Mr. Cameron

ISSUE FIFTEEN
APRIL - 1954

THE CANADIAN FISH CULTURIST

Published at Ottawa by
The Department of Fisheries of Canada

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Published under Authority
of
HON. JAMES SINCLAIR, M.P.
Minister of Fisheries

The History of Lake Minnewanka with Reference to the Reaction of Lake Trout to Artificial Changes in Environment

by

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Lake Minnewanka, located in Banff National Park, has been investigated on several occasions since 1936. Data have been collected by Dr. D. S. Rawson (1936, 1938, 1941 and 1943), by Warden J. E. Stenton (1945, 1947, 1949 and 1951), by Dr. V. E. F. Solman (1947), and by the author and his field party[1] (1952) with particular respect to lake trout, cisco and Rocky Mountain whitefish, plankton, bottom fauna, and the physical and chemical characteristics of the lake.

The lake trout population of Lake Minnewanka has suffered several ecological changes resulting from successive increases in the water level for electric power development. This lake, which was once popular for its lake trout angling, is now almost depleted of large individuals of that species and inhabited by a dense population of small lake trout. Since this lake is the largest body of water in the vicinity of Banff and the demand for angling is high, it is desirable to make attempts to improve angling prospects.

Lake Minnewanka is located about five miles from the town of Banff. At high water its surface lies at 4,840 feet above sea level. Surrounding peaks range in height from 7,000 to 9,000 feet. Under original conditions the surface level was 4,763.7 feet above sea level and the area was 3,464 acres. In 1911 and 1912, a small dam for electric power development was built across the Cascade River at the outlet of the lake, raising the level a maximum of 12 feet and adding 467 acres to the original lake area.

In 1941, a much larger and higher dam was built below the old one. This dam raised the water level an additional 64.3 feet and added 1,524 acres to the area of the former lake. The maximum draw-down of the water level is now 35 feet from the maximum level of 4,840 feet. At present, when the water in the reservoir is at its maximum level, the total area of the lake is 5,454 acres, i.e., 8.3 square miles. A new outlet diverts the water south through Two Jacks Lake, a new area of 96 acres, which flooded the former Summit Lake, and through a canal about $1\frac{1}{4}$ miles long. The draw-down of Two Jacks Lake is 16 feet, exposing nearly one-half of the lake bottom.

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[1] *F. H. Schultz, Limnologist, Canadian Wildlife Service, and J. Shapiro, summer assistant.*

The average depth of Lake Minnewanka is about 170 feet at maximum water level, and the maximum recorded depth is 325 feet.

The duration of ice cover is approximately 120 days. The lake usually freezes over by the end of December and breaks up in early May. During the period prior to 1941, the lake trout population was considered normal and provided adequate angling for that species. The present status of the lake trout population is demonstrated by the fact that the catch of lake trout by angling or by netting consists almost exclusively of fish measuring less than the legal length of 15 inches. Trolling for lake trout has become increasingly rare during the last four or five years and the catch of good-sized trout has decreased drastically. Angling for lake trout by still-fishing is now limited to the lower end of the lake and to the vicinity of the Cascade River outlet. Gill net tests have shown the presence of an unbalanced lake trout population consisting of a small proportion of lake trout weighing more than one pound and of a very large proportion of smaller individuals. The rate of mortality seems to be very high when the fish have reached 12 or 13 inches in length. The ecological conditions which have developed since 1941 seem inadequate for the survival and growth of lake trout after they have reached that critical period in their life history.

Physical—Chemical Conditions

Data available on water temperature, oxygen and pH since 1936 indicate that physico-chemical conditions of Lake Minnewanka have not changed to any great extent from year to year. Differences are considered to be within the range of variations caused by one season being earlier, later, warmer, or colder than another.

Dr. Rawson obtained data on water temperatures during the months of February and March, 1944. Temperatures ranged from 0·8° C. to 1·4° C. from surface to bottom in mid-February, and a uniform temperature from surface to bottom of 1·5° C. was recorded in mid-March.

During the summer of 1952, the highest surface temperature, 17·7° C. was recorded on July 17. In deep water, at 50 metres, a temperature of 9·0° C. was recorded on August 5.

Dissolved oxygen is plentiful at all times and at all depths. In spite of the increase in water depth and the decomposition of woody debris, the dissolved oxygen concentration near the bottom exceeds the minimum needed for fish.

Plankton

Qualitative and quantitative samples taken in 1941 led Dr. Rawson to the conclusion that up to that time there had been no important change in the composition of the plankton population of the lake. The dry weights of samples collected in 1941 were similar to those of samples secured in 1936 and 1938. In 1943, the average quantity of plankton per total vertical haul was nearly five times greater than the averages obtained from previous samplings, because of a pulse of the diatom *Frigilaria*. The analysis of material collected during 1952, which is now in progress, indicates that the same species are still present in the lake and that the density of population, even if it fluctuates according to the time and location of sampling, is within the range of averages obtained previously. The final figures are expected to indicate a slight increase in the plankton population. Like Dr. Rawson, the writer feels safe in saying that there is no evidence "that flooding has interfered with the plankton production and it may have resulted in some increase".

