herein described, together with a brief description of the lake and the fish population.

### Some Characteristics of Bill's Lake

Certain morphological features of the lake are as follows:

|                 |                                   |
|-----------------|-----------------------------------|
| Area.....       | 4.2 ha. (10.5 acres)              |
| Volume.....     | 38,570 cu. m. (1,362,000 cu. ft.) |
| Maximum depth   | 3.0 m. (9.8 ft.)                  |
| Mean depth..... | 0.9 m. (3.0 ft.)                  |

Bill's lake is a small body of water, biologically aged, and rapidly approaching senescence. Rooted aquatic vegetation has encroached over much of the lake bottom. The drainage basin covers about a square mile (2.6 sq. km.) and the outlet, after a run of a mile (1.6 km.), empties into Passamaquoddy bay. Drainage from springs is apparently sufficient to moderate the summer temperature of the deeper water, which otherwise would probably be unfavourable for speckled trout. In about a third of the area of the lake, the waters become stratified in summer although the maximum depth is only 3 metres, and some diminution of the dissolved oxygen content occurs near the bottom. Hydrographical data are given in Table I.

Table I. Hydrographical Data for Bill's Lake

| Depth<br>(metres)    | Temperature (°C.) |       | Dissolved Oxygen<br>(ml. per litre) |      | pH value |     |
|----------------------|-------------------|-------|-------------------------------------|------|----------|-----|
|                      | a*                | b*    | a                                   | b    | a        | b   |
| In lake              |                   |       |                                     |      |          |     |
| 0.....               | 25.1              | 15.65 | 5.24                                | 5.00 | 6.8      | 6.6 |
| 0.5.....             | 23.1              | —     | —                                   | —    | —        | —   |
| 1.0.....             | 18.25             | 15.45 | —                                   | 4.99 | —        | —   |
| 1.5.....             | 16.0              | 15.35 | 5.12                                | —    | —        | —   |
| 2.0.....             | 14.65             | 14.3  | —                                   | 4.99 | —        | —   |
| 2.75.....            | 12.8              | 13.7  | 3.88                                | —    | 6.2      | 6.6 |
| Bog Inlet.....       | 8.7               | —     | —                                   | —    | 5.4      | —   |
| Shore Spring I.....  | 8.8               | —     | —                                   | —    | 6.0      | —   |
| Shore Spring II..... | 6.45              | —     | —                                   | —    | 5.6      | —   |
| Bottom Spring        |                   |       |                                     |      |          |     |
| 0.8.....             | 8.65              | —     | —                                   | —    | —        | —   |

\*a—June 21, 1938; b—September 7, 1938.

### Treatment with Derris Powder

On June 16, 1938, Bill's lake was treated with 21½ lbs. of derris powder, containing 5% rotenone, which was sufficient to give a concentration of 0.25 parts per million. To assess the effectiveness of this low concentration in killing fish under natural conditions, the lake was again treated on September 8, 1938, with the highly lethal concentration of 1 p.p.m. In the interim, the outlet was screened to prevent upward movements of fish into the lake.

Distribution was made principally by towing derris powder in a gunny sack behind a row boat. Kneading was necessary to expel the powder from the sack. By weighting and moving a sack containing derris up and down an attempt was made to insure distribution at all levels in the deeper water.

### Standing Crop of Fish

The poisoning revealed the presence of the following species of fish: *Salvelinus fontinalis* (brook trout); *Couesius plumbeus* (lake chub); *Anguilla bostoniensis* (eel); *Pungitius pungitius* (nine-spined stickleback). A careful collection and enumeration of the dead fish, with the exception of the sticklebacks, was made after each treatment. The following numbers should be considered as minimal, however, since it is improbable that all the dead fish were collected.

|                             | Trout | Chub | Eel   | Stickleback |
|-----------------------------|-------|------|-------|-------------|
| After first treatment.....  | 3     | 656  | 2,042 | numerous    |
| After second treatment..... | 0     | 5    | 204   | few         |

As applied under the conditions obtaining in Bill's lake, 0.25 p.p.m. was not a sufficiently high concentration of derris to give a complete kill of fish.

Samples of eels (721) and chub (508) were preserved and subsequently measured and weighed. Assuming these samples to be representative, standing crops of 0.8 lb. of chub and 70.8 lbs. of eels per acre were calculated. The total standing crop of fish was considerably higher than the average of 22 lbs.

per acre (17 to 35 lbs.) recorded for five other lakes lying in regions of New Brunswick and Nova Scotia with similar rock formations and soils (Smith, 1938, 1940, 1941). The higher level of productivity in Bill's lake may well reflect its more advanced biological age.

### Trout Angling

As learned from local sportsmen, Bill's lake provided moderately good trout angling in the past. The catch declined, however, in the late twenties to the point where improvement was attempted by stocking (1928, 1930, 1931 and 1932 with 10,000, 5,000, 10,000 and 5,000 No. 1 fingerlings respectively, and with 100 and 262 old trout in 1930 and 1931—Rodd (1928, 1930, 1931, 1932)). No lasting improvement resulted, for during the years immediately prior to 1938 little angling was done in Bill's lake because, as locally stated, few, if any, trout could be caught. It was largely on this information that Bill's lake was selected for toxicity tests, since it was not desired to destroy an appreciable population of trout. The poisoning in 1938 revealed only three trout, but at least 2,246 eels which may be considered both competitors and predators of the former species.

Following the poisoning the lake was not stocked with trout, nor is it known to have been fished until 1942. In May of that year two anglers caught six trout 6 to 7 inches long. Apparently the lake was becoming restocked, during a period of little angling and before the re-establishment of a dominant eel population, from a reservoir of small trout which populate the outlet. (It would appear that the small outflow of water from the lake when poisoned did not result in a toxicity sufficient to destroy the fish in the outlet stream). On April 26, 1944, an angler took 17 trout in one and one-half hours of fishing. These trout averaged 11.0 inches (27.9 cm.) in total length and 0.4 lb. (181 gm.). As a result angling increased, and there are definite records of 132 trout being caught in 1944, or a yield of 5.3 lb. of trout per acre (5.9 kgm. per hectare) if the above catch may be considered representative. For comparison, the annual yield of trout to anglers from eight larger neighbouring lakes, biologically less aged than Bill's, has been in average 0.7 lb. of trout per acre (Smith, 1946). There are records of 42, 35 and 12 trout being taken in 1945, 1946 and 1947 respectively. No formal creel census was maintained on the lake, and a complete record of the number of trout angled was not secured. From the evidence at hand, however, it is indicated that the trout population is declining. Eels are now present in the lake (entering as elvers from the sea), and it would not be surprising if the conditions that existed in 1938 will soon obtain again in Bill's lake, since here the eels apparently find a very favourable environment.

### Comment

It is concluded that the destruction of eels in Bill's lake by poisoning with derris powder resulted in the re-population of the lake with trout from a stock in the outlet stream. Since it is difficult to prevent the migration of young eels into a lake, repeated treatment with poison would probably be

necessary for continued control of this species. However, the results argue for the effectiveness of the poisoning procedure as a means of destroying fish inimical to trout, and point to more permanent control when dealing with species whose re-entry into a lake is more easily prevented than in the case of the eel (cf. Catt and Needler, 1946).

Difficulty has been experienced in successfully treating lakes with stratified waters. Nevertheless, poisoning unwanted fish has sufficient merit as a fish-cultural procedure to warrant additional investigation into techniques of obtaining a proper distribution of poison in such waters. In any case, it is to be appreciated that the resultant improvement in trout angling is dependent upon the productive capacity of the lake.

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# Black Spot Disease of Bass

## PART II. SNAIL HOST OF UVULIFER AMBLOPLITIS<sup>1</sup>

by

**François de S. Lachance**

*Junior Research Assistant (now Medical Entomologist Colonial Service, Nigeria)*

As was shown in the first paper of this series (10), black spot disease in bass is widely distributed throughout the lakes of the Province of Quebec, and has been recorded from 32 of the 65 lakes and streams investigated. "Black spot" in bass in Quebec is caused by the metacercarial or infective stage of *Uvulifer ambloplitis*, a trematode which lives as adult in the belted kingfisher. The bird becomes infected by feeding on the black spotted fish. The adult parasite lays minute eggs, which pass into water in the bird's excreta and there, after a complicated development in certain species of snails, give rise to motile organisms called Cercariae which attack the fish, become encysted in them, and give rise to black spots. These cercariae were originally described elsewhere as *Cercaria bessiae*.

During the fall and winter of 1945-46 an endeavour was made to discover what species of snails found in the Quebec lakes and streams could act as intermediate hosts for this parasite, as well as to study the development of the metacercaria.

### Technique

Weed-inhabiting snails were collected from as many lakes and streams in the Eastern Townships and Laurentian Mountain areas as feasible, by sweeping a net through the aquatic vegetation. This net consisted of an open box, about six inches deep, cut from ordinary fly-screen netting, inserted into a rectangular frame, eight inches wide by 18 inches long, with a five-foot rod as a handle. However, ramshorn snails of the genus *Helisoma* (Fig. 1), being fairly large and not in the habit of congregating in one spot in numbers had to be collected by hand.

In the laboratory the snails were placed, two or three at a time, in a half-pint milk bottle and examined by a hand lens twice daily, in the morning and at night. Whenever cercariae were present, they could be seen suspended in the water, head downward with the furcae of the tail spread widely (Fig. 4). After tentative identification of cercariae in the water had been made by this method, a check was made by microscopical examination. All morphological observations were made on living material, both stained and unstained. Several intra-vitam stains were tried. The best of these were those used by Talbot (13) for the study of schistosome cercariae. The cercariae were first stained with very dilute neutral-red for about five minutes, then two or three

<sup>1</sup>Contribution from the Institute of Parasitology, Macdonald College, McGill University, with financial assistance from the National Research Council. Part I was published in *The Canadian Fish Culturist*—June 1947.

drops of Nile blue were added. Due to the rapid penetration of the Nile blue they were ready for study within a few minutes. In some instances, they were stained in neutral red followed by orange G. This stain was found more useful in staining the excretory system. Aqueous mounts of intravital stained cercariae can be preserved for a considerable length of time if the cover glass is surrounded by a film of melted vaseline or glycerine jelly to prevent evaporation of the water.

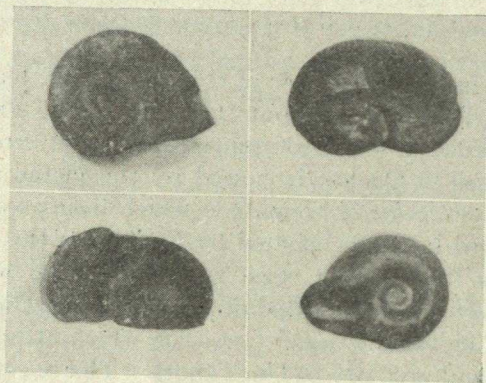


FIG. 1—*Helisoma anceps*, the natural intermediate host of *Uvulifer ambloplitis* in Quebec.

Measurements of cercariae were made with dead specimens, due to the fact that live cercariae have too great a power of extension and contraction. The best method of killing the cercariae was to place the water containing the cercariae in a small glass bowl, and to add an equal amount of boiling ten per cent formalin, pouring the latter in quickly. By this means very few specimens were distorted.

Two methods were used for obtaining metacercariae free from their cysts in infected fish. The first method consisted of placing the flesh of the infected specimen in artificial digestion fluid containing 5 grams Pepsin and 7 cc. of HCL per litre of normal saline. Usually a few hours at 40°C. were found to be sufficient to free the metacercariae which were found at the bottom of the container. The second method was a mechanical one, the cyst being removed from the fish tissue with a pair of fine forceps and placed on a microscope slide with a drop or two of water. A cover slip was then placed lightly over the living larval trematode and the temporary mount was ready for study. Studies were made on both stained and unstained, living and dead specimens.

Intra-vitam stains, as used in the study of the cercariae, were not found to be more useful or efficient than unstained live material. Permanent stains, e.g. Gower's alum-carmin, however, were found to be useful.

All drawings of cercariae and metacercariae were made with the aid of a camera lucida, but the detail drawing of the cercariae (Fig. 3) is a diagrammatic representation of the interpretations of the different structures from the studies of the large series of specimens used.

## Snails Collected and Examined

The following species of snails (15) were examined for cercarial infection:—

*Helisoma trivolvis macrostomum* (Whiteaves)

*H. campanulatum* (Say)

*H. anceps latchfordi* (Pilsbry)

*Amnicola limosa*

*Lymnaea stagnalis*

*Bythinia tentaculata*

*Physa* sp.

The snails were collected in from a few inches to about three foot of water. The majority were located on muddy bottom and were usually covered with dead organic material. Very few lived on rocks, aquatic plants and rotten logs; this is particularly true of the genus *Helisoma*.

The snails were identified by Mr. A. LaRocque of the Geological Survey, Ottawa. In this survey, *H. anceps latchfordi* was found in Wilson's lake (lac LaPêche) in the Gatineau district, and Mr. LaRocque notes that this is a new locality for this species.

Five species of snails were found to be infected with cercariae as follows:—

(a) *H. trivolvis macrostomum* infected with a furcocercous cercaria identified as *Cercaria wardi* (11).

(b) *H. anceps* infected with *Xiphidiocercaria* sp.

(c) Several snails belonging to the genus *Physa* sp., infected with a furcocercous cercaria identified as *Cercaria douglasi* (1).

(d) *Limnaea stagnalis* infected with an unidentified furcocercous cercaria.

(e) *Bythinia tentaculata* infected with an unidentified cercaria.

*Helisoma anceps* was the only snail found infected with the black spot cercaria (= *C. bessiae*). The percentage of cercariae in the snails collected was only 0.4 per cent. This species of snail has not been recorded previously as a host for this parasite.

In spite of the fact that *Helisoma anceps* was the only snail found infected in nature with the cercaria of *U. ambloplitis* in the province, and that *H. trivolvis* and *H. campanulatum*, the naturally infected hosts in the United States were found free from infection, there is still a possibility that the latter two may carry the disease in nature here. Several thousand *Helisoma* snails were examined during the present survey, but many thousands more need to be collected from a wide area over a long period of time and examined for the presence of escaping cercariae. This area should include both the Eastern Townships and the Laurentians.

## Morphology and Behaviour of the Cercaria

This is a holostome cercaria without a ventral sucker and with unpigmented eye spots; body about the same width as tail stem and bent ventrally when hanging at rest in the water (Fig. 4); digestive system very rudimentary; penetration glands six in number; tail-stem without caudal bodies; body spines on first third of the body; genital primordium large in size (Fig. 3).

The cercariae can be seen suspended in the water, head downward. In this position, the furcae or tail branches are held at a slightly obtuse angle to the tail-stem, the tail-stem itself very much like a closed finger (Fig. 4).

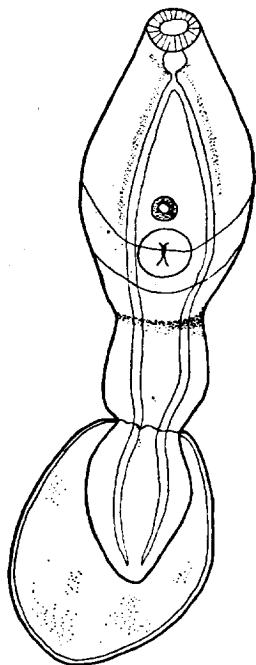


FIG. 2—Metacercaria of *Uvulifer ambloplitis* escaping from its cyst.

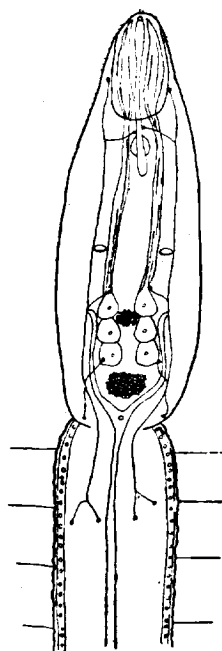


FIG. 3—Cercaria of *Uvulifer ambloplitis* showing internal anatomy of body and part of tail-stem.

After the free suspended cercariae have remained motionless for a while, they become suddenly active and move quickly upward for a short distance, until they regain their original position. They always move backward with the spiral wriggling movement characteristic of the holostome cercariae.

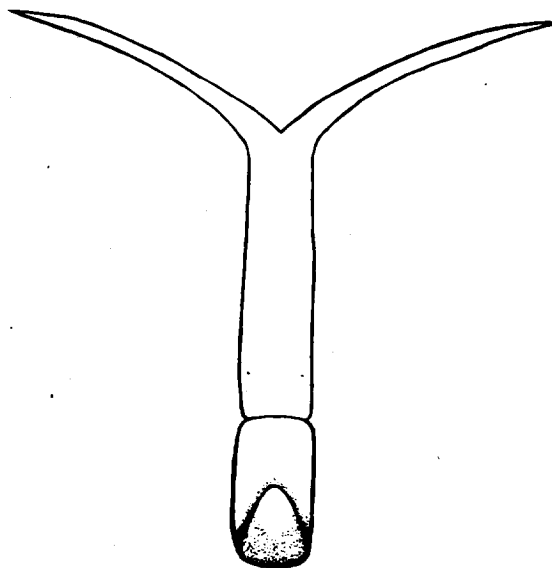


FIG. 4—Cercaria of *Uvulifer ambloplitis* hanging at rest in water. Note that the fore-body is bent ventrally upon itself.

### Infection Experiments and Results

Five species of fish were exposed to infection with the cercaria of *U. ambloplitis*.

- (1) *Ambloplitis rupestris*—rock bass.
- (2) *Lepomis gibbosus*—common sunfish.
- (3) *Simotilus atromaculatus*—horned dace.
- (4) *Catostomus catostomus*—white sucker.
- (5) *Lebistes reticulatus*—guppy.

The cercariae used in these experiments were obtained from snails collected in stream No. 2, one-and-three-quarter miles east of Foster, Quebec.

Because the rock bass and sunfish were collected in the Ottawa River, they were kept in the laboratory for three weeks before being exposed to infection to ensure that they did not carry a natural infection and to acclimatize them to laboratory conditions. The white suckers, horned dace and guppies had been in the laboratory for two years. Five rock bass, two sunfish, and a large number of white suckers, horned dace and guppies were used as controls.

The methods and times of exposure in carrying out the experimental infections with the species of fish mentioned above, were quite varied, so that each experiment requires individual description. Newly emerged cercariae

were used in all the experiments; the water was kept at a temperature varying between 18 and 22°C., except for two days when the temperature dropped to 16°C. The pH of the water in which the snails were kept was at all times exactly the same as the water in which the experimental fish were kept.

Three rock bass were placed in water with varying numbers of cercariae. The first one was exposed to about 300 cercariae for eight hours, the second to several hundred cercariae for 11 hours, and the third for 24 hours. This procedure was repeated three times at one-day intervals.

A sunfish was exposed to infection in the same manner as the third rock bass.

In these experiments the fish became very excited and showed great nervousness. They moved by quick and sudden jumps and spurts, rubbing their body on the sides and bottom of the aquarium. However, after about an hour they became quiet, remaining in one corner of the tank near the surface of the water, but each time the writer approached the tank during the infection period the fish began their characteristic movements.

Another rock bass was exposed by placing it and the cercariae in 60 cc. of water. Using the binocular dissecting microscope, with a 16x magnification, the penetration of the cercariae was observed. This fish was exposed to infection for 60 minutes, then removed to its original aquarium. This procedure was repeated four times in two days.

The cercariae were seen penetrating under the scales of the fish, but it was very difficult to observe which part of the fish they penetrated most frequently. This difficulty could hardly be overcome, due to the fact that the fish was in almost constant motion. However, the cercariae were seen to throw off their tails within two minutes of coming in contact with the fish. The actual time they took to penetrate the fish and disappear from view, after throwing off their tails, could not be ascertained, partly due to the fact that the cercariae do not attack the fish simultaneously.

Four sunfish were exposed to infection on different occasions in the same manner as the rock bass mentioned above. The penetration of the cercariae could not be observed because there was too much debris introduced in the small aquarium with the cercariae. After 40 minutes the fish were removed and the water containing the cercariae in which the fish had been exposed was examined under the low power of a compound dissecting microscope. A few tail-less cercariae were present, crawling on the bottom of the small aquarium; many tails, however, were seen floating about in the water. Among the tail-less cercariae on the bottom were several which were degenerating quickly. It is interesting to note that not one complete cercaria was noticed.

On the 18th and 19th days after the initial penetration of the cercariae in all the experiments mentioned above, some very small whitish spots could be seen on the rock bass and the sunfish, particularly at the base of the caudal fin, which was later found to be the most heavily infected part of the fish. On the following days, these whitish areas were seen more easily, being larger and numerous. On the 22nd and 23rd days, very dimly pigmented black spots were observed in these areas; these black spots increased in size and

number from day to day, and by the 28th and 29th days, they were quite large and obvious. These results confirm the findings of Krull (9) and Hunter and Hunter (5, 6), who reported that the fully developed cysts appear in about three weeks if the organisms are kept at a temperature of between 18 and 21°C. Black pigment-bearing cells appear in the loose connective tissue of the outer coat sometime during the third week.

The location of the cyst in the experimentally infected fish varied considerably. In one of the small rock bass, the cysts were found mostly at the base of the caudal and dorsal fins, while in another larger rock bass, the cysts were concentrated mostly at the base of the caudal fin, around the eyes, and in the mouth cavity. In most cases, cysts were recovered, also, from the myotomes, integument, and between the fin rays. Hughes (3) and Krull (9) have both reported finding cysts under the surface of the head in addition to the above mentioned areas, while Hughes (3) has, also, recovered them from the peritoneum.

The final experiments employed white suckers, horned dace and guppies. These three species of fish were kept in separate tanks of two gallons each throughout the experiments. They were exposed to infection by introducing hundreds of cercariae into the aquarium each time. These experiments proved that these three species of fish could not be infected with the cercariae of *Uvulifer ambloplitis*.

### Morphology of Cyst and Metacercaria

The cyst is composed of two parts, an outer black pigmented covering of host origin and an inner non-cellular hyaline layer of parasite origin. The inner cyst is thin, very tough, and closely invests the parasite. Within the cyst the metacercaria is folded back upon itself. When the animal is freed from its cyst, it is seen to have a deep constriction dividing the body into two well defined regions, the fore and hind-bodies (Fig. 2).

### Effects of Parasites on Fish

Krull (9) carried out penetration experiments with *Cercaria bessiae* on the common sunfish (*Eupomotis gibbosus*). He observed that heavy infection caused death of fish fry in two to four days, but showed that enormous infestations could be built up in small and medium size fish, and that fish of all sizes responded to the penetration of the cercariae immediately and in a very characteristic way. They were stimulated to activity and went through the water by spurts in all directions. Soon after the initial attack, they attempted to detach the cercariae by rubbing their bodies against the bottom and sides of the aquarium or against objects therein. This activity subsided in about 15 minutes, being followed by a flexing of the body while suspended in the water; this lasted for several seconds. Finally, the fish became exhausted and came to rest in some particular spot near the surface of the water, remaining motionless for an hour or more before resuming normal activity.

In 1933, Cross (2) made a study of perch and small mouth black bass and their parasites (cestodes, Acanthocephala, and trematode cysts). He showed that there was a decided difference in average length and weight

when uninfected and heavily infected fish are placed in separate groups according to the age of each specimen. Incidentally, perch and bass in one soft water lake were entirely free from trematode cysts in 1931 and 1932, but in 1933, after two summers of fertilization of the same lake with calcium and phosphorus, six per cent of the fish examined were infected with strigeid cysts. This seemed to be paralleled by an increase in the snail population.

Hunter and Hunter (5, 6, 7) in 1934 and 1938 reported that a heavy infection with metacercariae of *U. ambloplitis* in young and small mouth black bass caused a statistically significant loss in weight when compared with control fish. They suggested that this loss was due in part, at least, to disturbance of the normal metabolism of the host.

In 1941, Hunter and Hamilton (4) gave a report of their studies on host reactions to the metacercariae of *U. ambloplitis*; their findings are summarized as follows:—

- (a) An inner hyaline cyst of parasite origin appears within two to four days of the time the parasite reaches its definitive location.
- (b) The cysts appear to develop near the internal or external perimysium of the muscles.

### Summary

Black spot in bass in Quebec is caused by the metacercarial stage of *Uvulifer ambloplitis*, a trematode parasite of the belted kingfisher.

Not only were small mouth black bass and rock bass found to be infected, but sunfish were, for the first time, shown to suffer in nature from the same disease.

The snail intermediary in Quebec was shown experimentally to be *Helisoma anceps*.

*H. trivolvis* and *H. campanulatum*, which had been found to be infected in New York and elsewhere were not found infected here.

The cercaria encysts at the base and between the rays of the fins (especially the pectoral and caudal), around the eyes, in the mouth cavity, in the skin, and in the myotomes.

The encysted metacercaria stimulates the production of a black pigment in the third week after infection and causes the characteristic black spot.

*Helisoma anceps* is recorded for the first time from Wilson's Lake, where the disease is quite prevalent in bass.

Nine species of snails were found and examined during the survey. *H. anceps* is a newly recorded host for *Cercaria bessiae* in Canada.

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## Some Records of the Food of Brown Trout in Ontario

by

D. H. Pike

(Student, Dept. of Zoology, University of Toronto)

Examination of the contents of the stomachs of thirty-two brown trout caught in southern Ontario showed that twenty-six had eaten insects, ten had eaten crayfish and six had taken fish.

The stomachs examined in this study were taken from trout caught by Mr. Walter F. Wilson, of Kitchener, in the Speed, Sydenham and Saugeen rivers, Whiteman's Creek and River Styx in the counties of Wellington, Grey and Brant.

In the examination of the stomach contents, the number and volume of organisms taken from the surface and from below the surface were recorded separately. Detailed analysis of the stomach contents of each trout is given below.

The findings may be summarized as follows:

The trout ranged in size from  $9\frac{1}{2}$  to 20 inches.

Both insects and crayfish had been eaten by trout of all sizes from  $9\frac{1}{2}$  to 20 inches. Fish were eaten only by the larger trout, that is those from  $13\frac{1}{2}$  to 20 inches in length.

Of the insects eaten 79% by volume had probably been taken from below the surface of the water and 21% from the surface. By number the corresponding percentages were 29 and 71.

The largest numbers of surface insects and terrestrial insects were found in the stomachs of the smaller trout ( $9\frac{1}{2}$ -12 inches). Small Gerridae (*Hemiptera*) made up about 50% of these by number. In this connection it is possibly significant that the only trout caught on grasshopper bait were two small ones 10 and 12 inches in length respectively.

The only fish found in the stomachs were cottids.

Table 1. Number, Volume and Kinds of Organisms Found in Brown Trout Stomachs. Numbers in parentheses indicate volume in cc's.

| Field No. | Length inches | Date and Time taken 1944 | Locality               | No. of aquatic organisms in stomach |         |             |            | No. of terrestrial insects in stomach | Total Vol. |
|-----------|---------------|--------------------------|------------------------|-------------------------------------|---------|-------------|------------|---------------------------------------|------------|
|           |               |                          |                        | Fish                                | Insects | Crustaceans | Total Vol. |                                       |            |
| 1         | 20"           | 12:45 pm July 22.....    | Speed River.....       | 0                                   | 0       | 1 crayfish  | 1.0        | 0                                     | 0          |
| 2         | 20"           | 5:30 pm May 7.....       | Speed River.....       | 2 cottid (2.5)                      | 2 (2.0) | 0           | 4.5        | 0*                                    | 5.0        |
| 3         | 18½"          | 8:00 pm May 24.....      | Sydenham River.....    | 0                                   | 13      | 0           | 11.0       | 0                                     | 0          |
| 4         | 18½"          | 11:30 am May 14.....     | Speed River.....       | 1 cottid                            | 0       | 0           | 2.0        | 0                                     | 0          |
| 5         | 18"           | 6:30 pm June 6.....      | Unnamed River.....     | 1 cottid (1)                        | 0       | 0           | 4.0        | 0                                     | 0          |
| 6         | 17"           | 1:30 pm July 22.....     | Speed River.....       | 0                                   | 0       | 1 crayfish  | 0.1        | 0                                     | 0          |
| 7         | 17"           | 9:30 pm June 4.....      | Speed River.....       | 0                                   | 0       | 0           | 0          | 6                                     | 1.5        |
| 8         | 16½"          | Aug. 20.....             | Speed River.....       | 0                                   | 0       | 1 crayfish  | 2.0        | 1                                     | 1.1        |
| 9         | 16"           | 10:00 am Aug. 12.....    | Speed River.....       | 0                                   | 0       | 1 crayfish  | 5.8        | 4                                     | 0.5        |
| 10        | 15½"          | 8:50 pm May 21.....      | Speed River.....       | 2 cottid                            | 0       | 0           | 5.4        | 0                                     | 0          |
| 11        | 15½"          | 6:00 pm May 18.....      | Sydenham River.....    | Miscellaneous                       | 0       | 0           | 2.8        | 0                                     | 0          |
| 12        | 15½"          | 6:00 pm May 18.....      | Sydenham River.....    | 0                                   | 6       | 0           | 2.0        | 0                                     | 0          |
| 13        | 14"           | 6:00 pm Aug. 12.....     | Speed River.....       | 0                                   | 34      | 0           | 6.5        | 0                                     | 0          |
| 14        | 14"           | 6:30 pm June 18.....     | Whiteman's Creek.....  | 0                                   | 1       | 0           | 0.1        | 1                                     | 0          |
| 15        | 14"           | 5:00 pm July 22.....     | Speed River.....       | 0                                   | 0       | 1 crayfish  | 2.0        | 0                                     | 0          |
| 16        | 13½"          | 6:30 pm June 2.....      | Saugeen River.....     | 0                                   | 0       | 0           | 0          | 7                                     | 6.0        |
| 17        | 13½"          | 5:30 pm May 3.....       | Speed River.....       | 2 cottid (5)                        | 5 (1.5) | 0           | 6.5        | 2                                     | 1.5        |
| 18        | 13"           | 12:30 pm June 10.....    | Speed River.....       | 0                                   | 3       | 0           | 1.2        | 0                                     | 0          |
| 19        | 13"           | 5:00 pm June 18.....     | Whiteman's Creek.....  | 0                                   | 0       | 1 crayfish  | 5.0        | 0                                     | 0          |
| 20        | 13"           | Aug. 20.....             | Speed River.....       | 0                                   | 1       | 0           | 0.1        | 1                                     | 0          |
| 21        | 12½"          | 6:00 pm May 31.....      | Whiteman's Creek.....  | 0                                   | 23      | 0           | 15.0       | 0                                     | 0          |
| 22        | 12"           | 4:00 pm May 17.....      | River Styx.....        | 0                                   | 2       | 0           | 0.1        | 0                                     | 0          |
| 23        | 12"           | 6:00 pm Sept. 3.....     | Speed River.....       | 0                                   | 2       | 0           | 0          | 0                                     | 0          |
| 24        | 12"           | 5:30 pm Sept. 3.....     | Speed River.....       | 0                                   | 12      | 0           | 3.0        | 89                                    | 2.5        |
| 25        | 11½"          | 5:30 pm Aug. 12.....     | Speed River.....       | 0                                   | 3       | 1 crayfish  | 1.8        | 1                                     | 0.2        |
| 26        | 11"           | Aug. 20.....             | Speed River.....       | 0                                   | 1 (0.1) | 1 crayfish  | 0.3        | 7                                     | 0.8        |
| 27        | 10½"          | 7:35 pm July 29.....     | Speed River.....       | 0                                   | 0       | 0           | 0.0        | 50                                    | 1.0        |
| 28        | 10½"          | 7:30 pm July 29.....     | Speed River.....       | 0                                   | 0       | 0           | 0.0        | 0                                     | 0          |
| 29        | 10"           | 5:15 pm July 22.....     | Speed River.....       | 0                                   | 0       | 0           | 0.0        | 0                                     | 0          |
| 30        | 10"           | 6:30 pm July 22.....     | Speed River.....       | 0                                   | 0       | 0           | 0.0        | 14                                    | 0.2        |
| 31        | 10"           | 6:30 pm June 10.....     | Speed River.....       | 0                                   | 3       | 0           | 0.4        | 0                                     | 0          |
| 32        | 10"           | 6:30 pm June 10.....     | Speed River.....       | 0                                   | 17      | 0           | 1.5        | 8                                     | 0.5        |
| 33        | 9½"           | Aug. 20.....             | Speed River.....       | 0                                   | 0       | 1 crayfish  | 0.1        | 107                                   | 1.6        |
| 34        | 9½"           | 11:00 am April 30.....   | Lower Speed River..... | 0                                   | 2 (1.0) | 1 crayfish  | 1.6        | 1                                     | 0          |

\*Contained 1 frog.

## Recent Increases in Growth Rate in Two Species of Lake Manitoba Fish

by

W. A. Kennedy

(Associate Biologist, Central Fisheries Research Station, Winnipeg)

In the winters of 1945-46 and 1946-47 the Fisheries Research Board of Canada conducted a survey of the Lake Manitoba fishery with the active co-operation of the Manitoba Department of Mines and Natural Resources. One of the things discovered during the survey was that there had been an increase in average growth rate of saugers, *Stizostedion canadense*, and of dore, *Stizostedion vitreum*, during recent years. Some scales collected by the late D. Hinks in 1937-38, when he was employed by the Manitoba Government, were indispensable in establishing this fact.

Unfortunately part of Hinks' records have been lost, including records of the lengths and weights of the fish whose scales were taken in 1937-38. However, the size of mesh in which each was taken is known and this gives a rough index of the size of the fish. Standard methods were used to determine the ages of the fish from which these scales had been taken, and of the fish taken in our survey.

Table 1 shows that each size of gill net mesh took more older saugers in the winter of 1937-38 than in the winter of 1945-46. Since gill nets tend to select fish of a specific size range, this indicates that saugers of any given size were older in 1937-38 than in 1945-46. They were approximately as big after five years growth in 1945-46 as they were after seven years growth in 1937-38.

Similarly, Table 2 shows that any given size of gill net mesh took more older dore in the winter of 1937-38 than in the winter of 1945-46. They were approximately as big after four years growth in 1945-46 as they were after five years growth in 1937-38.

There can be little doubt that the growth rates of both saugers and dore increased between the years just prior to 1938 and the years just prior to 1946. Also the growth rate of saugers increased by more than did that of dore. An explanation can be found in the history of the fishery since 1930.

Prior to 1930 saugers were virtually unknown to the commercial fishermen of Lake Manitoba. During the thirties they began to appear in the catch in ever increasing numbers. There was a prolonged drought at the time and as a result the water level of Lake Manitoba gradually subsided, and there is good reason to believe that ecological conditions changed enough, as a result, that saugers were able to increase greatly in numbers. At the same time, probably because of the economic depression then prevalent, considerable numbers of gill nets whose mesh size was less than the then legal  $3\frac{3}{4}$ -inch minimum were being used. These nets of illegal mesh were able to catch saugers while the legal nets could not, so that more and more illegal nets were used. Eventually, in the winter of 1940-41, nets of  $3\frac{1}{4}$ -inch mesh or greater

were legalized. In that year and the next great catches of saugers were made and this species, which had been almost unknown such a short time before, became the most important one. It has remained the most important, or nearly the most important, ever since, although the catches have been considerably less than in the peak years, probably partly because of the end of the drought.

Almost four times as many fish were caught in the winters of 1940-41 and 1941-42 as in the average winter since then. Also in the four winters prior to 1940-41 production of saugers was higher than after 1941-42 even though it must have been almost entirely from an illegal fishery—hence from curtailed fishery. It is therefore reasonable to assume that there were more saugers present in the years just prior to 1937-38 than in the years just prior to 1945-46. The increase in growth rate of saugers can, then, be attributed to a decrease in numbers by exploitation.

The increase in growth rate of dore can also be attributed to a decrease in numbers of saugers, since saugers and dore are probably competitors for food at all stages in their life history. The fact that the growth rate of dore changed by less than did the growth rate of saugers indicates that inter-specific competition is less severe than intra-specific competition.

Table 1.

A comparison of the age distributions (percentage in each age group) in samples of saugers taken from Lake Manitoba in 1937-38 and in 1945-46 by 3-inch, 3½-inch and 3¾-inch mesh gill nets (stretched measure). Some data from 3¾-inch mesh are not included because only two saugers were taken by it in 1945-46. The Roman numeral refers to the year of life, for example an age IV fish is in its fourth year, which, since all were taken during the winter is approximately the same as being exactly 4 years old.

| Mesh Size    | Season  | Number in Sample | IV | V  | VI | VII | VIII | IX | X  | XI | XII |
|--------------|---------|------------------|----|----|----|-----|------|----|----|----|-----|
| 3-inch.....  | 1937-38 | 59               | —  | 5  | 25 | 24  | 22   | 19 | 5  | —  | —   |
|              | 1945-46 | 84               | 4  | 58 | 29 | 8   | 1    | —  | —  | —  | —   |
| 3½-inch..... | 1937-38 | 471              | 1  | 7  | 17 | 30  | 24   | 15 | 5  | —  | 1   |
|              | 1945-46 | 420              | 2  | 69 | 22 | 5   | 1    | 1  | —  | —  | —   |
| 3¾-inch..... | 1937-38 | 30               | —  | —  | 13 | 34  | 20   | 17 | 10 | 3  | 3   |
|              | 1945-46 | 167              | 8  | 44 | 38 | 7   | 2    | 1  | —  | —  | —   |

Table 2

A comparison of the age distributions (percentage in each age group) in samples of dore taken from Lake Manitoba in 1937-38 and in 1945-46 by 3-inch and 3½-inch mesh gill nets (stretched measure). Some data from 3¾-inch and 3⅞-inch mesh are not included because only four dore were taken in each in 1937-38.

| Mesh Size    | Season  | Number of Sample | III | IV | V  | VI | VII | VIII | IX | X | XI |
|--------------|---------|------------------|-----|----|----|----|-----|------|----|---|----|
| 3-inch.....  | 1937-38 | 48               | 6   | 27 | 38 | 27 | 2   | —    | —  | — | —  |
|              | 1945-46 | 71               | 18  | 55 | 17 | 9  | 1   | —    | —  | — | —  |
| 3½-inch..... | 1937-38 | 215              | —   | 13 | 33 | 37 | 10  | 4    | 4  | 3 | —  |
|              | 1945-46 | 73               | 4   | 23 | 38 | 18 | 14  | 0    | 0  | 2 | 1  |

## Summary of Literature on Aquatic Weed Control

by

**J. Murray Speirs**

*(of the Ontario Fisheries Research Laboratory, Department of Zoology,  
University of Toronto)*

Three main methods of attack have been tried for the control of undesired aquatic plants; (1) chemicals may be added to the water or sprayed on emergent parts of the plants, (2) biological controls, either plants or animals, may be added to the water, and (3) mechanical methods may be used. In presenting the available information on each method of control, the following topics will be considered: (1) the field of usefulness of the particular method, (2) method of application, concentration and quantities of chemicals to be used, and when possible their approximate cost, (3) the effects of the treatments not only on the plants but on other forms of life in the water and on the potability of the water, and (4) a bibliography of the literature dealing with each method.

### Mode of Action of Various Herbicides

Green plants take carbon dioxide and water, and using light energy which they absorb by chlorophyll in the chloroplasts of the leaves, they manufacture these raw materials into sugars. These sugars then combine with oxygen, providing the source of energy for the essential life processes of the plant—respiration, growth and storage of food reserves as starch. These life processes are carried out in a protein medium called protoplasm. This must remain in a liquid (or sol) form so that the raw materials can be transported to regions of chemical change, the metabolized products can be used for growth or storage and waste products can be eliminated.

The various herbicides owe their lethal actions to different modes of interference with the normal chain of events outlined above. Copper sulphate and other copper salts are protein precipitants, which kill by stopping the transport of materials. Arsenicals such as sodium arsenite inhibit respiration by blocking specific enzymes in the respiratory system (Breusch, 1944). Chlorine (as from sodium chlorate or chloramine in solution) forms hypochlorous acid, an active oxidizing agent, which apparently kills the plants by burning up their energy resources: bleaching is the visible effect of this action. The benoclor and diesel oil apparently act by dissolving the chloroplasts (or the chlorophyll in them) thus robbing the plants of their mechanism for obtaining energy from sunlight. The oil probably coats catalytic surfaces, thus decreasing respiratory activity. Many of the herbicides are phenol derivatives and may act like phenol which inhibits mitosis, and increases the respiratory quotient of plants, i.e., prevents growth and, by decreasing the oxygen intake, decreases the energy available to sustain life. 2,4-D (and apparently also ammonium sulphamate) burn up the starch and sugar reserves. They stimulate plant growth in very low concentrations but are lethal in higher concentrations. Nigrosine dye, water bloom, and filamentous algae

prevent light from reaching the larger submerged aquatics and so prevent photosynthesis.

#### REFERENCES

- |                             |                                          |
|-----------------------------|------------------------------------------|
| Breusch (1944)              | Goudey (1946)                            |
| Brooks (1946)               | Mitchell and Brown (1945)                |
| Brown (1946)                | Mitchell and Brown (1946)                |
| Eicher (1948)               | Oberle, Pearce, Chapman and Avens (1944) |
| Gauthier (1944)             | Smith (1935)                             |
| Gavaudan and Poussel (1944) | Walter and Nelson (1945)                 |

#### Chemical Controls

##### 1. *Copper Sulphate*: $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$

Copper sulphate is particularly useful for controlling *Chara*, a submerged aquatic which is not seriously affected by most other herbicides. It has also been used to control floating algal scums (as *Cladophora*) and Pondweeds (*Potamogeton*); but sodium arsenite is a better herbicide for these, for Smith (1936) found that *Potamogetons* were not affected by 3 p.p.m. of copper sulphate in Lake Jesse, Nova Scotia.

Copper sulphate may be applied in several ways: (1) it may be dissolved and sprayed over the water surface, (2) the crystals may be put in a burlap bag which is towed behind a boat until the crystals have all dissolved, (3) the bag of crystals may be suspended in a current of water, above the region where it is to take effect (as the inlet to a pond). In lakes it should be applied on a windy day (when there is a good circulation of water).

Various authors suggest concentrations from 0.12 to 2.0 p.p.m. (parts per million by weight) for control of *Chara* and other algae. The concentration to be used depends upon the temperature, alkalinity and organic content of the water. Organic and alkaline waters remove the copper by precipitation. Moore and Kellerman (1904) suggested that the effective concentration at 15°C should be increased 2.5% per drop of 1°C; an increase in concentration of 0.5% per 10 p.p.m. of  $\text{HCO}_3$ ; and an increase of 2% per 10 p.p.m. of organic matter in the water.

The algae and other *submerged* aquatics are killed (emergent forms are little affected). When they die, bacteria in the water increase and the weeds decay. Fish and other aquatic animals are apt to be killed at this time *by lack of oxygen*. This danger may (in the case of ponds with a controllable flow of water) be avoided by adding plenty of fresh water when plant decay begins. The concentration of copper sulphate necessary to kill fish varies a great deal with the alkalinity of the water and also with the species of fish: bullheads, eels and killifish are particularly resistant. Kellerman (1912) found that 1 p.p.m. killed fish (bullheads, suckers, trout) while in the hard waters of Lake Mendota in Wisconsin, 150 p.p.m. were needed to kill largemouth bass. Smith (1924) tabulated the effects on various fish and algae. Some authors recommend that cattle be excluded from treated water for several days while others say that the drinking of treated water is not harmful in concentrations used. The chief danger appears to be the production of a toxic water bloom following death of the poisoned aquatic plants (which then act as an organic fertilizer).

## REFERENCES:

- |                  |                   |                     |
|------------------|-------------------|---------------------|
| Brown (1940)     | Harkness (1933)   | O'Donnell (1943)    |
| Caird (1904)     | Kellerman (1912)  | Smith, G. M. (1924) |
| Caird (1905)     | Marsh & Robinson  | Smith, H. E. (1905) |
| Carpenter (1927) | (1908)            | Smith, M. W. (1935) |
| Carroll (1904)   | Moore & Kellerman | Smith, M. W. (1936) |
| Catt (1934)      | (1904)            | Surber (1943)       |
| Ellms (1905)     | Moore & Kellerman | Titcomb (1914)      |
| Ellms (1928)     | (1905)            | Whipple (1927)      |
|                  |                   | Wickliff (1931)     |

2. *Sodium Arsenite*:  $\text{-NaAsO}_2$  (mostly)  
 $\text{-Na}_3\text{AsO}_3$  (some)

Surber (1948) recommends sodium arsenite as the cheapest and best herbicide for the control of pond scum algae and such submerged aquatics as *Potamogeton*, *Anacharis* and *Najas* in small ponds. However, it does not control *Chara*, *Scirpus* (or other emergent forms), or *Nymphaea*.

This herbicide may be applied by spraying it over the water surface as recommended for copper sulphate.

Surber (1948) recommends a concentration of 4 p.p.m. of the commercial form which contains 32%  $\text{As}_2\text{O}_3$ , i.e., a concentration of 1.3 p.p.m. of  $\text{As}_2\text{O}_3$  is suggested. At this concentration no significant fish mortality was noted. A concentration of 10 p.p.m. killed only 13% of the largemouth bass in one pond over a ten day period, while in another experiment bluegills and crappies survived 12 p.p.m. for 6 days.

As in the case of copper sulphate, however, there is the danger of fish mortality due to oxygen depletion while the killed vegetation is decaying. This should be guarded against by adding plenty of fresh water to the pond during this period (usually beginning about 2 days after application of the herbicide). It is also recommended that cattle be excluded for several days after treatment. Drinking water *must not* contain more than 0.05 p.p.m. of arsenic.

## REFERENCES:

- |                          |               |
|--------------------------|---------------|
| Brown (1940)             | Surber (1932) |
| Surber (1929)            | Surber (1943) |
| Surber and Meehan (1931) | Surber (1947) |
| Surber (1948)            |               |

3. *De-K-Pruf-21*:

The chemical composition of this product is not known the writer, except that it contains copper. No information is available except from The Unexcelled Chemical Corporation, 11 Park Place, New York, 7, New York, who produce this product.

They recommend it for the control of algae on surfaces such as the cement or wooden sides of fish breeding tanks.

It is applied by draining the tanks for 48 hours, then spraying or brushing on the chemical. For spraying it should be thinned with No. 10 mineral spirits.

Rates of application from 150 to 250 sq. ft. per gallon for first coats and up to 400 sq. ft. per gal. for subsequent treatments are recommended.

No ill effects on fish were noted, the copper concentration in the water being less than 1 p.p.m.

The chemical apparently contains enough copper to inhibit the growth of algae and by making a smoother surface to the tanks allows them to be cleaned more easily when eventually algae do begin to collect again.

**REFERENCES:**—Anonymous (1947)

4. *Sodium Chlorate*:  $\text{NaClO}_3$

Sodium Chlorate may be used to control both submerged and emergent aquatics, but due to its fire hazard characteristics, it is *not* recommended for either purpose.

A concentration of 2 to 4% by weight in water solution may be used in spraying emergent vegetation. A wetting agent such as whale oil soap or Vatsol should be used with it. No information is available on concentrations needed for control of submerged aquatics, nor on the effects of the chemical on fish in the treated water or on cattle drinking it.

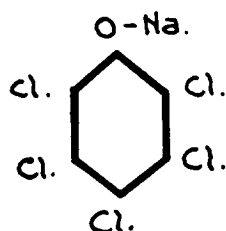
**REFERENCES:**—Crafts (1945); Surber (1948).

5. *Chloramine*:  $\text{NH}_2\text{Cl}$ .

Chloramine may be used instead of copper sulphate for the control of algae. It is prepared by dissolving 1 part by weight of ammonium sulphate in a little water adding 3 parts by weight of chloride of lime and diluting in water sufficient for spraying. It should be applied by spraying evenly over the water surface. The concentration recommended (Harkness, 1933) is 4 p.p.m. (3 lbs. chloride of lime plus 1 lb. ammonium sulphate per 100,000 gals. water). In this concentration, it is not likely to be directly harmful to cattle, fish or to swimmers, but the same precautions should be used as recommended for copper sulphate.

**REFERENCES:**—Harkness (1933)

6. *Santobrite*:



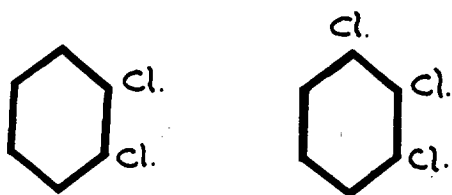
This chemical has been found effective in controlling water hyacinth, *Crassipes eichornia*, and is recommended for controlling algae in industrial cooling systems by Monsanto Chemical Corporation, St. Louis, Missouri. (Copper sulphate at 45 p.p.m.; and Benaclor 3 at 45 gal. per acre were not effective in controlling water hyacinth).

Growth of water hyacinth was retarded by a concentration of 5 p.p.m., while 80 p.p.m. were used to completely eliminate it. As an algicide, a maxi-

mum concentration of 13 p.p.m. has been recommended. At 80 p.p.m. it does not produce skin irritation. It is implied that 5 p.p.m. is not harmful to aquatic animals while 80 p.p.m. is harmful, but no definite data are given.

REFERENCES:—Hildebrand (1946); Hirsch (1942).

#### 7. Benoclor:



(Positions of Cl on rings uncertain—J.M.S.)

The Cloroben Corporation, Jersey City 2, N.J., puts out a variety of herbicides: Benoclor 3, Benoclor 3C, etc., apparently dichlorobenzol and trichlorobenzol with added emulsifiers. These are recommended for control of submerged and emergent aquatics in situations where fish and other aquatic life are relatively unimportant (as in some irrigation and drainage ditches). *Chara* and *Anacharis* are very susceptible. Pondweeds are not so vulnerable. Emergent plants (*Scirpus*, *Typha*, etc.) must be cut below the water line before treatment (on the same day as treated).

The benoclors are heavy liquids, usually applied by spraying them *underwater*. They sink to the bottom and appear to remain effective for several years (Crafts, 1945).

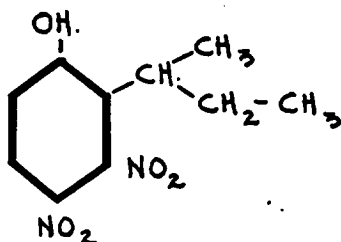
Very clear directions for use are issued in a pamphlet, "Aquatic Weed Control Manual" issued by Benoclor Corporation. Concentrations of 20-30 gals. per acre used to control pondweeds (*Potamogeton Robbinsii*) and water shield (*Brasenia*) in portions of a 195 acre lake in New Jersey. These were given two treatments (35 acres treated with 750 gals. in June-July; and 25 acres including some of the former area with 700 gals. in September). The total cost for this treatment was over \$3,000. Costs for ditch treatments were about \$50 per mile. Before concentrations strong enough to kill plants are reached, Benoclor kills aquatic life including fish, frogs, crayfish, mosquito larvae, and bacteria, producing a "slow, lingering death". Claims are made that fish mortality in lakes may be minimized by applying the solution in narrow strips. Due to unpleasant taste, livestock and birds will not drink the water so are apparently not endangered. When the water is used for irrigation, treatment should not be made until crops have passed the seedling stage as germinating and seedling plants are affected by it.

REFERENCES:—Boyer (1947); Crafts (1945); McGeorge (1946); Surber (1948).

#### 8. Dow Contact Herbicide:

This is used as a contact herbicide for spraying ditchbank emergents such as cattails (*Typha*) and bulrushes (*Scirpus*).

It is used in a concentration of 4 gals. per 100 gals. water and is sprayed on the emergents.



(Position on ring uncertain—J.M.S.)

=dinitro ortho secondary butyl phenol in a self-emulsifying oil.

REFERENCES:—Crafts (1945).

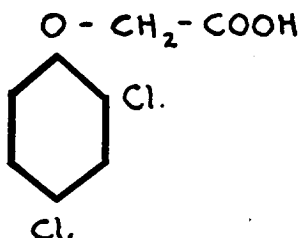
9. *Ammate* = *Ammonium sulphamate*:  $\text{NH}_4\text{SO}_2\text{NH}_2$ .

This is useful in the control of emergent aquatics. It may be used in treating submerged vegetation over small areas but it is considered too expensive for treating large areas.

A 5% solution used with a wetting agent such as whale oil soap or Vatsol is recommended for spraying emergent vegetation. Concentrations necessary to kill submerged vegetation are not given.

REFERENCES:—Crafts (1945); Surber (1948).

10. *2,4-dichlorophenoxyacetic Acid*:



This is recommended for control of emergent vegetation, such as cattails (*Typha*), spikerush (*Eleocharis*), bulrushes (*Scirpus*), burreed (*Sparganium*), and willow (*Salix*). It has been used experimentally to control submerged aquatics such *Anacharis*, *Potamogeton*, and *Naias*.

In the control of emergent vegetation, it should be applied in a spray with tributylphosphate as cosolvent and kerosene as carrier. For example, to make a 5% 2,4-D spray use 2 lbs. of 2,4-D, 2 quarts of tributylphosphate, and kerosene to make 5 gals. The 2,4-D should first be dissolved in the cosolvent, then diluted with the kerosene and thoroughly mixed. This oil spray has two advantages over water solutions of similar concentration: (1) the tributylphosphate has herbicidal properties and rapidly penetrates plant

tissues, (2) it imparts a glistening appearance so that it may be readily seen which parts have been sprayed.

This solution has the disadvantage that the tributylphosphate is very poisonous to fish, so should be used only on emergent vegetation. This 5% solution sprayed at a rate of 20 gals. per acre has been found very effective in controlling cattails and other emergents. Linton (1947) considered the action on willows and other shrubs was largely due to the oil carrier and found that the kill was not permanent. For submerged aquatics, triethanolamine may be used as cosolvent and water as a carrier: 1 lb. of 2,4-D to 1 qt. of cosolvent. Concentrations of 5 p.p.m. were effective in aquarium experiments in killing *Anacharis*, *Potamogeton crispus*, and *P. nodosus*; but in outdoor large scale tests, 10 p.p.m. were required to kill *P. foliosus*, *P. filiformis* and *Najas flexilis*. The cost per acre for control of submerged aquatics is generally over \$100. In a concentration of 100 p.p.m., 4 of 20 fish died—possibly due to oxygen lack in decaying vegetation. Treated water is not harmful to cattle and sheep, but the possibility of a toxic water bloom developing in the decaying killed weeds should not be overlooked.

#### REFERENCES:

- |                          |               |
|--------------------------|---------------|
| Hildebrand (1946)        | Offord (1946) |
| King and Penfound (1946) | Surber (1943) |
| Linton (1947)            | Surber (1947) |
| Mitchell et al (1946)    | Surber (1948) |

#### 11. Other Growth Regulators:

A number of substances related to 2,4-D have been used at least experimentally for aquatic weed control. These include:

- (A) 2,4,5—trichlorophenoxyacetic acid (2,4,5-T)
- (B) SLI-23 (a modified sodium salt of 2,4-D)
- (C) 2-methyl-chlorophenoxyacetic acid
- (D) Indole-acetic acid
- (E) Naphthalene-acetic acid
- (F) Indole-butyric acid
- (G) Indole-propionic acid
- (H) Phenyl-acetic acid

The actions of (A and B) on submerged aquatics were very similar to 2,4-D in similar concentrations. (C) is considerably more toxic to fish (1 p.p.m. killed 2 fish and 100 p.p.m. killed all fish in 24 hours).

(D to H) stimulated growth of aquatic green algae in low concentrations, such as:

- |                                                                                                                                                       |                                                         |
|-------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------|
| $\left\{ \begin{array}{l} 10 \text{ p.p.m. of D-} \\ 4 \text{ p.p.m. of E} \\ 6 \text{ p.p.m. of F,G} \\ 35 \text{ p.p.m. of H} \end{array} \right\}$ | a sugar solution added with D had an inhibiting effect. |
|-------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------|

They killed algae in higher concentrations, such as:

- |                                                                                                        |
|--------------------------------------------------------------------------------------------------------|
| $\left\{ \begin{array}{l} 30 \text{ p.p.m. of D to G} \\ 100 \text{ p.p.m. of H} \end{array} \right\}$ |
|--------------------------------------------------------------------------------------------------------|

REFERENCES:—Brannon and Bartsch (1939); Surber (1948).

## 12. Diesel Oil:

This is useful in the control of ditchbank emergents, where it is sprayed full strength on the bulrushes, etc.

REFERENCES:—Crafts (1945)

## 13. Nigrosine (a black aniline dye):

This is useful in inhibiting the growth of submerged aquatic plants.

In one experiment, it was applied at rates of 10 or more lbs. per acre of water. This concentration inhibited the growth of *Myriophyllum* not only during the year of application but during the following year. There was a temporary increase in plankton, possibly due to the fertilizing effect following the decay of *Myriophyllum*. The bottom temperatures of the treated ponds and lakes were also lowered appreciably.

The dye cost \$15 per lb. or \$36 per 100 lbs.

REFERENCES:—Eicher (1948)

## 14. Fertilizers:

These are recommended for destruction of submerged aquatics in large ponds. They operate by producing an algal "bloom" or dense growth of filamentous algae which shade out the larger submerged aquatics.

The most successful fertilizer in one series of experiments was 10-5-5, made up of ammonium sulphate ( $(\text{NH}_4)_2\text{SO}_4$ ); superphosphate ( $\text{Ca}(\text{H}_2\text{PO}_4)_2$ ); and potassium muriate ( $\text{KCl}$ ) in such proportions as to give 10 parts (by wt. of) N, 5 parts P, 5 parts K. The fertilizers should be applied at a rate of about 100 lbs. per acre, or 1 p.p.m. The cost was about 5c. per lb.

If too much fertilizer (e.g. 10 p.p.m.) is added, pond scum algae such as *Cladophora* are apt to develop. This produces unfishable water. Oxygen depletion is apt to occur, killing fish. Dead algae have been shown in some cases to produce toxic substances causing cattle poisoning and even fish mortality. Even the production of a normal water bloom is apt to produce poor fishing.

Combinations of organic fertilizers (such as cottonseed meal, soybean meal, sheep manure, etc.) with superphosphates are not recommended as they are apt to encourage pond scum, *Chara* and other algae so that even if fish production is increased fishing is rendered impracticable.

REFERENCES:—

Fitch et al (1934)  
Smith and Swingle (1941)  
Surber (1943)  
Surber (1948)

## Biological Controls

### 1. Water Bloom Algae:

Submerged aquatics may be killed by stimulating the growth of water bloom algae. For details, see Chemical Controls—Fertilizers.

## 2. *Carp*:

Carp may be introduced to control submerged aquatics but this is *not* recommended until a careful study has been made of the desirability of carp in the waterway system into which introduction is proposed.

Carp control submerged vegetation both by rooting it out and by increasing the turbidity of the water so that photosynthesis is impaired or prevented.

**REFERENCES:**—Black (1946); Wickliff (1931).

## Mechanical Controls

### 1. *Hand weeding*:

This method is recommended for control of cattails when only a few are present. It is too expensive, and not very effective, in established stands, since the rhizomes become interlaced and are very difficult to completely remove: unless removal is complete the stand rapidly becomes re-established.

**REFERENCES:**—Crafts (1945); Surber (1948).

### 2. *Hand Cutting and Raking*:

This method is used for control of aquatics along lake margins, and in ditches and canals in which the weeds seriously impede the flow of water. Since many of the submerged aquatics grow well from cuttings, this method may be no more than a temporary control and may even aid in the spread of the species. As it involves a lot of labour, it is a very expensive method. Wickliff (1931), however, recommended persistent cutting and raking to control pond lilies, pondweeds, rushes, cattails and sedges. He claimed that after the third cutting such plants will usually die.

**REFERENCES:**—Crafts (1945); Wickliff (1931).

### 3. *Fire Hose and High Pressure Nozzle*:

By first draining a pond, this method may be used to root out aquatics which form a mat along its bottom. *Eleocharis* has been controlled in some ponds by this method.

**REFERENCES:**—Surber (1948).

### 4. *Plowing*:

*Eleocharis* may be plowed under after its roots have formed a mat but not until the pond is first drained and allowed to dry sufficiently for plowing.

**REFERENCES:**—Surber (1948).

### 5. *Draining*:

Burreed (*Sparganium*) and some other aquatics may be killed by draining the pond and allowing it to dry out thoroughly.

**REFERENCES:**—Crafts (1945); Surber (1948).

### 6. *Mechanical Weeder*:

Various mechanical weeders are used to keep navigation channels open. Like hand cutting and raking, their effect is only temporarily beneficial, the

ultimate result aiding in the spread of the very weeds whose control is being attempted.

**REFERENCES:**—Brown (1940); Crafts (1945).

#### 7. *Dredging:*

This method effectively removes all aquatics both submerged and emergent from drainage and irrigation ditches but costs from \$100 to \$1,000 per mile of ditch. The control is not permanent as the weeds are piled up along the ditch banks and eventually grow again.

**REFERENCES:**—Crafts (1945).

#### 8. *Chaining:*

In this method, a very heavy chain is dragged along the bottom of a ditch by tractors or teams, one on each bank. At intervals, the chain is cleared of the accumulated aquatics with rakes and piled on the ditch banks. The immediate cost of this method is much less than the cost of dredging but the effect is more temporary.

**REFERENCES:**—Crafts (1945).

#### 9. *Burning:*

Various "flame-throwers" or "sizz-weeders" have been used very effectively to control emergent aquatics along ditchbanks.

**REFERENCES:**—Crafts (1945).

### SUMMARY

Several methods are generally available to control particular aquatics. To control emergent aquatics such as cattails, bulrushes and spike rushes, 2,4-D or ammate probably give the most permanent control: dredging and the use of a flame thrower are effective as temporary controls. To control undesired algae, copper sulphate appears to be the best chemical at present: chloramine may be equally useful but has not been so thoroughly tested: for algae coating concrete or wooden walls of fish tanks or reservoirs, De-K-Pruf-21 is suggested. For pondweeds the most effective control appears to be sodium arsenite but this chemical must be used with caution where it is likely that the water will be later used for drinking purposes by mammals (including man): the benocloris are effective controls where fish and other aquatic animals are unimportant: nigrosine dye may be used to shade out the pondweeds where the black colour imparted to the water is not a consideration; in some waters pondweeds have been controlled by adding enough fertilizer to the water to produce a water bloom which shades out the pondweeds: this method may have merit where dense growths of algae are considered preferable to growths of pondweeds. Water-lilies are particularly resistant to chemical methods of control: persistent cutting is the only method of control which appears to give satisfactory results as yet.

*The writer wishes to thank the Ontario Research Commission, under whose auspices this bibliographic research was carried on; Eugene W. Surber and G. M. Linton for permission to quote from their letters; Miss J. M. Graham, F. E. J. Fry, R. R. Langford, G. H. W. Lucas, and T. F. West for critical reading of parts of the manuscript and technical assistance.*

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# **Turbines and Descending Salmon and Trout Smolts (and Eels) : IV**

*Review by*

**A. L. Pritchard**

*(Director of Fish Culture Development, Department of Fisheries)*

*Turbines and Descending Salmon and Trout Smolts (and Eels) : IV., by C. V. Otterstrom. Report of the Danish Biological Station, XLVII, 1942, Copenhagen 1945.—11 pages, 10 text figures.*

This paper, recently come to hand, reports on a number of experiments on turbines of various types and sizes in order to discover how great a danger such machines present to fish.

In the first series of tests investigations were made on two Francis turbines of the Finshyttan system, those of the stamp mill of Ribe and the middle mill of Ribe. These have runners with a diameter of 104-173 cm. (40.9—68.1 in.) with 13 bucket vanes. The guide vanes number 20, are 63 cm. (24.8 in.) in height and adjustable with a maximum aperture of 15 cm (5.9 in.). The rotation speed is about 80 revolutions per minute. Fish of various types including roach, rudd, perch, pike, rainbow trout and eel were inserted into the machine through a wooden trough and collected in a bag at the spill-way gates. Since a comparatively small number were hurt, the conclusion was reached that turbines such as these "must be considered in the main harmless to the descending trout and salmon smolts; but probably some of the silver eels would be spoilt by passage through the turbines, and hence it is desirable that the eels are caught before getting so far."

The second series of tests was carried out on the turbine at the Holstebro power station. This is the Kaplan type, 870 h.p., having a runner diameter of 1500 mm. (49.2 ft.), 4 bucket vanes and a constant speed of 214 revolutions per minute. The vanes are adjustable being nearly in a vertical position with the greatest space between them when the turbine is running at full charge (about 500 kw.) but being turned more horizontally with a comparatively small space at low charge (e.g. 130 kw.). A charge of 300 kw. is most frequently used. Fish including roach, dace, pike, rainbow trout and eel were fed into the turbine through a rubber hose with the operation at various charges. This type of turbine is far from harmless with damage at low charge where it usually operates, obviously much higher than at full charge. The majority of salmon and trout smolts will pass through fairly well but so many eels were killed that it was recommended that they be taken before reaching the turbines.

In connection with the above paper, it is interesting to quote from a presentation by Mr. Harlan B. Holmes concerning similar work on the Columbia river, U.S.A., entitled—The Passage of Fish at Bonneville Dam (Dams and the Problem of Migratory Fishes—Special Symposium Issue. Stanford Ichthyological Bulletin, Vol. 1, No. 6, May 3, 1940, pp. 183 and 184).

"A series of laboratory and field tests revealed the fact that, from the standpoint of the passage of fish, hydraulic turbines differ all the way from

literal sausage grinders to a very satisfactory route for the passage of fish. The Bonneville turbines, due to their great size, low pressure, slow speed and type of design, fortunately fall at the latter end of this range of variation, leaving little to worry about. Consideration of screening therefore was discontinued.

From the standpoint of passage of fish, one of the Bonneville turbines can be visualized by considering a vertical cylinder in which a propeller similar to a ship's propeller is mounted in such a way that water flowing downward through the cylinder, will turn the propeller. . . . The runner is 23 feet in diameter, and rotates at a constant speed of 75 revolutions per minute.

After dispensing with the problem of the passage of fish through the turbines, there remained the question of possible injury to the fish that would pass under the spillway gates. Laboratory experiments had demonstrated that the pressure conditions would not be injurious, but there remained the general turbulence below the spillway. It was not possible to make such analysis of this condition. We still should be worried about the situation, were it not for the general observation that seaward migrants regularly pass through similar turbulent conditions at natural and artificial obstructions, such as at Celilo Falls on the Columbia and at Oregon City Falls on the Willamette."

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1948

# The Canadian Fish Culturist



A Department of Fisheries Publication

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*A Bulletin of Information and Opinion  
as to Fish Culture in Canada*

VOLUME IV

MAY  
1949

No 5 ✓

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Requests for earlier issues of the Canadian Fish Culturist continue to be received. A limited number of copies of the issue for August 1948, Vol. III, No. 4, remain on hand and distributions will be made on request until the supply runs out. However, no copies of the issues for November 1946 and June and December, 1947, are now available.

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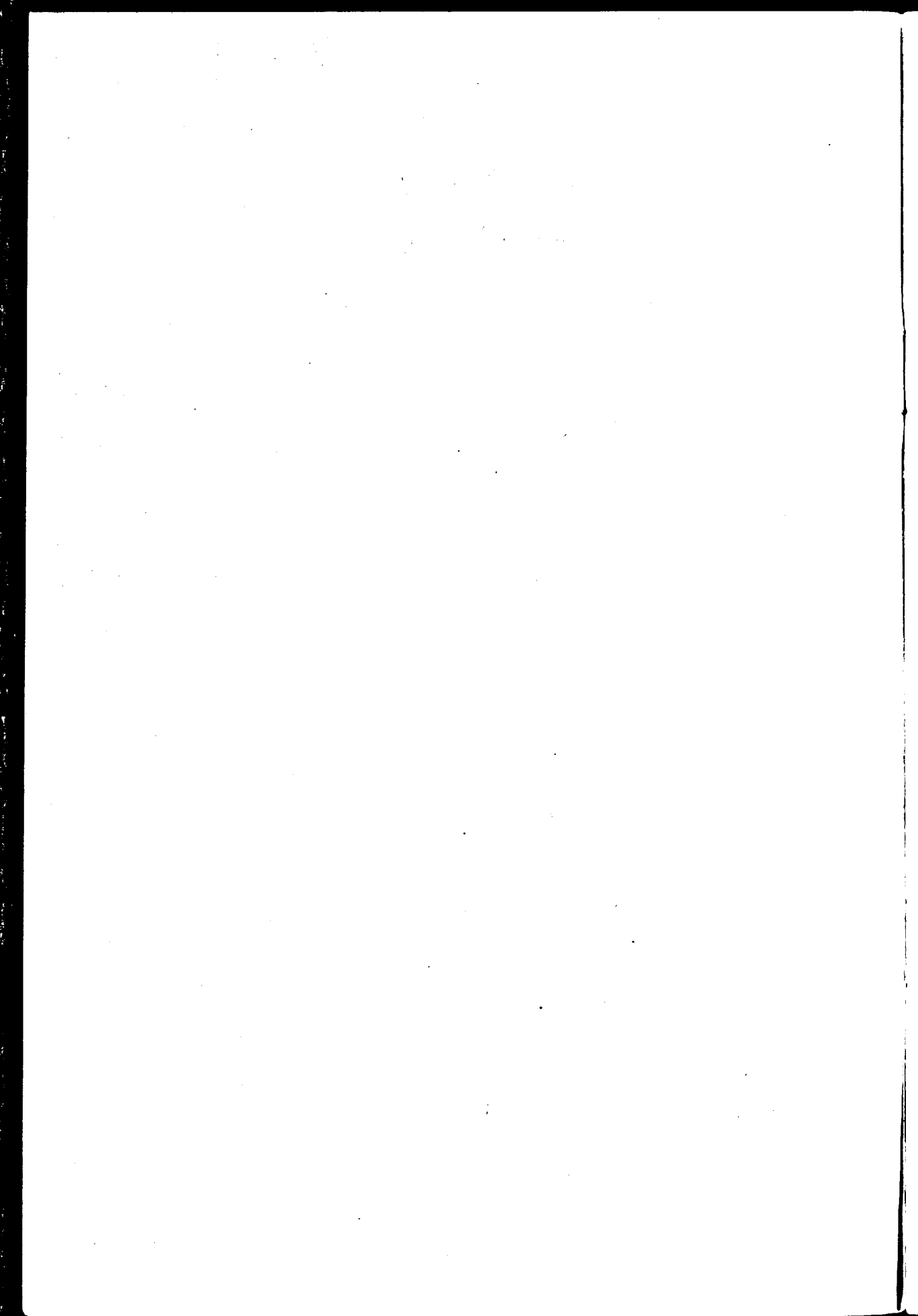
*A Department of Fisheries Publication*

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as to Fish Culture in Canada*

VOLUME IV

MAY  
1949

No. 5



# Estimating Lake Populations<sup>1</sup>

by

W. A. Kennedy

Associate Biologist, Fisheries Research Board of Canada, Central Fisheries Research Station,  
Winnipeg, Manitoba.

Biologists have been estimating lake populations of the smaller, slower, aquatic organisms for many years. For bottom fauna a sufficient number of random samples of a known area of bottom are secured, and the number of each species is determined. The average number per unit area occurring in each type of habitat is calculated, and then, knowing now much of the lake bottom is represented by each type of habitat, the total population within the lake is estimated. Populations of plankton are similarly calculated, sampling known volumes of water rather than known areas of bottom.

These methods depend on the fact that the apparatus used is large, relative to the organisms studied, and the organisms are relatively slow. For fish and other comparatively large aquatic animals no suitable apparatus exists which would permit these methods of estimation to be used. Presumably a gigantic purse-seine fished according to some random, stratified sampling scheme would be appropriate.

There are a number of cases on record of lakes in which all the fish were deliberately killed and all that could be recovered were counted. Rounsefell (1946) has brought together information on 51 lakes of known area in which the total population has been so determined. He shows that the weight of fish per unit area is inversely proportional to water surface area, and that the following mathematical relationship exists:

$$\begin{aligned} \log. \text{ total weight of fish in pounds per acre} = \\ 2.4294 - 0.4001 (\log. \text{ acres of water surface}) \end{aligned}$$

That is, the average total population is about 270 pounds per acre in a one-acre pond and only about 30 pounds per acre in a 200-acre lake. Application of the above equation may be of some value in estimating lake populations. It should be realized, however, that the equation is based on results in lakes of less than 200 acres, mostly in Illinois, Michigan, Indiana and Wisconsin, and that many lakes in Canada would not support fish populations of this magnitude. Also most of the lakes were poisoned because of atypical conditions existing at the time, and further, not all of the fish poisoned were recovered to be counted.

If a lake were fished intensively so that catch per unit of effort became negligible within a season, and if repeated sampling, continued for several years, showed no appreciable change in catch per unit of effort, then the total catch in the first year would be a good estimate of the original population of catchable size in the lake. The original populations of several lakes have been estimated on the basis of fishing which approximately fulfilled these conditions.

<sup>1</sup> A review presented before Committee on Biological Investigations, Fisheries Research Board of Canada, Ottawa, January 4, 1949.

### Direct Count Possible Without Killing

Sometimes special circumstances make possible a direct count without killing the fish. For instance bodies of water may be suddenly drained, as about 1,000 acres of the Winnipeg River, Manitoba, recently were in connection with a power development, or certain species may migrate annually out of a certain area by way of a narrow exit where it is possible to capture and count them, as in Whitetrout lake, Algonquin Park, Ontario.

Biologists would welcome some means of using availability, which is catch per unit of effort, to estimate populations. However, there is no method now in use by which this can be done. Because of the many unknown factors involved it is probably not even safe to place too much trust in estimates of relative populations on the basis of relative availabilities. In a few cases availabilities have been calculated for lakes where good estimates or counts of population are also recorded. No doubt when sufficient data of this sort have been accumulated they will be useful in estimating populations.

Bajkov (1932) has used Derzhaven's method for estimating the whitefish (*Coregonus clupeaformis*) populations of Lakes Winnipeg, Winnipegosis, and Manitoba. Total annual catches for 1916-1928 from the lakes in terms of numbers of fish, plus a random sample from the catch in each for age determination, were required for such calculations. As an example, 3.4 per cent of the fish in a random sample from Lake Winnipeg in 1928 were in their 13th or subsequent year of life, so that of the 1,000,000 whitefish caught that year approximately 34,000 were survivors of the 1916 year class (lumping the negligible few from the 1915, 1914, etc., year classes with the 1916 year class). Similarly, of 942,000 caught in 1927 approximately 50,870 were survivors of 1916 and 1917 year classes. Summation of all such values calculated for the years 1916-1928, inclusive, gives all the 1916 year class fish caught in 14 years, all the 1917 year class fish caught in 13 years, etc., that is, the total population present in 1916, if natural mortality is presumed to be negligible.

As Ricker (1948) points out, these particular calculations are of little value. The method assumes a uniform rate of exploitation over the time considered (which has not been the case), a uniform rate of recruitment (which has probably not been the case), and negligible natural mortality (which is unlikely, especially in the first year of life). Natural mortality can be a very important factor. In unexploited lakes all mortality is natural mortality, and some approximate values for annual mortality rates which have been calculated for whitefish in such lakes are as follows: Lake Opeongo, Ontario, 50 per cent; Shakespeare Island lake, Ontario, 10 per cent; Kakisa lake, Northwest Territories, 50 per cent; Great Bear lake, Northwest Territories, 30 per cent.

Fry (in press) has followed the Lake Opeongo lake trout fishery for longer than a year class is vulnerable to the fishery, and so is in a position to make similar calculations which are unaffected by any fluctuations that may have

taken place in fishing intensity or in recruitment, although he has not actually made such calculations. He has an estimate of natural mortality, which is apparently of less importance than fishing mortality.

### **Best Method for Estimating Fish Populations**

Apparently the best method for estimating fish populations is to catch some of the fish, mark them in some way, release them alive, allow them to mix thoroughly with the unmarked fish, then draw a large random sample from the population, and from the ratio of marked to unmarked fish in the sample, and knowing the total number marked, calculate the total population. Generally the "large random sample" is actually drawn by a fishery, with provision made for observers to record proportion of marked to unmarked fish.

The necessary calculations are straightforward if all the fish are tagged immediately before fishing begins, and if observations on the ratio of tagged to untagged are carried on for only a short time. There are a few factors that have to be considered, however, and due allowance must be made for their effects. Tags and other marks are notorious for causing abnormal mortality. The presence of a tag may change the odds of a fish being captured, as for instance, the tag may entangle in a gill net which would otherwise fail to catch the fish, or a jaw tag may lead to a decreased tendency to take a baited hook. Tags may be lost, and mutilated parts may regenerate. Fish of different sizes may not be equally vulnerable to the fishery. The marked fish may not be thoroughly mixed with the unmarked ones.

In this connection it is important to realize that part of the population may be "uncatchable". For instance, Carlander and Lewis (1948) estimated that there were 300 black bullheads (*Ameiurus melas*) in a certain pond on the basis of capture by seining, tagging, and recapture by seining. After poisoning 1,350 were counted. He felt that very close to the estimated 300 bullheads were swimming around at the time that the estimate was made and that the remainder were lying in the bottom mud where they escaped the seine both times, that is, they were "uncatchable". Carlander and Lewis actually made an estimate of "catchable" fish.

If marked fish are recovered over a longer time, the necessary calculations are more complex, and factors in addition to those listed above must be considered. Fish too small to be taken at first will grow and enter the fishery. Marked fish may disappear because of natural mortality. If marked fish are caught but not recorded, the estimates will be distorted.

There are also methods of estimating populations where tagging takes place during the fishing season, and when recoveries are made for more than one year. Ricker (*loc. cit.*) outlines methods which apply to all situations likely to be encountered.

The above remarks may be summarized as follows:

1. A number of fish populations have actually been counted and these counts may be useful in estimating other populations.

2. At present, catch per unit effort is of little use in estimating fish populations.

3. The sums of the number of fish in each year class in the annual catch may be used to estimate a former population, if allowance is made for natural mortality.

4. Marking and releasing fish for subsequent recapture is the best method now available for estimating fish populations.

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## **The Removal of Undesirable Fish from the Head Waters of Dorion Rearing Station in 1948**

*by*

**G. C. Armstrong**

*(Biologist, Ontario Department of Lands and Forests)*

The renovation of the Dorion rearing station afforded an ideal opportunity to rid the headwaters of the hatchery of infected fish. Previously, when the hatchery was in operation, a number of the diseases encountered were directly attributed to the permeation of the infectious diseases from the fish in the pond. This condition was almost impossible to remedy without transferring the complete stock of fish and closing the station for a period. Nets were set in the pond but while this procedure undoubtedly controlled the population it did not reduce it sufficiently to destroy this source of infection.

When the construction operations had progressed sufficiently to permit the permanent damming of the headwaters, plans were drawn up for the removal of the fish population by a treatment of Calcium Hypochlorite (HTH). Before this treatment was carried out it was thought necessary to reduce the abundant growths of submerged aquatic plants. While the plant life in itself was not of direct concern, it would undoubtedly reduce the strength of the chlorine and retard the penetration of the chemical.

The headwaters or pond covers an area of approximately six acres. With three stop-logs in the dam the volume of water was estimated at 105,600 cu. ft. or 660,000 gallons. The average depth of the pond would be about four feet. The bottom is principally mud and clay with a small area of gravel along the east shore.

The pond is fed by a number of springs scattered about the eastern portion. Considerable seepage also enters the pond from the east and north-eastern banks of the shoreline. The rate of flow produced by these sources was estimated at 7,516 gallons per minute.

### **Matted Beds Three Feet Thick Not Uncommon**

The plants cover almost the entire bottom with the exception of areas about the larger springs and gravel beds which were almost void of plant life. However, in other portions, matted beds three feet thick and covering an area of a square yard or more, were not uncommon. These latter areas were heavily laden with silt and quite resistant to the eddies stirred by the springs.

The reduction of the plant life appeared necessary to ensure complete destruction of the fish population. In reducing the aquatic plant population both chemical and mechanical methods were used. Raking was conducted by one man for a period of ten days. Each day an average of ten punt-loads were removed from the pond but at the end of the period, these one hundred or so punt loads had made very little impression on the total growth.

Following this operation the pond was chemically treated with four hundred pounds of copper sulphate. The treatment was carried out by dispersing the powder over the surface of the water. The pond was divided in four areas and four boats, each manned by two men, spread one hundred pounds of the chemical over their respective areas. Unfortunately the powder which had been stored at the station was in a dampened condition and large lumps had to be crushed before the dispersal.

When the application had begun, the stop-logs were added to the dam. The water was backed up for a period of two hours in which time the solution became much diluted. The stop-logs were then removed, two at a time, until the water had assumed its original level.

### **Thought Inflow Distorted Concentration**

In evaluating the results of the treatment, no apparent reduction or kill of the aquatics was noted. During the treatment three fish appeared to be in discomfort but no actual deaths were observed, although, theoretically the strength of the solution was approximately 60 p.p.m. Immediately following the application it is thought the tremendous inflow of water distorted this concentration. Other factors, such as the moistened condition of the chemical and the period of time required for distribution, combined to reduce the toxic effect of the treatment.

In view of these results, numerous mechanical methods were devised and tried. First, a wire seine was put in operation. The seine was carried out to the centre of the pond by two boats. Then with a man operating each end from a punt the seine was hauled ashore by two horses. This method proved ineffective because the gradient of the bank was too steep and it was impossible to keep the poles and seine from digging into the bank and upturning. This method was abandoned in favour of fitting a wire netting cage to the rear of a set of harrows. Two guide wires fastened to the cage and leading edge of the harrows supported the basket-shaped net. This apparatus was carried by punt to the centre of the pond and dropped overboard. A team of horses then hauled it ashore. This method, although crude, did clean a considerable portion of the bottom. However, only half the pond could be worked as the horses could only operate along the south shoreline. The steep banks and heavily wooded shoreline to the north impeded further operations with the use of this mechanism.

The final and most efficient method involved the use of a heavy iron cage operated by a winch. The cage was hauled by a cable which stretched from the winch across the pond through a pulley attached to a tree and finally fastened to the cage. A return cable from the opposite end of the cage to the reverse drum of the winch brought the cage back. With this set-up the cage collected a swath of weeds in each trip across the pond.

The cage was built eight feet long, three feet high and four feet wide. The bottom and removable back door were made of 3/8" steel plate. The sides were of heavy wire screening of 1" mesh supported by an angle iron frame.

The top of the cage was open. At each outside corner end an extra piece of angle iron was welded on forming a groove which secured the removable gate.

Following a few experimental trials the cage was cut to half the length and extra angle iron supports were added to the tail gate and sides. Originally when the cage was loaded, it placed too much strain on the cable and winch and it is doubtful if the cage itself could have withstood many heavy loads.

The modified cage when placed in operation worked very effectively. As the program progressed a change was made in the pulley hook-up. Rather than transfer the pulley from tree to tree, a short length of cable was strung between two trees running parallel to the shore and as the areas were cleaned the pulley was moved along the cable.

This operation was conducted for three days and together with the results previously attained, the growth was considerably reduced. Odd, small patches still remained but they were not large or dense enough to reduce the HTH treatment appreciably.

### **Treatment with HTH**

All the springs or depressions in the bottom were marked by long poles to ensure that sources of fresh water would be heavily treated. For this reason burlap sacks were filled with varying amounts (10-25 lbs.) of the chemical. These sacks, 25 in number, were then distributed to 20 odd depressions. In some instances where the springs were very active, a partly filled barrel or two bags were sunk to the bottom of the spring. The sacks were all weighted and tied to the stake in order that a concentrated solution would be present at the inlet. Following the distribution of the sacks the four boats used in this operation were loaded each with a barrel of the chemical. One boat manned by two men mixed the solution and sprayed it over the surface waters while the other three boats also manned by two men spread the solid particles over the surface. The seepage waters entering the pond from the east shore were treated thoroughly by one man detailed for the task. The four boats employed covered the area of the pond four or five times until a total of 1,500 pounds of the chemical had been dispersed. Numerous tests for the strength of the solution with orthotolidine indicated a very strong solution. At the beginning of the operation all the stop-logs were pulled in the dam and the pond was lowered to the limit. One man was posted at the dam to replace the logs on the first indication that the solution was coming through. At this moment the 13 logs were added. The time required for the water level to reach the top of the stop-logs was about three hours.

The effects of the treatment was noticeable shortly after the first application of the chemical. The speckled trout (*Salvelinus fontinalis*) exhibited very little resistance to the treatment. Hectic signs of distress were noted shortly after the trout were subjected to the chemical. The majority of the trout had succumbed 15-30 minutes after the initial application. The spoonheaded muddler (*Cottus ricei*) was also present in very great numbers.

These fish appeared much more resistant to the treatment. While they displayed signs of distress they appeared able to endure the toxic environment much longer than the trout. A few muddlers survived for three hours or more, however, a later examination revealed no fish life whatsoever. A number of earthworms were noted on the bottom. These too appeared overcome by the chemical.

When the solution reached the top of the dam and began overflowing, the neutralizer was applied. This operation was conducted by suspending two sacks full of sodium thiosulphate just above the overflow. Four hundred yards downstream by the remains of an old damsite a further application was added. Here, three bags of neutralizer were suspended in the narrow channel. Between the two dams the chemical still persisted until the headwaters cleared. Below the second dam, after the water had flowed through the neutralizer for the second time, the waters were tested and results indicated a very weak solution of the chemical.

The effects of the chemical between the two dams may have proven toxic to a few of the animals present. A number of muskrats housed along the border of this discarded pond were very much aroused when the solution reached the area. Although in a diluted state the chemical was still quite evident and these muskrats quickly left the water. A number of fish were seen floating down through the second dam but it was thought that the majority of the fish were flushed over the first dam.

During the evening as the bags of neutralizer were dissolved more chemical was added. By 10.00 p.m. the solution was in a much diluted state. The bags were filled once more and the operation was abandoned. A total of 800 lbs. of sodium thiosulphate was used during the operation. By morning a survey of the pond and stream revealed no trace of the chemical. Numerous dead muddlers and speckled trout were observed on the bottom of the pond. The cleaning up operations of removing the fish carcasses, poles, empty drums and bags completed the operation.

# Identification of Atlantic Salmon and Brown Trout Based on a Comparative Morphological Study

by

**Hugh R. McCrimmon**

*Department of Zoology, University of Toronto.*

Atlantic salmon (*Salmo salar*) and brown trout (*Salmo trutta*) are often not readily distinguishable. The study here reported was undertaken for the purpose of finding some diagnostic features which might be depended on to separate them. Part of the material examined was obtained from the collection of the Royal Ontario Museum of Zoology through the courtesy of Prof. J. R. Dymond. The remainder was collected from Duffin Creek, Ontario County, Ontario. The number examined was 41 Atlantic salmon and 41 brown trout. In all 35 Atlantic salmon and 35 brown trout with lengths from 55 to 230 millimeters were examined, and also six salmon and six trout with lengths from 300 to 780 millimeters.

## Methods

The material from Duffin Creek was collected from 1945 to 1948. All the material was examined during 1947 and 1948.

Measurements of the various body characters commonly used by systematic ichthyologists were employed in this study. Measurements made were standard length, body width and depth, head length and depth, caudal peduncle length and depth, eye, snout, interorbital, and maxillary length, number of rays, height, and length of dorsal and anal fins, length of pectoral and pelvic fins, number of branchiostegals and gill-rakers, number of scales on lateral line and from posterior of base of adipose diagonally to lateral line.

## Results

### A. A COMPARISON OF MERISTIC STRUCTURES.

#### (1) Scale counts.

- (a) Lateral line scales. This is a measurement of oblique scale rows from the posterior margin of the head to the end of the vertebral column. Difficulties arise in the determination due to the branching or insertion of extra scale rows particularly along the anterior portion of the body. An exact count is particularly difficult in the smaller specimens.

For *S. salar* the number of scale rows was found to have mean value of  $111.2 \pm 1.2$ . The number of scales along the lateral line of *S. trutta* gave a mean value of  $112.3 \pm .82$ .

(b) Scales form the posterior base of the adipose to the lateral line. Counts were made along the diagonal scale row and the scale touching the lateral line was excluded from the count. Determinations on the diagonal scale row gave a mean value of  $10.8 \pm .82$  for *S. salar* and of  $15.2 \pm .16$  for *S. trutta*.

(2) Dorsal fin rays.

Both species were found generally to have 12 developed dorsal rays. The majority of the fish possessed one or two rudimentary rays followed by one or two undivided rays, followed by 10 or 11 divided rays.

(3) Anal fin rays.

Anal fin rays vary in number from 9 to 11 for both species. The most common arrangement was one rudimentary, one divided, and 8 undivided rays.

(4) Gill-rakers.

The number of gill-rakers on the first arch on the left side gave a mean value of  $19.8 \pm 1.6$  for *S. salar*. A mean value of  $17.0 \pm .01$  was obtained for *S. trutta*.

(5) Branchiostegals.

The number of branchiostegals on the left side was found to give a mean value of  $11.9 \pm .03$  for *S. salar* and of  $10.0 \pm .01$  for *S. trutta*.

(6) The counts which have been found to show a difference for the two species are presented in the following table.

Table I

| CHARACTER                                                               | <i>Salmo salar</i> | <i>Salmo trutta</i> |
|-------------------------------------------------------------------------|--------------------|---------------------|
| Number of scales from posterior of base of adipose to lateral line..... | $10.8 \pm .82$     | $15.2 \pm .16$      |
| Number of branchiostegals on left side.....                             | $11.9 \pm .03$     | $10.0 \pm .01$      |
| Gill-rakers on first arch of left side.....                             | $19.8 \pm 1.6$     | $17.0 \pm .01$      |

## B. A COMPARISON OF BODY PROPORTIONS.

The relations of the body parts measured to the standard length of the two species was investigated. The data were expressed in the form of a double logarithmic plot. Huxley (1922) has shown that the logarithms of any body measurement when plotted against the logarithms of the body length give a straight line relationship over a considerable size range which can be expressed by the equation  $\log y = \log b + a \log x$ .

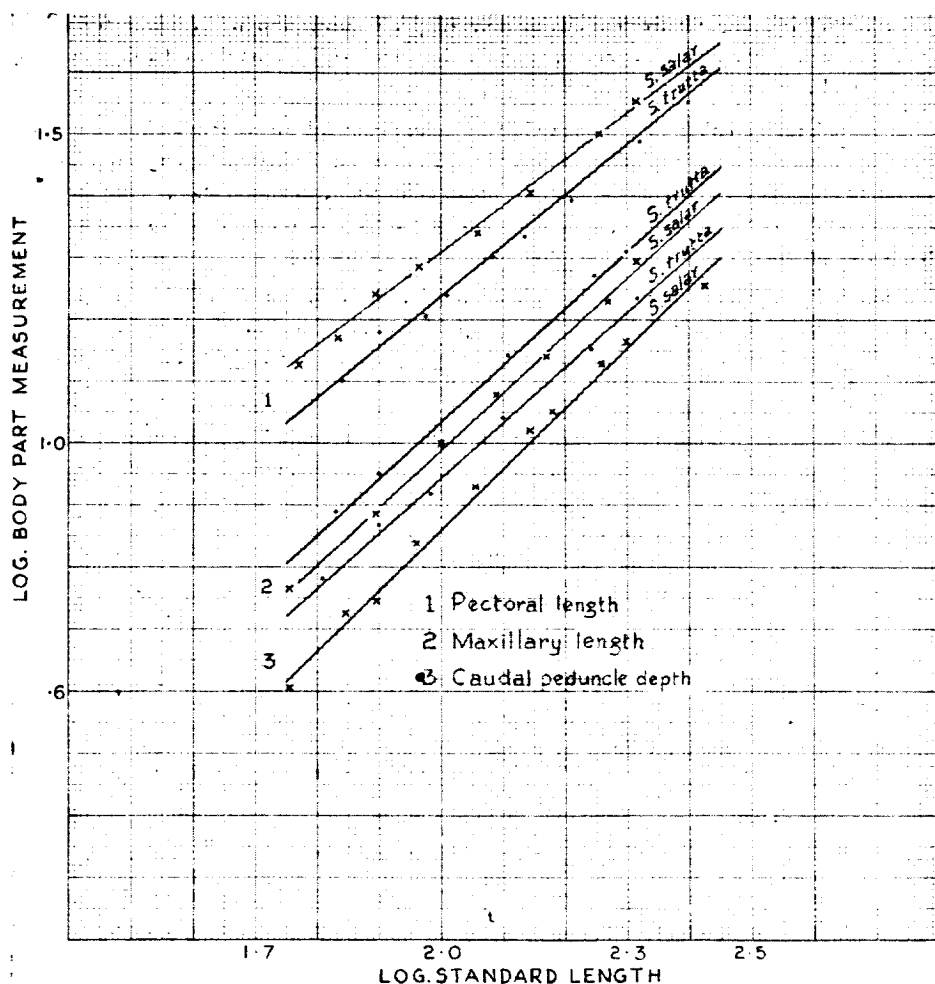


FIGURE 1.  
Relation of Measurement of Body Part to Standard Length.  
A Double Logarithmic Plot.

All body measurements recorded were plotted in this way. Distinct lines for each species were found for the logarithms of (1) pectoral length, (2) maxillary length, and (3) caudal peduncle depth when plotted against logarithms of standard length for fish of lengths of 50 to 250 millimeters. These lines are shown in figure 1. Other measurements showed a less marked or no difference in the two species.

#### C. APPLICATION OF DATA TO DISTINGUISH *Salmo salar* FROM *Salmo trutta*.

The difficulty in distinguishing young Atlantic salmon from brown trout in streams which both frequent has been realized. For this reason a consideration of methods by which they may be distinguished is given.

The double logarithmic curves on graph I show distinct curves for each species when pectoral length, maxillary length, and caudal peduncle depth are plotted against the standard length.

From Figure I it may be seen that (1) the pectoral fin of the young salmon is proportionately longer than that of the brown trout, (2) the maxillary length of the young brown trout is proportionately longer than that of the salmon, and (3) the caudal peduncle of the salmon is more slender than that of the brown trout.

The twelve larger specimens with lengths of from 300 to 780 millimeters showed the caudal peduncle of the salmon to be more slender than that of the trout. Further, the meristic counts presented in Table I were found to be valid.

These data are presented in the following tabulated key as the ratio of the body part measurement to the standard length. It is hoped that this key may provide a means of distinguishing the two species.

**Table II**  
DISTINGUISHING CHARACTERISTICS OF ATLANTIC SALMON (*Salmo salar*)  
AND BROWN TROUT (*Salmo trutta*)

| CHARACTER                                                                         | <i>Salmo salar</i> | <i>Salmo trutta</i> |
|-----------------------------------------------------------------------------------|--------------------|---------------------|
| Number of scales in oblique row from posterior base of adipose to lateral line... | FEWER THAN 13      | MORE THAN 13        |
| Number of gill-rakers on first arch on left side                                  | MORE THAN 18       | FEWER THAN 18       |
| Number of branchiostegals on left side.....                                       | GENERALLY 12       | GENERALLY 10        |
| *Ratio of maxillary length to standard length                                     | LESS THAN 1/10     | GREATER THAN 1/10   |
| Ratio of caudal peduncle depth to standard length.....                            | LESS THAN 1/13     | GREATER THAN 1/13   |
| *Ratio of pectoral length to standard length                                      | GREATER THAN 1/5   | LESS THAN 1/5       |

\* Limited to lengths of from 50 to 250 millimeters.

## Small Mouthed Black Bass in the Waters of New Brunswick and Nova Scotia

by

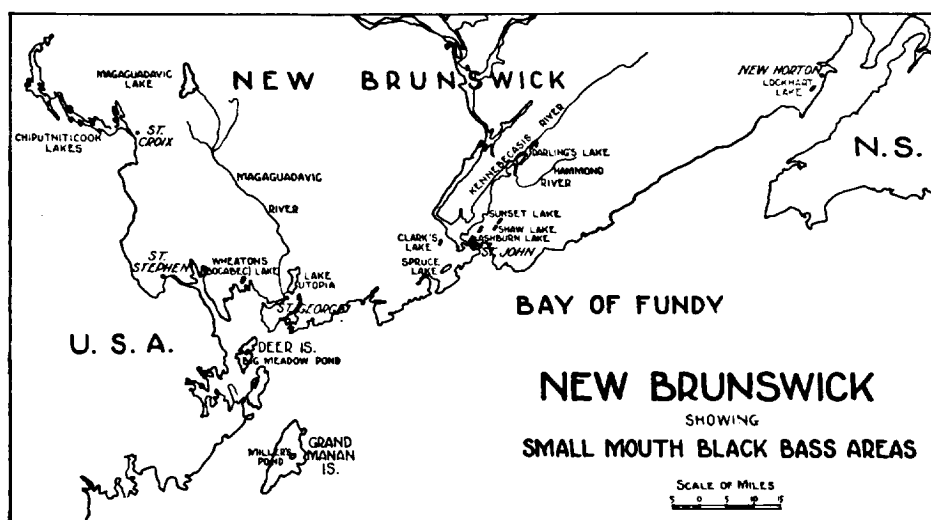
**James Catt**

*Regional Supervisor of Fish Culture, Dominion Department of Fisheries  
Saint John, N.B.*

Although the small mouthed black bass (*Micropterus dolomieu*) is not native to the Maritime provinces, after introduction it has been established in some New Brunswick localities for many years. Recently its range has been extended by transfer to certain carefully selected waters in Nova Scotia.

The exact details of the method by which and the time at which the species entered New Brunswick are not available but from present information it seems that the first appearance was in the Chiputniticook lakes on the New Brunswick-State of Maine border *about 80 years ago*. It is believed that they obtained access to the lakes from a pond in Maine privately-owned and stocked by a bass angling enthusiast. This pond drains into the International water. *About 20 years later* bass appeared in the Kennebecasis river and Spruce lake both of which discharge into the tidal portion of the St. John river. Following this two small privately-owned lakes were stocked presumably with parent fish taken from the Kennebecasis, namely, Ashburn lake, St. John county, discharging into Courtenay bay, Saint John harbour, and Sunset lake draining into St. John river through a swamp and the lower Kennebecasis. It appears that the swamp acts as a barrier to migration, otherwise the bass would probably be found in Dolans lake.

*In 1905*, 13 bass were introduced into Lockhart lake, N.B. *In 1908*, 300 fingerlings were taken to Laytons lake, N.S. *In 1922*, 27 were placed in Wheatons lake, N.B. *In 1925*, Big Magaguadavic lake was stocked with 143 parent fish from Spendic (Chiputniticook) lake.

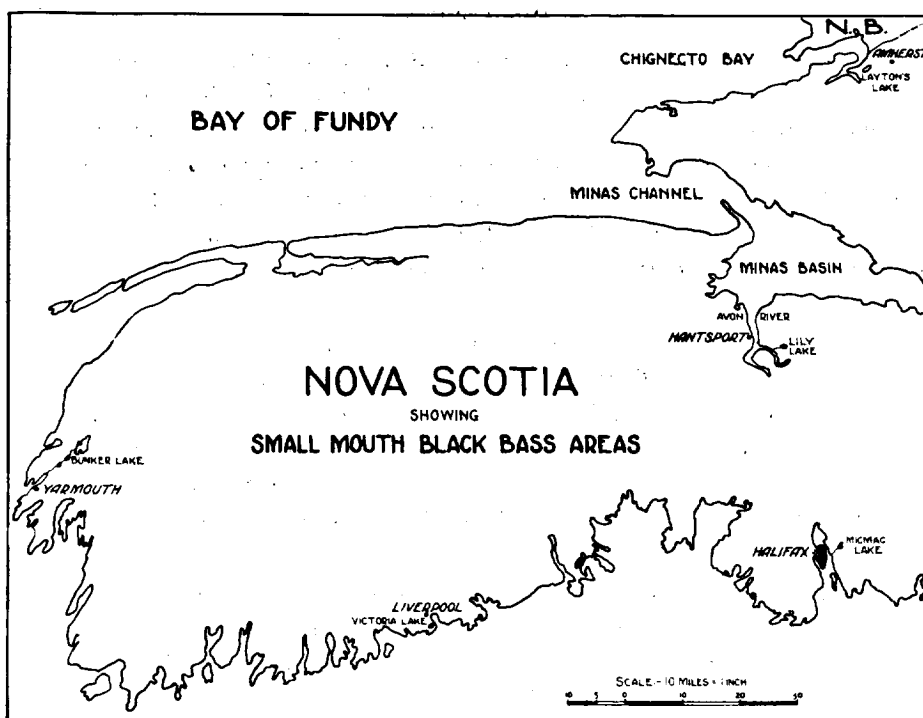


Following this last stocking the Federal Department of Fisheries seriously considered the effect of the introduction of non-indigenous species on the native forms such as the speckled trout (*Salvelinus fontinalis*) and Atlantic salmon (*Salmo salar*). Although the black bass is an excellent game fish and could inhabit warmer water than the others, there was danger that it might through migration and predation supplant species which were more highly prized. As a result, a regulation was made prohibiting the introduction of any non-indigenous fish to any water without permission of the Minister. The result was that later extensions of range were limited and controlled at least to the extent of examination of areas before transplantation.

In September, 1925, 42 adults from Spendic lake and Hammond river were transferred to Wheatons (Bocabec) lake, N.B. In 1942, 107 adults were taken from Wheatons lake to Bunker lake, Nova Scotia, and 27 from the same body of water were placed in Big Meadow pond, Deer Island, N.B. In 1943, 38 bass from Lake Utopia in the Magaguadavic watershed were taken to Miller's pond, Grand Manan, N.B. In 1944, from a number of bass captured at the mouth of Trout brook, Lake Utopia, N.B., 61 were taken to Micmac lake, Halifax county, N.S., and 21 to Shaw lake, St. John county, N.B. In 1945, 33 Lake Utopia bass were planted in Layton lake, Cumberland county, N.S., and in 1946, 37 were also transferred thereto and 14 planted in Shaw lake, N.B. During 1947, Victoria lake, Queens county, Nova Scotia, received 39 bass and Shaw lake, St. John county, N.B., 4. Of these, 17 were captured in Wheatons lake and the balance in the Magaguadavic watershed. In 1948, 44 bass from Lake Utopia were taken to Lily Lake, Hants county, N.S., and 7 to Clark's lake, St. John county, N.B.

The unpreventable and unauthorized advent of the small mouthed black bass from United States waters into Chiputniticook lake was followed by a rapid diminution in the numbers of speckled trout, whitefish (*Coregonus clupeaformis*), and to a lesser degree, seago salmon (*S. salar seago*). As the bass spread down the St. Croix river, the trout fishery continued to decline both in the mainstream and some of the tributary brooks and lakes. The unauthorized introduction of the species into Magaguadavic lake was even more disastrous since the watershed included some of the finest speckled trout waters in the province where now the bass are found in increasing numbers.

The introduction into Kennebecasis, on the other hand, presents an unusual and interesting case where a trout fishery has apparently been little affected by predator exotics. In the locale of their distribution, including Darling's lake and the delta of the Hammond river at its confluence with the Kennebecasis, the waters have never really provided good trout habitats but have always contained large numbers of pickerel (*Esox niger*). Perhaps peculiarly the bass do not appear to have spread upstream any considerable distances into the better trout areas. Their downstream expansion seems to have stopped where the river enters the very brackish tidal waters of the St. John although it is possible that some may have reached the Grand Bay area when heavy freshets offset the normal salinity. Undoubtedly the bass do take



some toll of smolts descending the Kennebecasis and Hammond but this is not believed to be serious. In Sunset lake although the body of water is small and the bass are reported to grow to a fair size (2 to 2½ lb.), the trout population has succeeded in maintaining itself to some degree.

In recent plantings bass have been limited to waters considered unfavourable to the indigenous species, *e.g.*, Wheatons lake, or to those from which it is evident they cannot migrate to other areas, *e.g.*, Ashburn, Sunset and Spruce Lakes.

Reports are not complete for all the various areas in which introductions were made in addition to the St. Croix, Magaguadavic, and Kennebecasis systems. It is known that the experiment with Lockhart lake in 1905 was a failure probably because a break in the dyke let the sea water into the lake. It is suggested that the 300 fingerlings taken to Laytons lake in 1908 were consumed by perch predators. The 1922 planting in Wheatons lake apparently did not succeed since by 1925 none were reported. The later attempt in 1925 was eminently successful. Miller's pond in Grand Manan, after a three-year closure, produced in 1946—146, 1947—85, and 1948—67. The drop in the last two years is ascribed to less intensive fishing rather than to a decrease in population. Reports indicate that some bass were captured during 1948 in the Shaw lake watershed which includes Kelly and Quinn lakes. Anglers have also reported taking bass in the Micmac lakes.

### DISCUSSION

The history of the black bass in New Brunswick and Nova Scotia makes generalizations and prediction of results of future introductions difficult. In some instances success has been attained in providing angling to meet the rapidly increasing demands both from residents and tourists and there is no doubt that some waters not entirely suitable for trout and salmon are now productive. On the other hand, there is no doubt that in some areas the more valuable fisheries have been reduced without the establishment of an equally valuable one.

The bass has numerous commendable attributes. It is a game species which provides an excellent fight when taken on baits, plug, spinner or fly. It is palatable although to some perhaps not as desirable as the trout. It is a warm water species and can be fished to good advantage in the summer months when the main trout fishery is past. Being a warm water species, it should utilize to some extent the littoral waters in the summer when they are vacated by the trout.

Because the species may be very detrimental to indigenous forms, it is considered that further introduction should be carefully considered. One must be sure to limit it to areas where little or no harm can be done. In the meantime investigations should be carried out to determine more about its life history, growth, behaviour, habits and habitats. Certain valuable data could now be obtained by examining and recording information on conditions and yield, etc. , in the many new areas where plantings have been made. Only after a fairly complete and satisfactory picture of the species is obtained, would it be safe or wise to consider any relaxation in the present restricted planting policy.

# The Status of the Hatchery

by

**Richard B. Miller**

*Associate Professor of Zoology, University of Alberta.*

(This paper was given at the Alberta Provincial Government—National Parks Fisheries Conference held in Banff, Alberta, in September, 1948.)

The subject of the efficiency or otherwise of sport fish hatcheries has been threshed over many times in the last few years. We ourselves discussed it briefly at our 1945 meeting in Jasper. But to us who are still, mainly, hatchery men, the subject should be, and I hope is, a very important one, worthy of our consideration.

I propose to give you first, a review of the research done in the United States and other parts of Canada on this topic; second, I wish to try to evaluate what the hatchery has done in Alberta; and third, I shall suggest what role the hatcheries should play in Alberta in the future.

## Review of Research in Hatcheries

The pioneer work of this sort was begun in the 1920's in Canada by Dr. R. E. Foerster of the Pacific Biological Station at Nanaimo, B.C., of the Fisheries Research Board of Canada. The Dominion had been spending large sums in the operation of the salmon hatcheries in British Columbia and it was decided to find out if these expenditures led to any results. The sockeye salmon come up the Fraser river and into small headwater lakes. Here they spawn on the beaches or in gravel beds of the tributary streams. The fry hatch in the spring and after a variable period in the lake (one to several summers) go to sea. Dr. Foerster's work was done on Cultus lake where from 5-80 thousand fish spawned each year. A hatchery was located here and screens across the lake outlet were built so that all fish entering or leaving were stopped and counted. The experiment tested three things. (1) The fish were counted and allowed to spawn naturally. The downstream migrants (their progeny) were counted the next year. (2) The fish were counted, their eggs taken and reared in the hatchery to be planted as eyed eggs—and the downstream migrants counted as before. (3) The fish were counted, then eggs taken, and reared to the fry stage—planted and downstream migrants taken. The experiment lasted ten years, the methods being used alternately. Over the years, the number of eggs which survived to the downstream migrant stage varied from 1-3 per cent for natural, 2-4.5 per cent for fry and 1-4.7 per cent for eyed eggs. There is no significant difference between these figures and salmon procreation was discontinued in B.C.

Foerster's work brought out another interesting point; the mortality of 94-97 per cent occurring in all methods took place *after* the fry stage was reached. Natural fertilization and subsequent hatching were close to 100 per cent efficient. Nothing can be gained over nature by fertilizing and hatching in a hatchery.

Subsequent work has shown this to be generally true for trout. Investigations into the efficiency of natural fertilization have revealed that Cut-throat trout are over 90 per cent, Brown 99 per cent and Brook and Rainbow trout over 80 per cent efficient in nature.

Foerster's work (1936) touched off a great deal of similar research in the United States. Fry or fingerlings were marked by fin-clipping, liberated in streams, and the angler's catches carefully examined during the succeeding years. The first phase of this work was with fry and fingerlings.

Virginia, 1936—1.5-6 per cent return of 4 inch fingerling trout.

Virginia, 1940—268 trout recovered of 11,107 planted in one stream (2.4 per cent).

California, 1941—130,000 brown trout fry yielded 0.2 per cent.

10,000 speckled trout fry yielded 0.8 per cent.

Michigan, 1939—No returns of brook trout over 1.6 per cent.

These studies demonstrate the futility of planting fry or fingerlings in streams.

Studies on lakes give more encouraging results. Thus in California lakes Needham and Sumner (1941) found:

5,028 2-inch Eastern Brook Trout yielded 4.3 per cent to angler.

2,080 5-inch Eastern Brook Trout yielded 25.6 per cent to angler.

But in lakes where trout already existed, returns were not so good. In Fish lake, where rainbow are native, Needham and Cliff (1938) found that only 1.15 per cent of planted eastern brook were taken by anglers.

Using all three common trout, Wales (1946) tested fingerling survival in Castle lake, California. He found 3.5, 5.5 and 1.9 per cent of rainbow, brown and brook fingerling, respectively, survived.

In June lake, California, where no native fish spawn, Vestal (1943) observed 54 per cent survival to anglers of 100,000 planted trout.

It is readily apparent, then, that survival of fry and fingerlings is much better in lakes than in streams, but mainly in lakes where no native trout were present or spawning facilities not available.

As the survival of fry and fingerlings proved to be so poor, especially in streams, hatcheries began to plant larger and larger fish. Now the main plants are of "keeper" or legal size trout. The first research was to determine when it was best to plant these large fish. Some of the findings are as follows:

| Place                          | Authority                                 | Kind of Trout           | Survival for<br>Spring plant<br>% | Survival for<br>Fall plant<br>% |
|--------------------------------|-------------------------------------------|-------------------------|-----------------------------------|---------------------------------|
| Michigan.....                  | Shetter and Hazzard 1942                  | Brook<br>RB<br>Brown    | 25.5<br>19.6<br>11.3              | 4.4<br>4.9<br>5.8               |
| Pine R., Michigan..            | Shetter and Hazzard 1938                  | Brook<br>RB             | 1.8<br>17.5                       | —<br>—                          |
| Michigan.....                  | Shetter and Hazzard 1941                  | All varieties           | 4.9-61.9                          | 5.3                             |
| Michigan.....                  | Smith 1941                                | Brook                   | 19.6                              | 1.0                             |
| Connecticut.....               | Hunter, Thorpe and<br>Grosvenor 1941..... | All species             | 41.8-33.3                         | —                               |
| Massachusetts.....             | Nesbitt and Kitson 1937                   | All species             | 35.0                              | 7.0                             |
| N. Carolina.....               | Chamberlain 1943.....                     | RB                      | 44.0                              | 2.3 to 5.5                      |
| Minnesota.....                 | Smith, L. L. 1943.....                    | Brook and<br>Brown..... | 14.1                              | 1.9                             |
| Wisconsin.....                 | Williamson and<br>Schneberger 1943.....   | Brook and RB            | 25.0                              | —                               |
| Pennsylvania.....              | Trembley, G.L. 1945.....                  | All species             | 50.8                              |                                 |
| Castle Lake, Calif...          | Wales, 1946.....                          | All species....         | 35.40 in lake                     |                                 |
| Arizona and New<br>Mexico..... | Gee 1942.....                             | All species....         | 45.1                              | —                               |

This great body of evidence shows a return from spring planted legal-sized fish of about 5-50 per cent, average around 30 per cent. From fall planted fish the returns are, with a few exceptions, negligible. This suggests that the planted fish fail to survive over the winter. Investigation has shown that this is indeed the case. The reason that spring plants give returns is that they are caught the *same season* they are planted.

Shetter (1947) found that in Michigan streams, spring planted legal trout were caught in the first two weeks of open season. Those not caught then were never caught. Likewise, Williamson and Schneberger (1943) in Wisconsin found no survival to second season.

Trembley (1945) in Pennsylvania found 76 per cent of recoveries of planted trout were made in the first day of season. After six weeks, negligible numbers

of planted fish were caught. Smith and Smith (1945) found most were caught in the first three to four weeks of the season in Minnesota streams. They found only two per cent turning up the following season.

The causes of this failure to survive are not surely known. Needham and Slater (1944) have shown that competition with native fish for food will eliminate hatchery fish in streams they have studied. Schuck (1948) suggests that hatchery fish do not survive because (1) they have been poorly fed; (2) no exercise; (3) have had too constant temperature; (4) they are injured in handling.

It boils down to this fact; hatchery fish, even 7-8 inch fish, will not survive over winter in streams where there is a population of native fish of their own kind. The hatcheries in the U.S., therefore, are giving this kind of fishing:

Chamberlain (1943) reports that in the Pisgah Forest, North Carolina, anglers spend \$1.00 per day to catch 8-inch Rainbow trout weighing  $3\frac{1}{2}$  ounces.

King, Willis (1942) report that in Great Smoky Mountain National Park three years of fishing yielded 133,638 trout of which:

114,050 were under legal size.

19,588 were legal—averaging 8.7 inches long.

285 were over 12 inches.

13 were over 16 inches.

### **Hatchery in Alberta**

We have reviewed what has been discovered about hatcheries in the United States. Let us now look over the situation in Alberta.

**THE RAINBOW TROUT.**—Over the past twenty years, an enormous effort has been made to establish this species in Alberta waters. From 1941-1945, 977,000 have been placed in Lake Minnewanka, with no showing. About five million have been planted in the Bow and its tributaries. The showing is not impressive. Only in lakes of this drainage has success been achieved, notably the Kananaskis lakes. Little success has followed plants in the Oldman drainage. Nowhere on the Saskatchewan drainage streams has a real population of rainbow been established. Apparently they are unable to compete with the native cutthroat trout. The plantings appear to have created a new fish—a rainbow cutthroat hybrid, but we do not know, as yet, if this fish can maintain itself.

In the Athabaska drainage, there is no native cutthroat and here the rainbow has taken a firm hold. In the McLeod and its tributaries, they are enormously abundant. But this water is poor in food and too cold for rainbows. As a result, it is rare, indeed, to catch one over two ounces in weight. These poor little dwarfs actually mature and spawn, grow old and die, without achieving legal length.

We must conclude that most Alberta streams are not suited to rainbow trout, but that some of our lakes are. It is possible that the migratory habits of rainbow explain, in part, why they have disappeared from streams and remained in lakes.

With brown trout we have had better success. This fish seems able to establish breeding populations in cutthroat streams possibly because it spawns at a different time of year. It has also proved suitable in warmer streams which previously contained no trout.

Similarly, brook trout, with different spawning season and habits than cutthroat, can establish themselves among them. Also, many of our waters are too cold to make good cutthroat streams and here brook trout should be tried. Recent trials on the Sheep and Highwood and Elbow look very promising.

### CONCLUSION

What is the hatchery man to conclude from all this? Is the hatchery no good and should it be abandoned? Or, if it is some use, what should our planting policies be?

I would say the hatchery is definitely necessary to a sport fishery, but it should be used differently than it has been in the past.

We should not regard the hatchery as a machine to turn out fish for anglers to catch. We cannot afford to raise legal fish and we have not the facilities to plant them in all streams before the fishing season opens. This provides poor fishing anyway—7-8 inch fish weighing two ounces—and we now have better fishing from native stocks. Instead, we should look upon the hatchery as first, an experimental instrument, and second, as an "ace-in-the-hole" in case of disaster.

With regard to the first use, as an experimental instrument: if a stream is providing fishing, it is useless to plant fish in it. But if there is reason to believe another species would give better fishing, then use the hatchery, e.g., brook trout in the Macleod and upper Bow tributaries where the present trout make a poor showing in the cold water.

Or, where there are no native trout, the hatchery may be used to try and establish a population. Once a spawning population is established, the hatchery's task is done.

Or, in lakes and, perhaps, in some streams, where a hatchery-introduced population has no spawning grounds, annual plantings may be necessary and desirable.

The second use of the hatchery is as an "ace-in-the-hole". Our east slope streams are subject to natural disasters, particularly seasons when the water may be very low in the fall. As our native trout winter in the small streams, very severe, perhaps complete winter kills may result. The hatchery should always have on hand a supply of native trout to re-establish such streams.

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# Trout Fisheries in New Zealand—Their Development and Management

Review by

**A. L. Pritchard**

(Director of Fish Culture Development, Department of Fisheries)

*Trout Fisheries in New Zealand—Their Development and Management.* By Derisley F. Hobbs. New Zealand Marine Department, Fisheries Bulletin No. 9. Wellington, 1948. 175 pages, 31 plates, 4 text figures.

This paper written by an author who has established an enviable reputation for careful and wide scrutiny of literature, for meticulous attention to the detail of his data, for sound and conservative conclusions and for clear simple presentation, is certainly one of the most, if not the most, comprehensive recent publication on the problems of trout fishery development. While the material refers particularly to New Zealand, the principles enunciated have world-wide application and should be seriously considered by all those involved in the study of fish culture in the broad sense.

In this book the practices used for the maintenance of trout stocks in New Zealand are reviewed in the light of recent research both there and in other countries. Past operations are appraised and suggestions made for future policy. It is evident that much information is wanting to settle controversial problems but the presentation serves a useful purpose in drawing attention to the gaps in the essential knowledge.

Four main subjects are treated:

- I—*Historical*.—Including a review of the administrative organization in the country, the general history of the fish introductions and the factors which have affected the development of the fisheries. The latter involves a discussion of environmental changes such as erosion, vegetation, water diversion, pollution, etc., the history of the trout stocks, their behaviour and changes in abundance, and the development and distribution of angling.
- II—*Recent Management of the Fisheries in New Zealand*.—Herein the author presents an analysis of the expenditures and incomes from the fisheries, the theoretical basis of hatchery policy, the scope and nature of their operation, an analysis of losses in artificial propagation in all stages compared with those in nature and a discussion of the significance of the quantities produced in hatcheries.
- III—*Recent Investigational Work on Fisheries Management in Other Countries*.—This section brings together most of the information from investigations comparing the results of artificial and natural propagation. Losses of artificially propagated trout after liberation are discussed. The relative values of the use of fry, fingerlings or older fish are presented as well as the stocking of lakes by hatcheries.

IV—*Future Management and Development of Fisheries.*—After reviewing past stocking and exploitation, the author discusses the development of new fisheries and the management of existing ones. Complete analysis is presented of the possible use of hatcheries, the chemical improvement of environment through control of pollution and fertilization, etc., the biological improvement of conditions by introduction of food organisms and control of predators and competitors, and the physical improvement of environment toward gaining better spawning grounds, increased cover, etc. Under Fisheries Protection, the subjects of poaching, fish salvage and the effect of regulations are treated at length, finally turning to the question of administration.

Supporting data for some of the conclusions are included in five short appendices at the end of Hobb's report.

The following conclusions are reached on the basis of the available evidence:

- (1) There is no evidence which suggests that throughout New Zealand in the last sixty years there has been a progressive deterioration in the capacity of most waters to produce trout.
- (2) The available evidence is against the view that any serious deterioration of stocks has occurred in the last fifty years. The average size of brown trout has been fairly well maintained. A tremendous increase in total angling effort has taken place since before 1900. There is no doubt that in many waters there has been a sustained higher yield than in early times but the sharing of this yield among more anglers may have caused a drop in the catch of the individual.
- (3) The demand for angling appears to have increased more than proportionately to the increase in population.
- (4) Geographic distribution of angling does not follow the spread of human population but is greatly conditioned by the quality of fishing.
- (5) In most districts the major portion of the revenue has been used in hatchery work.
- (6) In the initial *acclimatization phase* when new species were being introduced and spread, hatcheries were useful for reception of eggs and assembly of stocks for distribution.
- (7) From small seedings, stocks have developed well or poorly in accordance with the suitability of environments for natural propagation, growth and survival. The present distribution and density of populations represent this suitability rather than the extent of releases of artificially propagated fish.
- (8) For the *maintenance of stocks*, artificial propagation in New Zealand does not add significantly to the total quantity of trout since it is not usually an appreciably more efficient process than natural.

- (9) Eggs have been collected from most easily obtainable wild stocks rather than from unexploited populations or from those where there is poor expectation of survival.
- (10) Exploitation of stocks for eggs includes cases where not only the fish stripped but many others were denied access to the good spawning grounds thereby. In one case, however, the eggs removed were in excess of what could have been accommodated by the available beds.
- (11) Artificial propagation even at great cost, can only be applied to a small fraction of the total eggs produced. For this reason, even if it were applied only in waters where there was an extremely high expectation of loss, it could not cause a significant increase in total stocks.
- (12) The transfer of hatchery eggs which comprised only small fractions of those available in very few waters, has affected only a nominal reduction in the collection district and has made only nominal additions to populations in the locality of release.
- (13) In certain lakes where survival conditions are good, small fisheries have been maintained by transfers of fish some of which were drawn from hatcheries.
- (14) Preoccupation with artificial propagation of a fragmentary number of total eggs has led to neglect of reasonable protection of the natural spawners and their progeny and of other possibilities of management certainly not more speculative than artificial propagation.
- (15) Bag limits appear to have had no general significant general effect in the conservation of stocks and size limits have had a possibly significant influence only in certain waters.

The author maintains that in addition to changes in the administrative machinery, three things are necessary if fisheries management is to be put on a sound basis.

"The first of these is for a modest appreciation of the limited extent of present knowledge. The second is for a realization of the meagre extent of the resources and powers with which man seeks to maintain or modify stocks. Thirdly, there is need for the abandonment of measures based on assumptions and their replacement in part by measures warranted by existing knowledge, and, in part, experimentally, by those provisional measures indicated as most promising by such evidence as is available."

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# The Canadian Fish Culturist



A Department of Fisheries Publication

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Requests for earlier issues of the Canadian Fish Culturist continue to be received. A limited number of copies for the issue of May, 1949, remain on hand and distribution will be made on request until the supply runs out. However, no copies of earlier issues are now available.

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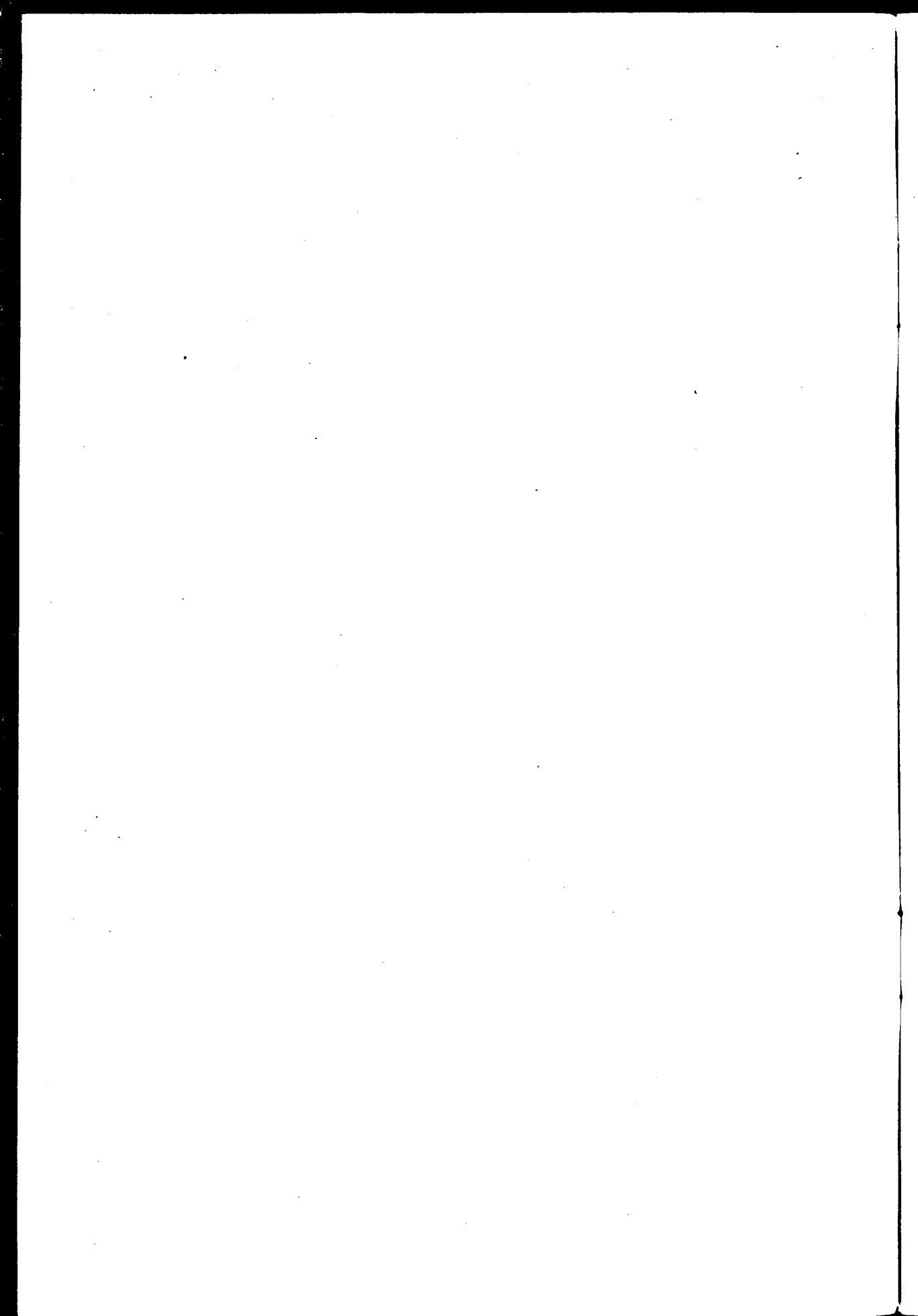
# The Canadian Fish Culturist

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## The Grayling (*Thymallus signifer*) in Northern Saskatchewan

by

D. S. Rawson

*Professor of Biology, University of Saskatchewan, Saskatoon.*

The grayling (*Thymallus signifer*) is a fine game fish and one of the few in Saskatchewan that can be taken consistently with fly tackle. Since it occurs only in the northern third of the province it has until recently been little known. Varied and conflicting reports have been heard as to its appearance, habits and game qualities. Now that air transportation has made accessible many northern waters, anglers are discovering the pleasures of grayling fishing. For these reasons, the Fisheries Branch of the Saskatchewan Department of Natural Resources has undertaken investigations of the game qualities, present distribution and fish culture possibilities of the grayling. Early observations have suggested that its range might be extended southward and tests are now in progress.

### Distribution

Grayling are found in considerable numbers around the shores of our large northern lakes and in many of the tributary streams. From Lake Athabaska we have specimens and records from the north and south shores and especially from the east end. Black Lake and Sullivan Lake, both connecting with the Fond du Lac River near Stony Rapids, are known to have large numbers of grayling. In June, 1949, excellent fly fishing for grayling was found below Woodcock Falls on the Fond du Lac River, 15 miles above Stony Rapids. Specimens from Wollaston Lake have been taken mostly from the southwest but they are found in the outlet, Fond du Lac River, both above and below Hatchett Lake. They are present also in the Cochrane and Geikie Rivers and abundant in High Rock Lake, one of the headwaters of the Geikie. Reindeer Lake specimens come from Brochet at the north, Boundary and Tate Islands in the central part and Southend near the outlet. It was in the latter area that large spawning individuals were taken in May 1948 and 1949. The Reindeer Lake grayling are so large that they are often taken in the commercial gill nets of 5½-inch stretched mesh. Cree Lake, about 120 miles west of Reindeer, also contains grayling.

The records of grayling from streams south of these four large lakes are difficult to verify. They occur in the Clearwater River which rises in Saskatchewan and flows northwest to meet the Athabaska at McMurray. Specimens have been taken at Preston Lake, near the headwaters of the Clearwater and at Portage La Loche, near the Alberta boundary. There have been persistent rumours of grayling in the Mudjatick River and other streams in

the northern half of the Churchill drainage but it has not yet been possible to verify these. They are said to be found in Upper Foster Lake which is close to High Rock Lake mentioned above. They are known to occur in the Reindeer River below the Whitesand dam (nine miles south of Reindeer Lake) but we have no records of grayling taken between this point and the junction with the Churchill River. Thus grayling distribution in Saskatchewan can be said to be wide in the Athabaska drainage, general in the Reindeer Lake area and doubtful in the remainder of the Churchill drainage. It should be noted that Wollaston Lake is centrally located and drains into both the Athabaska and Reindeer systems. At the present time the outflow to Reindeer Lake through the Cochrane River is about twice that which leaves via the Fond du Lac River.

The waters in which grayling now occur appear to be much like those on other parts of the Pre-Cambrian Shield as far south as the Churchill River. It seems reasonable, therefore, to attempt the extension of its range by planting in such places as Lac la Ronge and Amisk Lake (near Flin Flon). Further encouragement may be taken from the fact that a closely related subspecies thrives in Montana.

### Life History and Rate of Growth

The spawning run of grayling was observed at Rocky Falls on the Reindeer River, about five miles south from the outlet of Reindeer Lake. In 1948, spawning had begun by May 26 and was complete by May 30. In 1949 it began about May 25 and was complete by June 2. At this season Reindeer Lake was still mostly covered by ice and the temperature of the river water at the point of spawning ranged from 7.0° to 9.5°C. (44.6 to 49.1°F.). Most of the fish in spawning condition were taken in water from three to 10 feet deep, over gravel or rocky bottom, and in relatively quiet areas close to eddies or rapids. They were more abundant just above the rapids than below them. In other locations in northern Saskatchewan, grayling are reported to run into the mouths of small streams for spawning. There are no small streams near Rocky Falls and it is believed that spawning occurs on the rocky bottom of the main river.

Brown (1938a) notes that the grayling in high lakes in Montana usually spawn between May 15 and June 20. In these lakes the spawning is limited to a few days and often follows immediately after the ice goes out. The general observation is that stream populations in Montana spawn earlier (April and May) and that the spawning period extends over a longer period than that in lakes.

The run of grayling at Rocky Falls in 1948 and 1949 was made up of large individuals. They ranged from 16 inches (fork length), 2.1 pounds to 19.8 inches, 3.8 pounds. The average was about 17 inches, 2.8 pounds. Most of these fish were five and six years old with a few four and one seven years. A typical pair of spawning fish, five years old, is shown in the photograph, Figure 1. The male was 18 inches in length and weighed 2.5 pounds. The

female was of the same length, 18 inches, but distended with eggs and therefore heavier, weighing three pounds. Of special interest is the marked difference in the dorsal fins. That of the male is much longer, extending back to the adipose. It is also low in front and high behind. The female dorsal is shorter, about 1.5 inches short of the adipose, and unlike that of the male it is high

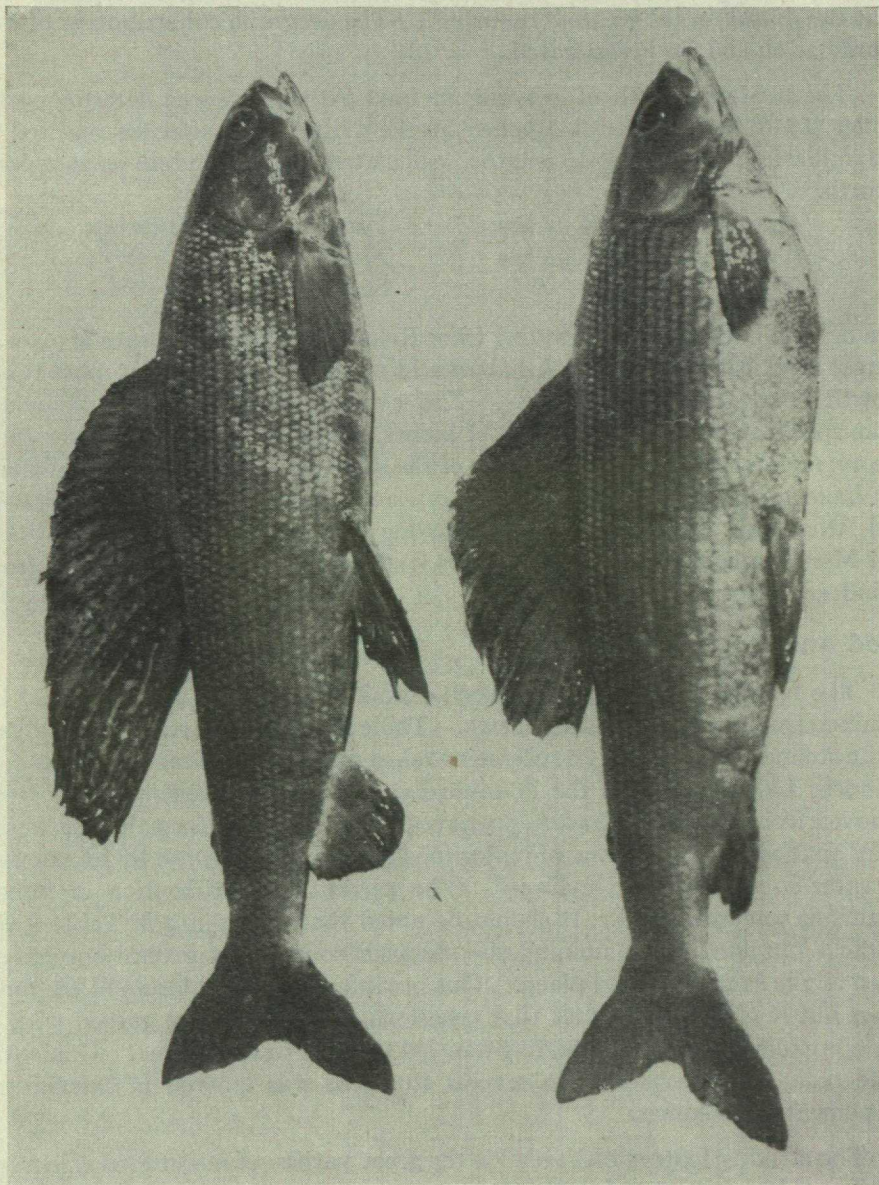


Figure 1.

A pair of spawning grayling from Reindeer Lake, May 24, 1949. Male above 18 inches long 2.5 pounds, female below 18 inches and three pounds.

in front and low behind. This sexual dimorphism was found constant in all sexually mature specimens from Reindeer and Wollaston Lakes. It was not evident in immature specimens nor in one male from Lake Athabaska, which was approaching maturity. This difference has not been recorded by Miller (1946) in grayling from Great Bear Lake nor is it mentioned in various papers which the writer has examined, although Jordan and Evermann (1896) say that the dorsal fin is "greatest in males". The geographic distribution of this character should be investigated.

The rate of growth of grayling in Lake Athabaska was determined by Miller (1946) from material supplied by the writer. His analyses resulted in the following average fork lengths, calculated at the end of each year's growth.

|           |            |            |             |
|-----------|------------|------------|-------------|
| One year  | 4.4 inches | Four years | 12.0 inches |
| Two years | 7.5 inches | Five "     | 13.7 "      |
| Three "   | 10.0 "     | Six "      | 14.8 "      |

Age determinations for 26 grayling from Reindeer Lake show a rate of growth almost identical with that of Athabaska in the first two years but more rapid growth from three to six years. The average length of eight Reindeer Lake specimens five years old was 17 inches, which is two inches longer than the average for Athabaska specimens of the same age. Grayling from Wollaston Lake appear to have a growth rate intermediate between those of Reindeer and Athabaska. Great Bear Lake grayling grow more slowly (Miller 1946) and Montana lake grayling (Brown 1943) about the same rate as those from Reindeer Lake.

### Food and Angling Qualities

The food of the grayling has been examined whenever samples could be obtained from northern Saskatchewan. Table I presents the results of analysis of the stomach contents of 26 specimens taken from Athabaska, Wollaston and Reindeer Lakes and from the Fond-du-Lac River. The food materials were removed from the stomachs and preserved in five per cent formalin for laboratory analysis. The volume of major food items was measured by immersion in water in a graduated cylinder. The percentage contribution of minor organisms was estimated. It should be noted that the figures in Table I are averages obtained by combining the stomach contents of several specimens taken at the same time and place. This provides a general picture of the food taken but it obscures the fact that occasional specimens were gorged with a single organism, e.g. some grayling had fed only on caddis larvae. Unidentifiable organic matter found in several stomachs was ignored in calculating the percentage volumes.

The striking feature of Table I is the great variety of insect food taken by grayling. More than 36 families were represented and a much larger number of species. Terrestrial insects often made up more than 50 per cent of the stomach contents and usually exceeded the volume of aquatic insects present. Ants and beetles were predominant but almost all kinds of terrestrial insects

**Table I.**  
**Stomach Contents of Grayling from Northern Saskatchewan (Expressed as percentage of total volume)**

| Number of Specimens<br>Length, inches             | Lake<br>Athabaska             |                              | Fond-du-<br>Lac. R.           | Wollaston<br>Lake            |                               | Reindeer<br>Lake             |                              |
|---------------------------------------------------|-------------------------------|------------------------------|-------------------------------|------------------------------|-------------------------------|------------------------------|------------------------------|
|                                                   | 4<br>12-16<br>June 26<br>1943 | 3<br>11-13<br>Aug. 8<br>1945 | 3<br>13-15<br>June 20<br>1949 | 2<br>8-15<br>Aug. 20<br>1949 | 4<br>10-14<br>Aug. 12<br>1946 | 5<br>16-17<br>May 30<br>1948 | 5<br>17-18<br>May 24<br>1949 |
| <b>TERRESTRIAL INSECTS</b>                        |                               |                              |                               |                              |                               |                              |                              |
| Orthoptera—                                       |                               |                              |                               |                              |                               |                              |                              |
| Locustidae (Grasshoppers).....                    | —                             | 14                           | —                             | 12                           | 8                             | —                            | —                            |
| Tettigoniidae (Longhorned Grass-<br>hoppers)..... | —                             | —                            | 3                             | —                            | 6                             | —                            | —                            |
| Coleoptera—                                       |                               |                              |                               |                              |                               |                              |                              |
| Carabidae (Ground beetles).....                   | —                             | +                            | 5                             | +                            | —                             | —                            | —                            |
| Silphidae (Carion beetles).....                   | —                             | —                            | —                             | 2                            | —                             | —                            | —                            |
| Elateridae (Click beetles).....                   | 6                             | 8                            | —                             | —                            | —                             | —                            | —                            |
| Buprestidae (Metallic borers).....                | +                             | —                            | —                             | —                            | 5                             | —                            | —                            |
| Scarabaeidae (Dung beetles).....                  | 10                            | —                            | —                             | 1                            | —                             | —                            | —                            |
| Cerambycidae (Long-horn beetles)                  | —                             | —                            | —                             | 2                            | 10                            | —                            | —                            |
| Chrysomelidae (Leaf beetles).....                 | +                             | 2                            | +                             | —                            | —                             | —                            | —                            |
| Curculionidae (Snout beetles).....                | —                             | 6                            | —                             | —                            | —                             | —                            | —                            |
| Hemiptera—                                        |                               |                              |                               |                              |                               |                              |                              |
| Pentatomidae (Stink bugs).....                    | +                             | —                            | —                             | —                            | —                             | —                            | —                            |
| Aradidae (Flat bugs).....                         | +                             | —                            | 2                             | —                            | —                             | —                            | —                            |
| Miridae (Plant bugs).....                         | —                             | —                            | —                             | 27                           | —                             | —                            | —                            |
| Homoptera—                                        |                               |                              |                               |                              |                               |                              |                              |
| Cicadellidae (Leaf hoppers).....                  | —                             | 2                            | —                             | 1                            | —                             | —                            | —                            |
| Neuroptera—                                       |                               |                              |                               |                              |                               |                              |                              |
| Sympherobiidae.....                               | —                             | —                            | —                             | 2                            | —                             | —                            | —                            |
| Diptera—                                          |                               |                              |                               |                              |                               |                              |                              |
| Bibionidae (March flies).....                     | +                             | —                            | —                             | —                            | —                             | —                            | —                            |
| Rhagionidae (Snipe flies).....                    | —                             | —                            | —                             | +                            | —                             | —                            | —                            |
| Anthomyiidae.....                                 | +                             | +                            | —                             | 1                            | —                             | —                            | —                            |
| Muscidae (House flies).....                       | 20                            | —                            | —                             | 2                            | +                             | —                            | —                            |
| Hymenoptera—                                      |                               |                              |                               |                              |                               |                              |                              |
| Tenthredinidae (Sawflies).....                    | —                             | 2                            | 2                             | —                            | —                             | —                            | —                            |
| Formicidae (Ants).....                            | 7                             | 15                           | 10                            | 15                           | 30                            | —                            | —                            |
| Apidae (Honey bees).....                          | —                             | 3                            | —                             | —                            | —                             | —                            | —                            |
| Ichneumonidae (Ichneumons).....                   | +                             | —                            | —                             | 1                            | —                             | —                            | —                            |
| Total Terrestrial Insects.....                    | 43                            | 52                           | 22                            | 56                           | 59                            | 0                            | 0                            |
| <b>AQUATIC INSECTS</b>                            |                               |                              |                               |                              |                               |                              |                              |
| Plecoptera (Stone flies).....                     | 12                            | —                            | 2                             | —                            | —                             | 10                           | —                            |
| Ephemeroptera (May flies).....                    | 4                             | —                            | 9                             | +                            | —                             | 5                            | 35                           |
| Odonata—                                          |                               |                              |                               |                              |                               |                              |                              |
| Zygoptera (Damsel flies).....                     | —                             | —                            | —                             | 3                            | —                             | —                            | —                            |
| Anisoptera (Dragon flies).....                    | —                             | 18                           | —                             | 18                           | +                             | —                            | —                            |
| Coleoptera—                                       |                               |                              |                               |                              |                               |                              |                              |
| Dytiscidae (Diving beetles).....                  | —                             | +                            | 6                             | —                            | —                             | —                            | —                            |
| Gyrinidae (Whirligig beetles).....                | —                             | —                            | 4                             | —                            | —                             | —                            | —                            |
| Hydrophilidae (Scavenger beetles)                 | —                             | 4                            | 6                             | —                            | 4                             | —                            | —                            |
| Hemiptera—                                        |                               |                              |                               |                              |                               |                              |                              |
| Gerridae (Water striders).....                    | —                             | —                            | 2                             | —                            | —                             | —                            | —                            |
| Notonectidae (Back swimmers)...                   | +                             | —                            | 1                             | —                            | —                             | —                            | —                            |
| Corixidae (Water boatmen).....                    | 4                             | 5                            | 12                            | 1                            | —                             | +                            | —                            |
| Trichoptera (Caddis flies).....                   | 6                             | 15                           | 21                            | 4                            | —                             | 60                           | 55                           |
| Diptera—                                          |                               |                              |                               |                              |                               |                              |                              |
| Simuliidae (Black flies).....                     | 6                             | —                            | —                             | 4                            | —                             | —                            | —                            |
| Chironomidae (Midges).....                        | —                             | —                            | 5                             | 1                            | 2                             | —                            | —                            |
| Total Aquatic Insects.....                        | 32                            | 42                           | 68                            | 26                           | 6                             | 75                           | 90                           |
| <b>MISCELLANEOUS ORGANISMS</b>                    |                               |                              |                               |                              |                               |                              |                              |
| Spiders.....                                      | —                             | —                            | —                             | 14                           | 15                            | —                            | —                            |
| Oligochaeta (Earthworms).....                     | 3                             | —                            | —                             | —                            | —                             | —                            | —                            |
| Hirudinia (Leeches).....                          | 22                            | —                            | —                             | —                            | —                             | —                            | —                            |
| Gordiacea (Hair Worms).....                       | —                             | 6                            | —                             | 3                            | 8                             | —                            | —                            |
| Amphipoda (Shrimps).....                          | —                             | —                            | —                             | —                            | 12                            | —                            | +                            |
| Fish eggs (Grayling).....                         | —                             | —                            | —                             | —                            | —                             | 15                           | 2                            |
| Plant materials.....                              | —                             | +                            | 10                            | —                            | —                             | 10                           | 8                            |
| Total Non-insect Food.....                        | 25                            | 6                            | 10                            | 17                           | 35                            | 25                           | 10                           |

and spiders were taken when available. Aquatic insects such as caddis, mayflies, stoneflies and dragonflies were important food items. The specimens taken at Rocky Falls in late May 1948 and 1949 had fed almost entirely on caddis larvae and mayfly nymphs. At that season, with the ice just gone from the lake, little or no terrestrial food was available. At this time also the grayling had eaten moderate numbers of their own eggs, a situation similar to that observed by Brown (1938b) in Montana lakes. Of the non-insect foods taken, spiders, leeches and hair worms predominated. Field notes on stomachs examined but not measured, indicate that amphipods and cladocerans are of considerable importance as grayling food, especially in the first and second years. Plant materials found in the stomachs have been calculated as part of the food volume but it is somewhat doubtful whether these were taken as food or by accident.

Detailed studies of the food of the grayling have been made in Montana waters by Brown (1938b) and in Ford Lake, Michigan, by Leonard (1938 and 1939). Both investigators found a great variety of insect food similar to that recorded above for Saskatchewan grayling. The habit of feeding on whatever may be available is emphasized by Leonard's observation (1938) of great differences between the morning and evening food of grayling from one location. Miller (1946) lists a varied diet for the grayling in Great Bear Lake and indicates that terrestrial insects are the principal summer food.

The omnivorous habits of the grayling and especially the wide variety of insects eaten, are directly related to its qualities as a "fly fishing" species. Tests of its angling qualities in northern Saskatchewan were made in June 1949, by N. Ferrier who visited Stony Rapids, Cree Lake and Wollaston Lake areas. He reports that a great variety of artificial flies, tied on number 10 and 12 hooks, were successful in taking grayling. Using a light seven-foot fly rod and light line he found that fish from one to two pounds provided excellent sport, comparable in his opinion to that furnished by eastern-brook or rainbow trout.

### **Spawning and Rearing Operations**

Grayling eggs were collected in 1948 and 1949 by Mr. F. S. Mitchell of the Saskatchewan Fisheries Branch. These were taken at Rocky Falls five miles south of the outlet of Reindeer Lake. The parent stock was caught in gill nets of four and one-half inch mesh and number 90 thread. They were then transferred to wire retainers of one-inch bar mesh. The grayling were tightly gilled in the nets and suffered some damage but the location was such that traps could not be used. By clearing the nets at frequent intervals it was possible to keep alive about 80 percent of the fish caught and to use them later for spawning.

The fish were spawned by the usual technique and fertilized by the "dry" method. Most of the females produced between 4,000 and 7,000 eggs but a few of the largest yielded more than 10,000 per fish. The eggs when taken measured 10 to the inch but after several hours of "hardening" they increased

to six to the inch. They were non-adhesive and heavy, sinking quickly in water. The males produced a very small quantity of milt and it was found advisable to use the milt of one male for the eggs of not more than two females.

The eggs reached the eyed stage in about 12 days after fertilization and in water of 7 to 9°C. (44.6 to 48.2°F.) Hatching required an additional 4 to 6 days in temperatures which ranged from 9 to 11°C. (48.2 to 51.8°F.). The yolk sac was absorbed in about eight days after hatching. Various workers have had difficulty in feeding the minute grayling fry. Brown (1938a) reports success with beef liver or heart ground repeatedly through a plate with 1/64-inch openings. In the absence of suitable equipment for this procedure the fry was fed for the first three days on commercial goldfish food. After this time the goldfish food was supplemented with a mixture of alfalfa meal, milk powder and soy bean meal which they ate readily for several weeks. They were later given liver prepared with an ordinary grinder but appeared to take very little of it. The fry were released on the fourth week at which time they were from 1 to 1½ inches in length.

In early June 1948, Mr. R. W. Davis, manager of the Hudson's Bay Mining and Smelting power plant at Island Falls, was given about 150 eyed eggs from which he hatched 77 grayling fry. These were fed for one month on goldfish food and later with ground beef and a weekly feeding of liver. During the summer this was supplemented by insects, molluscs and shrimps collected from the intake screens at the power plant. The fish were held in two concrete tanks each 3 x 4 x 10 feet. Each tank received a generous supply of running water. This came in from above as a jet which carried plenty of oxygen and circulated it through the water. The water temperature varied from 0.5°C. (32.9°F.) in winter to 21°C (69.8°F.) in summer. The fish were fed successfully throughout the year and when examined by the writer on May 25, 1949, they ranged from 4.5 to 7.0 inches in length and were in excellent condition. Mr. Davis hopes to expand his rearing facilities and to assist if possible in establishing grayling in the Island Falls area.

### Distribution

In the 1948 operation 400,000 grayling eggs were taken. A first shipment of these was taken by plane to Island Falls where 75,000 eyed eggs were placed in Flanagan Lake and the remainder to Flin Flon where 75,000 were planted in Amisk (Beaver) Lake. At the same time six adult grayling were released in Flanagan Lake. The second lot of 250,000 eyed eggs was taken to Lac la Ronge and planted near the outlet of the lake. Eight adult fish, four males and four females, were also released in Lac la Ronge.

The 1949 operations were hampered by severe weather conditions but approximately 200,000 eggs were taken. Some of these were taken to Lac la Ronge where a small hatchery had been set up. Sixty-thousand fry were hatched and 56,000 of these were released in Lac la Ronge near the hatchery site. Four thousand were fed for about five weeks then transferred to the Montreal River (outlet of Lac la Ronge) where they were released below the

Nistowiak Falls. A further lot of nine adult grayling 15 to 18 inches long had been released in Lac la Ronge near the mouth of the Montreal River when the eggs were brought in by plane.

It is, of course, too early to predict the result of these transfers of grayling southward within the Churchill River drainage. Progress to date has been satisfactory and no unfavourable conditions have been encountered.

### Acknowledgement

The writer is indebted to the Saskatchewan Department of Natural Resources for the opportunity to participate in the grayling work. He wishes to commend Fisheries Officer F. S. Mitchell for his excellent work in the field, much of it carried on under difficult conditions.

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## National Parks Creel Census

by

V. E. F. Solman

*Chief Biologist, Dominion Wildlife Service*

The idea of recording angling catches is at least several hundred years old, even on this continent, since many historical accounts record catches made by explorers.

The idea of recording the number of fish caught from water areas as a measure of the productivity of the areas for fish is also well over a hundred years old. Salmon angling clubs in many parts of the United Kingdom and on some of the more famous rivers of Quebec and the Maritime provinces have records of complete catches extending over many years.

These early attempts to collect information dealt with either single individuals or the membership of clubs or other rather limited organizations.

One of the first attempts to collect angling statistics regarding the catch of large numbers of anglers from extensive water areas was the collection of data regarding the length, weight and number of fish taken from the waters of the Maligne System in Jasper National Park, beginning in 1933. Angling in the area was first permitted in that year. The information regarding the catch of each angler was recorded by a person duly authorized to collect such information. At that time a part of the regulations governing angling in National Parks required that each angler make a return regarding his catch before leaving the area. The regulation is still in effect with minor modifications.

A considerable volume of data was collected in this manner and an analysis of these data has indicated that one unit of the system, Beaver Lake, is probably the most productive body of water of which we are aware in any National Park in Canada. This lake, with an area of only 90 acres and a depth of only about six feet produced, during the period 1933-1947 a total of 18,500 pounds or over nine tons of Eastern Brook Trout or an average of 13.7 pounds of trout per acre per year for a period of 15 years. Angling in the area has not been so heavy since 1942 with the result that the apparent productivity, as indicated by catch statistics has fallen.

Also in the early '30's certain areas in the U.S. began to experiment with the collection of angling catch statistics over large areas frequented by the general public.

The Vermont test-water studies (Lord 1946) were among the earliest efforts in this direction. In this operation, certain water areas were designated each year by the State legislature as "test-waters". All anglers fishing in such waters were required by law to file catch returns with special wardens

who patrolled the areas. The test-waters were changed each year and in this manner information for a considerable number of areas for one-year periods was obtained.

### **First Creel Census Operations**

One of the first creel census operations in Canada conducted in the manner now widely used throughout Canada and the United States, was that begun in Algonquin Provincial Park in Ontario in 1936, by the Ontario Fisheries Research Laboratory (Fry 1939). This was one of the first creel census operations in which emphasis was placed on the collection of data regarding individual sizes of fish caught, methods of angling and most important, time required to take fish (fishing effort). This census was begun, and is being continued, as a basic tool in the management of the game fish populations of the area. Changes in open and close seasons, angling regulations of several types, stocking schedules and other management operations are based, in large measure, on the information collected through the creel census each year supplemented by special studies conducted by fisheries investigators in areas where insufficient or inconclusive information is secured through the creel census.

Since its introduction in 1936 in Algonquin Park, the creel census system has been extended to other Provincial Parks in Ontario by the Ontario Fisheries Research Laboratory.

Creel census operations of a similar type were begun in Prince Albert National Park, Saskatchewan in 1940 and extended to five other parks in 1941. Since then other extensions of the work have been made and in 1948 creel census data were collected from 11 National Parks. These data were collected for the most part through the voluntary completion, by the anglers, of special creel census cards provided for the purpose. In some areas, where a more complete census is desirable, fisheries officers have been employed to assist in the collection of creel census data from anglers. Park wardens and other park personnel also assist greatly in inducing anglers to complete creel census cards.

A publicity campaign, begun in 1946 and expanded in 1947, in which reports on the results of the creel census operations in various parks were supplied to anglers who expressed an interest in the work has resulted in a considerable increase in the number of creel census returns. This is particularly true of certain areas. The distribution of "Anglers Guides", providing information on angling regulations, means of access to angling areas, suggestions regarding lures and other information useful to anglers, in nine National Parks has also helped to increase the volume of creel census returns.

During 1948, a total of 6,070 creel census cards were completed and returned, reporting the capture by 7,968 anglers, of 29,542 fish from 117 lakes and 68 streams in 11 National Parks. An analysis of this information, and its correlation with previous data from the same areas, enables the Dominion Wildlife Service to evaluate the success of fisheries management procedures

used in the National Parks. This also enables the Service to modify these procedures where necessary in order to ensure the most satisfactory and effective use by anglers of each water area.

### **Use of Creel Census Cards**

The creel census cards at present in use in the National Parks are the result of a series of modifications based on eight years experience and are designed to secure, in the simplest possible manner, data regarding the species of fish caught, their lengths, their numbers, the type of lure used in the capture, the time of day, and most important, the time, in hours or minutes, required for the capture. With this information available on a card from which the information can be conveniently extracted, the analysis of the data is greatly simplified.

It is possible, for instance, to plot a histogram showing the frequency of capture of fish of different sizes from any lake. If this indicates that too large a proportion of the angling catch consists of immature fish, then steps may be taken, by changing the regulations, to protect the desired portion of the fish population.

If the fishing effort, or number of hours required to capture a fish, becomes progressively greater for a given species of fish during succeeding years, this may be an indication of the imminent depletion of this species and steps may then be taken to check such depletion by whatever means may be most suitable, before it has reached serious proportions.

There has not, except in the case of the Maligne system in Jasper Park, been an attempt to collect creel census data for the total catch of fish taken by anglers from National Park waters. Indeed in many cases it is extremely difficult, for several reasons, to arrive at a satisfactory estimate of the percentage of National Park anglers who have, in the past, completed creel census cards. Until 1948, angling in the Mountain National Parks was conducted under license but free fishing privileges were granted to motorists and their families who purchased park seasonal motor vehicle permits. Since the proportion of motorists who availed themselves of the free angling privilege was not known, so the total number of anglers operating was not known.

A recent revision of the regulations, governing angling in National Parks, has abolished the free fishing privilege accorded to motorists with the result that in 1948, for the first time, the total number of licensed anglers in the mountain Parks was known. This information in conjunction with the creel census information collected from the same areas permitted the calculation, for the first time, of the total drain on the fish resources of the areas.

Distribution of fish and other management operations in the parks have been based, as far as possible, on the data available from the creel census together with those obtained by special studies of specific problems. This basis has proven quite satisfactory in a general way. The data obtained this

year on total angling catch will, I believe, permit further refinements in the management programme with still more favourable results.

Beginning in 1948 in connection with and largely dependent on the creel census organization, is a programme of marking fish, by tagging and fin-clipping in order that their history from release to capture by anglers, may be studied. This programme, though only begun, has already given some interesting information regarding movement of lake trout in a large lake. The major importance of this programme lies in its bearing on hatchery operation. We do not know what contribution fish planted from hatcheries into certain water areas, make to the angling catch from those areas. We are relying on the returns of tagged and marked fish, through the creel census by licensed anglers, to give us the answers to these questions. It is quite probable that a different answer will be obtained from each water area investigated. In any event, until we have the answers, we cannot be sure that we are using our hatchery facilities and other management tools to the greatest advantage.

The development of means of recording and using angling catch statistics for the improvement of angling has extended over a long period of time and is still undergoing refinement. However, we now feel that we have the means at hand, through the National Parks Creel Census, of directing our fisheries management operations toward the production of angling which will satisfy increasing numbers of anglers.

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## A Population Estimate Based on Catch-Effort Statistics

by

D. N. Omand

*Ontario Fish and Wildlife Division*

The Department of Lands and Forests of the Province of Ontario has for some years been conducting a programme of removing smallmouth black bass (*Micropterus dolomieu*) from waters in the province where these are exceptionally abundant, but slow growing, and transporting them to waters where angling has given a low yield. The present paper concerns itself with an effort to estimate the standing crop of fish in one such harvested lake (O'Reilly Lake) on the basis of catch-effort data.

O'Reilly Lake is a small body of water of 100 acres in area lying near the edge of the Pre-Cambrian Shield in Olden township of Frontenac County. The water is quite clear, and there is no visible inlet or outlet. Springs occur occasionally along the shore. The shoreline is about 80 per cent rock with scattered areas of marsh and sand beach. The lake is surrounded by rolling, rocky farm land. Angling is limited to a few boats a week, there being no public road to the lake.

The work was begun on August 1, 1949, and fishing was continued for 18 days. During that time, 1,893 bass were removed from O'Reilly Lake for planting elsewhere in that district.

In accordance with our usual method, trap nets were set in the lake, and catches recorded from day to day. It was found that a net set in a likely looking spot would fish well, for a few days, when catches would drop off sharply. The net was then moved, in some cases only about 200 yards, and high catches would again be reported. The entire impression was one of exploitation of a series of local populations, usually in sheltered bays. The setting of the trap net is limited to rather shallow water (up to 10 feet) and no effort at exploitation of these areas where shore water was over this depth was made.

In addition to smallmouth bass, sunfish (*Lepomis gibbosus*), suckers (*Catostomus commersonii*), pike (*Esox lucius*), and bull head catfish (*Ameiurus nebulosus*) were encountered in the lake.

In order that the fishing effort might be reduced to standard units, trap nets were used, with 100-foot leads, of  $2\frac{1}{2}$ -inch mesh and six-foot cribs of two-inch mesh. These nets are of the usual commercial type, made up for work of this nature. Nets of the same size were selected for purposes of standardization. They were lifted every day and moved when fishing began to drop off. Such nets retained no fish of less than six inches fork length, and the following

discussion therefore refers only to fish of greater size than this. For the purpose of calculation, one unit of effort is taken as one trap net set for 24 hours, and the unit of catch is one fish. The time unit is one day.

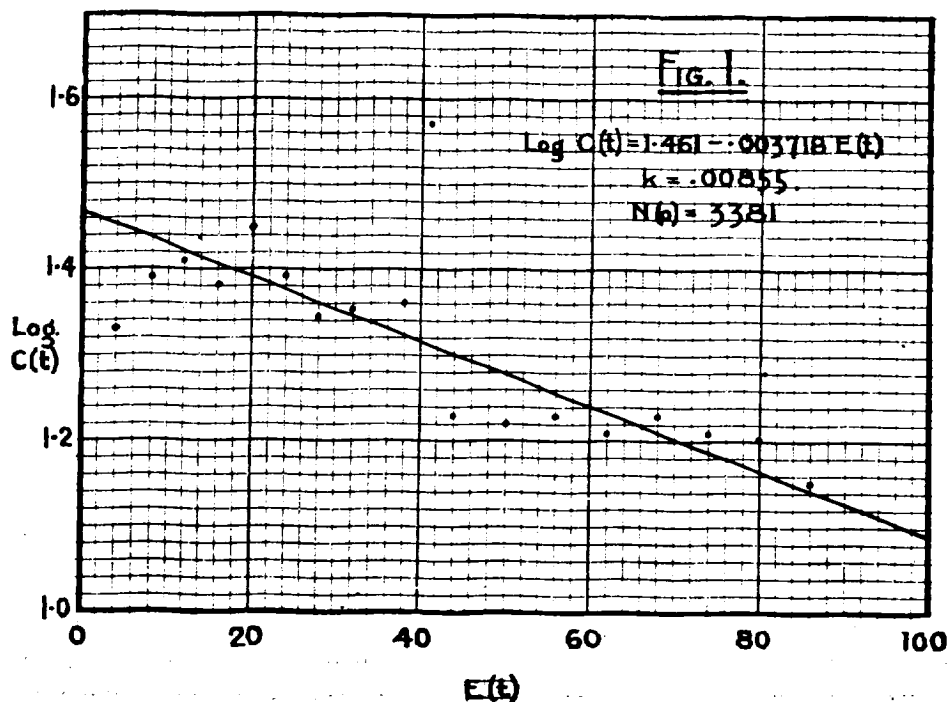
### Measured and Scale Samples Retained

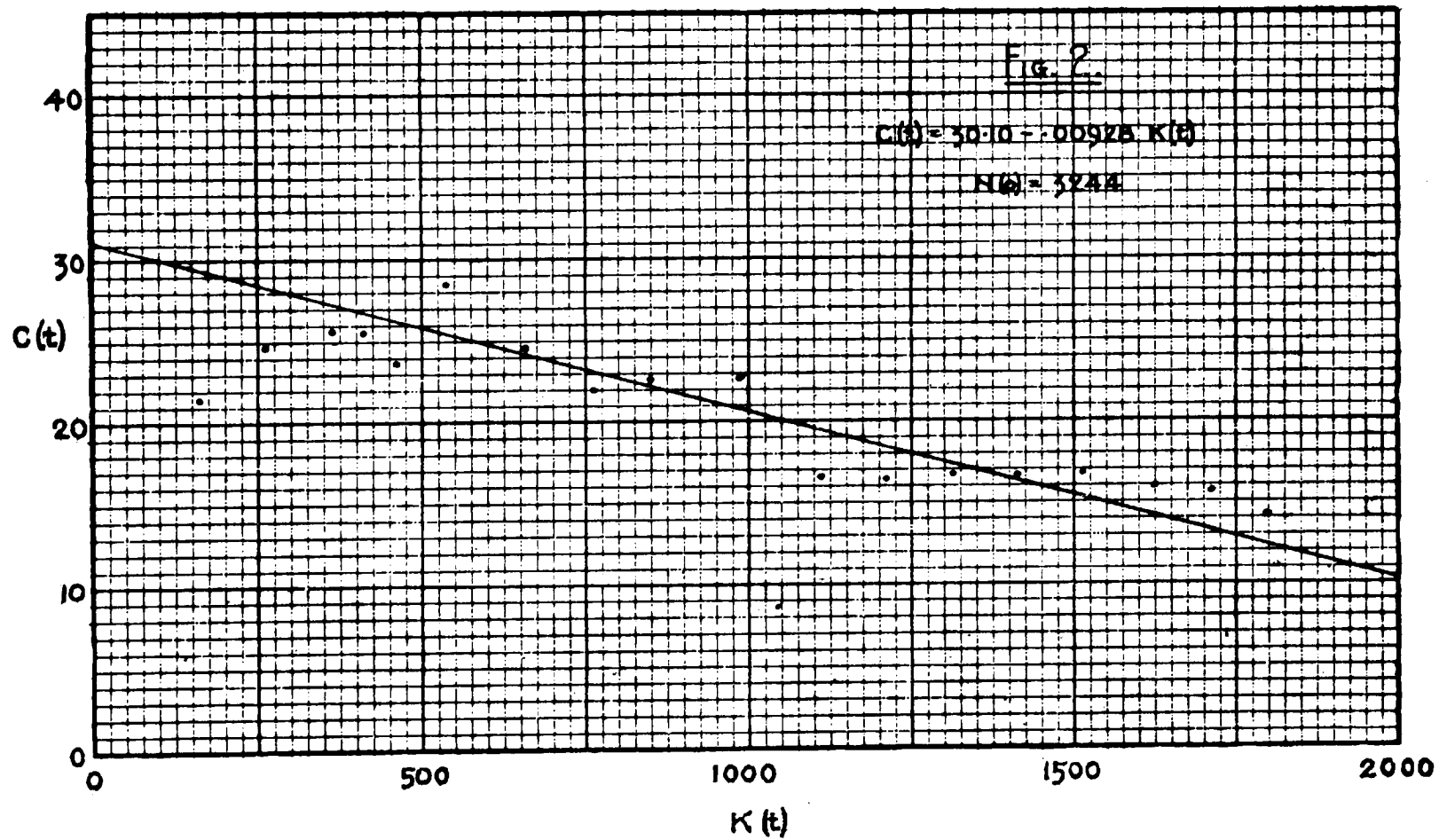
Of the 1,893 fish taken in the trap nets, 156 were measured and scale samples were retained. This sample was believed to be fairly random, and measurements were taken to the nearest half inch. The mean of this sample was  $8.84 \pm 1.52$  inches and the range was six inches to 14.5 inches. Distribution about the mean was normal except that the lower tail was cut off at six inches, the lower limit of effectiveness of the trap net.

The method of population estimation used here was described by De Lury (1947). It is based on the belief that the number of fish taken from a population by successive units of effort is governed by the total population available, and hence the population may be estimated on the basis of the observed catch per unit of effort.

De Lury bases his calculation on three assumptions.

(1) The population is closed. The effects of migration and natural mortality are negligible. An endeavour was made, by fishing intensively for the shortest possible period, to satisfy this requirement. Undoubtedly, a certain number of individuals entered the size group dealt with during the 18 days of netting, and some natural mortality and angling mortality occurred, but it is believed that this is negligible in comparison with the total of 1,893 fish removed.





(2) That the units of effort do not compete with one another. It is believed that the nets were set in such a way that no two were competing during a given time interval.

(3) That catchability, defined as the proportion of the total population remaining in the lake taken by one unit of effort, is constant. While it is expected that day to day variations such as a decreased catch after a cool night, will occur, this assumption implies the absence of trend in catchability during the sampling period. The assumption is justified to some extent by observation since a straight line relationship in Figs. 1 and 2 is admissible.

In Table I, column one refers to time interval, and column two,  $c(t)$ , to catch per unit time. Column three indicates effort per unit time and column four indicates catch per unit effort or  $c(t)/e(t)$ . Columns five and six refer to cumulative catch  $K(t)$ , and cumulative effort,  $E(t)$ , up to the time interval concerned, i.e. at  $t-1$ , and  $\log C(t)$  is self explanatory. These symbols are taken from De Lury (1947).

TABLE I.  
Catch—Effort Data of the O'Reilly Lake Bass Fishing

| 1<br>Time<br>Interval<br><br>t | 2<br>Catch Per<br>Unit Time<br><br>c(t) | 3<br>Effort Per<br>Unit Time<br><br>e(t) | 4<br>$C(t) = \frac{C(t)}{e(t)}$ | 5<br>Cumulative<br>Catch<br><br>K(t) | 6<br>Cumulative<br>Effort<br><br>E(t) | 7<br>log C(t) |
|--------------------------------|-----------------------------------------|------------------------------------------|---------------------------------|--------------------------------------|---------------------------------------|---------------|
| 1                              | 167                                     | 4                                        | 41.75                           | 0                                    | 0                                     | 1.623         |
| 2                              | 86                                      | 4                                        | 21.5                            | 167                                  | 4                                     | 1.33          |
| 3                              | 98                                      | 4                                        | 24.5                            | 253                                  | 8                                     | 1.39          |
| 4                              | 102                                     | 4                                        | 25.5                            | 351                                  | 12                                    | 1.41          |
| 5                              | 95                                      | 4                                        | 23.75                           | 453                                  | 16                                    | 1.38          |
| 6                              | 114                                     | 4                                        | 28.5                            | 548                                  | 20                                    | 1.45          |
| 7                              | 98                                      | 4                                        | 24.5                            | 662                                  | 24                                    | 1.39          |
| 8                              | 88                                      | 4                                        | 22.0                            | 760                                  | 28                                    | 1.34          |
| 9                              | 133                                     | 6                                        | 22.2                            | 848                                  | 32                                    | 1.35          |
| 10                             | 137                                     | 6                                        | 22.8                            | 981                                  | 38                                    | 1.36          |
| 11                             | 101                                     | 6                                        | 16.8                            | 1118                                 | 44                                    | 1.23          |
| 12                             | 99                                      | 6                                        | 16.5                            | 1219                                 | 50                                    | 1.22          |
| 13                             | 101                                     | 6                                        | 16.8                            | 1318                                 | 56                                    | 1.23          |
| 14                             | 98                                      | 6                                        | 16.4                            | 1419                                 | 62                                    | 1.21          |
| 15                             | 101                                     | 6                                        | 16.8                            | 1517                                 | 68                                    | 1.23          |
| 16                             | 97                                      | 6                                        | 16.2                            | 1618                                 | 74                                    | 1.21          |
| 17                             | 94                                      | 6                                        | 15.7                            | 1715                                 | 80                                    | 1.20          |
| 18                             | 84                                      | 6                                        | 14.0                            | 1809                                 | 86                                    | 1.15          |
|                                |                                         |                                          |                                 | 1893                                 | 92                                    |               |

If the three assumptions indicated above are admissible, De Lury has shown that  $\log C(t) = \log [k N(o)] - k \log e E(t)$ , where  $k$  is the proportion of the remaining population captured by one unit of effort, which is constant by assumption (3) above, and  $N(o)$  is the number of fish present at time  $o$ , or at the beginning of the experiment.

Values of  $\log C(t)$  are plotted against  $E(t)$  in Fig. I. As will be seen by examining this figure, a straight line relationship is permissible throughout

the range, and a straight line was drawn through these points by the method of least squares, the equation for this line being  $\text{Log } C(t) = 1.461 - .003718 E(t)$ .  $k \log e$  may then be equated to  $.003718$ , and  $k = .00855$ . If  $\log [k N(o)]$  is then equated to  $1.415$ ,  $N(o)$  is computed to be  $3381$ . On this basis, a figure of about  $3,400$  fish of the size group dealt with is estimated for the population at the beginning of the fishing effort.

From the equation  $\log C(t) = \log [k N(o)] - k \log e E(t)$ , the equation  $C(t) = k N(o) - k K(t)$  may be derived.

As a check upon the above results,  $C(t)$  was plotted against  $K(t)$  (Fig. 2). A line was drawn through the points from  $K(t) = 0$  to  $K(t) = 2000$ , by the method of least squares and the equation  $C(t) = 30.10 - .00928 K(t)$  is derived. The intercept on the x axis then gives the total of fish in the lake at the beginning of the experiment, since this indicates the limit of catch when  $C(t) = 0$ . This figure is  $3244$ , giving a figure in some agreement with the previous estimation at the beginning of the experiment.

O'Reilly lake has an area of about  $100$  acres measured by planimeter on topographic map  $31 \frac{c}{10}$  (Tichborne). On the basis of these calculations, a standing crop of about  $30$  bass of six inches and over per acre is indicated. Such a figure is of little value, since it is obvious that not all the area of the lake is occupied by fish.

While the figure for total population is of theoretical value only without supporting evidence such as might be provided by a tagging programme, it is interesting to note that on this basis, well over half the fish in the lake were removed before catches began to fall off markedly. It is hoped that it will be possible to conduct a similar experiment in conjunction with a properly designed tagging experiment during the summer of 1950, since it would be most desirable from the practical point of view if cropping limits could be set on lakes used in this harvesting programme. Important data on recruitment might also be derived if the programme were conducted over a series of years.

The author wishes to express his gratitude to Dr. D. B. De Lury of the Ontario Research Foundation and Dr. F. E. J. Fry of the University of Toronto for a critical reading of the manuscript and to Mr. J. S. Hazzard of the Ontario Department of Lands and Forests for his work in setting and lifting the nets and recording the catch.

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## Artificial Hybridization of Eastern Brook Trout and Lake Trout

by

J. E. Stenton

Warden, Lake Minnewanka District, Banff National Park

In the fall of 1946, a successful attempt was made to cross Eastern Brook Trout, *Salvelinus fontinalis*, and the Lake Trout, *Cristivomer namaycush*. In this first attempt a female Brook trout and a male Lake Trout were used; these eggs hatched successfully, but it was noted that a few specimens had deformed caudal fins, and all of them died. The balance, unfortunately, were all lost when chlorine was introduced into the Banff water supply.

In the fall of 1947 another attempt, on a larger scale, was made to hybridize the species. In this second trial the species concerned were crossed both ways, that is, a female Lake Trout to a male Brook Trout and vice versa. The stripping was carried out by the dry method and fertilization was successful in both cases. The Lake Trout used in this experiment were netted from Lake Minnewanka, and the Eastern Brook Trout were taken from the Third Vermilion lake and transported to Lake Minnewanka, a distance of 11 miles.

In view of the difficulty with the water at the Banff Hatchery at this time, temporary troughs were set up in the rock tunnel, under the main dirt dam at Lake Minnewanka. This tunnel was used to supply water to the old power house, prior to the construction of the present dam. After the flow of water was closed off from this tunnel, the Calgary Power Company installed a wood stage pipe, two feet in diameter, inside the tunnel, with a gate valve at both ends of the line. The top end of the tunnel was then sealed with a heavy slab of concrete; this work was carried out prior to raising the level of the lake. The water now charging this wood stave pipe, and which was used in the temporary troughs, is drawn from the lake at a depth of approximately 55 feet below the present surface of the lake. Thus the water had a constant temperature which slowly declined as the winter advanced.

The water temperature, when the eggs were first introduced on October 22, was 46°F., and the air temperature in the tunnel was 50°F. These temperatures declined slowly until a minimum water temperature of 38°F. and an air temperature of 40°F. were reached on December 18, following which they remained steady through the balance of the winter. It was quite obvious that the water governed the air temperature as it remained just two degrees warmer than the water. The tunnel was in total darkness and all work was carried out with the aid of flashlights.

During the early part of November the eggs went unchecked for a period of five days. Upon returning it was found that the fungus *Saprolegnia* had attached and covered all of the eggs, and approximately 75 per cent were dead. It was also noted that a heavy cover of dead plankton was present in all baskets and covered the bottoms of the troughs. It is suspected that this was the major cause of the rapid spread of fungus on what appeared to be healthy strong eggs. A great deal of work was necessary to try and save the remaining live eggs as they were still in the tender stage. However, success crowned the efforts and it was possible to bring a number of the remaining eggs through to the hatching stage. These eggs were moved from the tunnel to the Banff Hatchery on January 24 and remained there during the balance of the incubation period.

The change from the tunnel to the hatchery resulted in another slight drop in the water temperature.

The Lake Trout—Brook Trout hybrids reached the eyed stage on December 18, 57 days after being placed in the tunnel; hatching was completed at the Banff Hatchery by March 21, 151 days from the time of fertilization. The water temperature averaged 39°F. during the period. Approximately the same number of days were required to hatch the straight lake trout eggs. The Brook Trout-Lake Trout hybrids hatched approximately 10 days earlier and the straight Brook Trout at about the same time.

All of the Brook Trout-Lake Trout hybrids died, but a number of the Lake Trout-Brook Trout hybrids are progressing satisfactorily at the Banff Hatchery.

The final results of this cross are, as yet, uncertain. The fish may prove to be sterile, and reproduction will not occur.

Water temperatures recorded in the tunnel were as follows:—

|             |       |     |       |
|-------------|-------|-----|-------|
| October 22  | 46°F. | Air | 50°F. |
| November 3  | 44°F. | Air | 46°F. |
| November 11 | 42°F. | Air | 44°F. |
| November 19 | 40°F. | Air | 42°F. |
| December 6  | 38°F. | Air | 40°F. |

Water temperature of 38°F. and air temperature of 40°F. continued throughout the balance of the winter.

The fish that were hatched in the spring of 1947 are now, at 21 months of age, ranging from 12 to 14 inches in length and are very active, rising readily for flies caste on the surface of their pool. Unfortunately none of the true fry of the parent species were retained to act as a control on the growth rate.

In general appearance the hybrids favour the lake trout, but the vermiculations of the brook trout are evident on closer examination and a row of pale yellow spots is apparent just above the lateral line. The back is a pale green colour and the under section is white with no apparent colour markings.

These species were crossed again in the fall of 1947 and showed much the same conditions as earlier work with a good percentage of the Lake trout (female) and the Brook trout (male) hatching normally. On the other hand where the sexes were reversed a fairly large number hatched with a deformed caudal fin. All died. The balance are doing nicely at the Banff Hatchery. In the case of the deformed caudal fins it is estimated that the cross resulted in a much larger embryo and the Brook trout egg was not large enough to permit normal development of this appendage.

## Recognition of Trout in Alberta

by

Richard B. Miller

Associate Professor of Zoology, University of Alberta

The trout of Alberta waters are not easy to identify. For rainbows and cutthroats, particularly, a rather elaborate series of measurements to determine relative sizes of body parts is necessary for absolute identification. However, it is possible to distinguish trout species fairly well using a colour characteristics and, in the following key, this method is used. One anatomical character has been retained; this is the nature of the teeth (vomerine teeth) borne on the vomer bone in the roof of the mouth. This is illustrated in the accompanying figure. (A similar figure was used originally by Professor J. R. Dymond).

### Descriptive Key to Alberta Trout

#### GROUP A. Chars.

Lake trout, eastern brook, Dolly Varden.

Vomer bone with teeth toward front only; spots on body pale in colour ranging from yellow to red; leading edges of paired fins white; no rainbow stripe and no black spotting; fall spawning.

#### (1) Lake trout (*Cristivomer namaycush*):

Except at spawning time (September-November), this trout never has bright colours; it is dull grey or greenish; the spots are very pale, sometimes almost grey and occur on both back and sides; the tail has a deep fork; found across Canada in deep lakes; now established in Ghost River reservoir; a slow growing fish which will not stand heavy fishing.

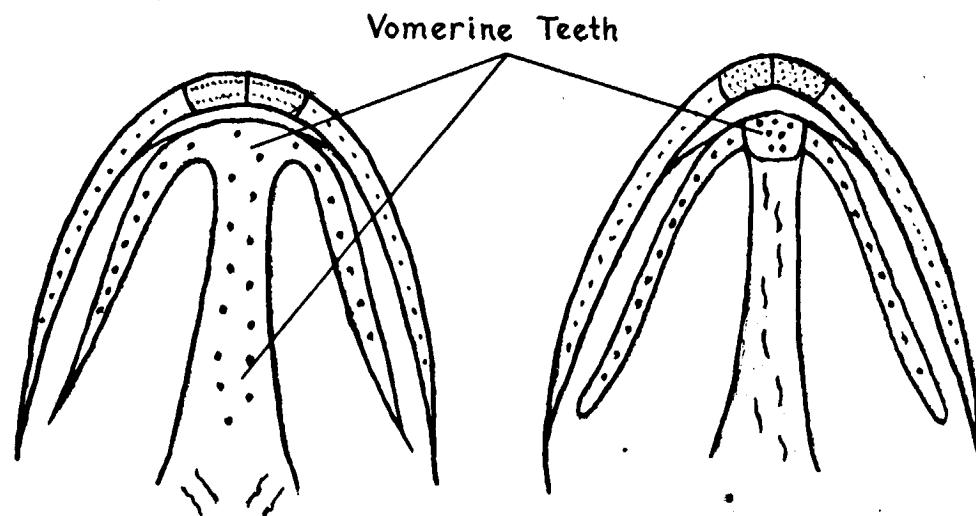
#### (2) Eastern brook (*Salvelinus fontinalis*)

Colours usually bright, sides with red spots surrounded by blue borders; back with dark wavy marks ("worm tracks"); tail either square or only slightly forked.

Native of eastern Canada as far west as Nelson River in Manitoba, introduced widely in Alberta and established in Maligne, Raven, Sheep, Highwood and Elbow Rivers.

#### (3) Dolly Varden (*Salvelinus alpinus*)

Colours duller than eastern brook; back uniformly dark; spots on sides yellow to orange or pink, without blue borders; tail forked but not so deeply as lake trout. The uniform dark back distinguishes it easily from lake trout; native to whole of east slope drainage.



ROOFS OF MOUTHS

TROUT - LEFT (B)

CHAR - RIGHT (A)

## GROUP B. Trout

(Cutthroat, rainbow, brown or Loch Leven, rainbow-cutthroat hybrid)

Vomer bone with teeth on its whole length; black spotted on sides.

(1) Brown or Loch Leven trout (*Salmo trutta*)

Tail fin without spots; red spots on sides mixed with the black ones; these red spots often have blue borders; presence of black spots, and vomerine teeth distinguish it from eastern brook; no rainbow stripe.

Native of Europe, now widespread in slow North American trout streams; in Alberta found in Bow from Calgary up and in upper Red Deer tributaries.

(2) Cutthroat trout (*Salmo clarkii*)

Creases beneath lower jaw bright scarlet (cutthroat mark). The cutthroat mark is sometimes pale or even absent; rainbow stripe often present; on some, the sides and belly are pale but on many, the lower sides and belly are pink; this pink colour becomes stronger when the fish dies and begins to dry out.

Native to Saskatchewan drainage; absent in Athabasca.

(3) Rainbow trout (*Salmo gairdnerii*)

No cutthroat mark; rainbow stripe from cheeks to tail, along middle of each side; the red or pink colour does not extend to lower sides and belly as in cutthroat.

Widely planted in Alberta; established in a few lakes. A small variety (probably Dymond's subspecies *whitehousei*) is native to the Athabasca drainage. The rainbow has largely failed to survive in the streams of the Saskatchewan drainage; it has crossed extensively with the native Cutthroat in these waters.

(4) Rainbow-cutthroat hybrid (*S. clarkii* X *S. gairdnerii*)

This fish is best known in the Bow River below Calgary where it has been extensively studied by W. M. Gilmour. It is locally called "Steelhead". The colour is generally silvery; the rainbow stripe is present on small fish but faint or absent on fish of a pound or more. Sometimes a cutthroat mark is present which may be yellow, orange or red; it varies in length from a mere spot to the full length characteristic of the cutthroat trout. On a hook they behave like rainbow, leaping frequently. Mr. Gilmour observed spawning and the fish is self-maintaining.

## Experimental Use of Fertilizer

Review by

M. W. Smith

*Senior Biologist, Atlantic Biological Station (Fisheries Research Board of Canada), St. Andrews, N.B.*

*Experimental use of fertilizer in the production of fish-food organisms and fish.* By Robert C. Ball. Michigan State College, Agricultural Experiment Station. Technical Bull. 210. pp. 1-28, 1949.

As a co-operative effort, the Institute for Fisheries Research of the Michigan Department of Conservation and the Michigan State College have undertaken investigations to determine the effectiveness of fertilizing representative Michigan waters for increased fish production. Although much has been learned in the southern United States upon the principles of fertilizing ponds, the author states: "Because of the many physical, chemical and climatological differences existing between the southern and northern regions, it was believed that the recommendations for fertilizing southern ponds would not be applicable to those in Michigan." However, the similarity of many aquatic environments in southern Canada to those in Michigan prompts a definite interest upon the part of Canadian investigators in the Michigan program.

This paper presents results upon the fertilization of a number of ponds (0.46 to 7.1 acres) at Wolf Lake, Drayton Plains and Hastings Fish Hatcheries. At each location, paired ponds, selected for similarity in character, were employed for each particular experiment, one being fertilized while the other remained unfertilized and served as a control. The experiments ran for one summer.

Most of the fertilized ponds received barnyard manure in early spring at the rate of one ton per  $1\frac{1}{2}$  acres, then all were treated, about 60 days later beginning on June 18, 1946, with a commercial fertilizer of the formula 10-6-4 ( $N-P_2O_5-K_2O$ ), at a rate of  $33\frac{1}{2}$  lbs. per acre per week until August 26, 1946. Results disclosed that weekly or fortnightly applications at the above rate produced no better effects than applications of 100 lbs. every 3-week interval.

The production of plankton, bottom organisms, tadpoles was decidedly greater in the fertilized water. Improvements in production of minnows (creek chub and white sucker) for bait and of the largemouth black bass and bluegills did not keep step in a consistent manner with the greater production of fish foods. In certain instances survival of the fish was too low to capitalize fully upon the productive capacity of the fertilized water, while in others "volunteer" fish, such as the brook stickleback in abundance, introduced a disturbing factor. Divergence in the series of biological events in the ponds which appeared similar at the outset of the experiments in physical, chemical and biological features gave varied results, difficult of evaluation.