Bottom Fauna

Since fluctuations in the population of bottom organisms were forecast as a result of flooding, biologists who have investigated Lake Minnewanka have paid particular attention to the collection and analysis of this material.

As expected the construction of the new dam and the 64-foot raise in water level were followed by a decrease in the average number of bottom organisms to the acre and by a change in relative abundance of the constituent organisms as shown by Dr. Rawson's studies carried out in 1943. In 1947, six years after the construction of the dam, an increase in bottom fauna was recorded by Dr. Solman. Samples secured during 1952 seem to indicate that the bottom organisms are in the process of adaptation to the new environment and that their production per unit of area has further increased. Table 1 summarizes data on bottom fauna in Lake Minnewanka in the years 1936 to 1952.

Table 1

Year of Collection	Number of Samples	Per cent composition by number of		Average dry weight of organic matter per acre, in lbs.
		Chironomids	Sphaeriidae	
1936	42	52·5	38·6	6·5
1941	22	58·8	28·6	3·5
1943	64	92·7	2·7	2·9
1947	29	92·6	1·5	4·0
1952	40	93·5	4·6	5·1

Organisms usually found on or in the lake bottom include larvae and pupae of aquatic insects such as chironomids, mayflies and caddis flies, and also sphaeriids, gastropods, amphipods and oligochaetes. Samples collected in 1936 and 1941 indicated that chironomid larvae and sphaeriids were the main components of the bottom fauna. In 1943, a sharp decrease in sphaeriids and a sharp increase in chironomids were noted. In 1943 and 1947, chironomids constituted 93 per cent by number of the total number of organisms collected. The 1952 samples present the same high proportion of chironomid larvae. Amphipods have fluctuated between 1·7 and 3·1 per cent of the total number of animals during the period of 1938 to 1947, but oligochaetes, gastropods and larvae of insects other than chironomids are almost absent in recent samples.

The newly-flooded areas from which the water is withdrawn for almost five months of the year are not productive. Chironomid larvae are found in small numbers, and they are of a much smaller size than those collected at the same time in deep water.

It is believed that eggs laid by adult flies on the surface of the water fall to the bottom. When the water recedes they are left bare. The development of the eggs is delayed, therefore, until they are again in the water. Because of the possible annual fluctuation of 35 feet, the 645 acres left uncovered by water for part of the year will never permit the growth of aquatic or semi-aquatic vegetation and the bottom fauna in this area is expected to remain limited.

Among the species of fish inhabiting Lake Minnewanka, the suckers, the Rocky Mountain whitefish, and the lake trout, normally piscivorous, are bottom feeders. Cisco are generally plankton feeders. It is interesting to note that, in spite of the increase in the proportion of young lake trout which have been found to feed almost exclusively on chironomid larvae, the bottom organisms are increasing in number, thus indicating that the bottom fauna is not being fully utilized by the species of fish present in the lake.

Spawning Grounds for Lake Trout

In his 1938 report Dr. Rawson estimated that the 12-foot vertical variation in water level resulting from the first impoundment must have "profound effect on the spawning and development of the lake trout, if it does not altogether prevent reproduction". Because of annual plantings of lake trout fingerlings since 1914, catches of small fish could not be considered evidence of successful natural reproduction. These plantings were discontinued in 1938 because of the difficulty of securing eggs. After construction of the 1941 dam it was believed that lake trout spawning and early development was in danger. For this reason the licence issued on May 14, 1947, for the storage of water and the development of water power at Lake Minnewanka stipulated that the Company was to safeguard game fish in Lake Minnewanka and pay for the restocking of this lake.

Observations made with an underwater television camera have indicated that spawning grounds for lake trout are still available in deep waters and that eggs were laid at depths beyond the limit of lower water. It seems that the annual draw-down of water has not interfered with lake trout spawning activities, and, further, that the survival of eggs and fry is greater than before the construction of the 1941 dam. This condition might possibly be explained on the theory that the activity of spawners over spawning grounds before the dam was constructed may have resulted in low survival of eggs and that consequently production of young fish and return of adult fish were low. Similar observations made on Pacific salmon have shown that, if small runs of mature fish occurred in one year, large returns of spawners of that year-class were later recorded.

The Lake Minnewanka conditions could be compared with those described by Sven Runnstrom, who studied the Arctic char population in a regulated lake in Sweden. Runnstrom recalls that, when the dam was constructed at the outlet of Lake Torron, the fisheries biologist had forecast a reduction in the trout population, owing to failure of spawning and the destruction of eggs left dry in shallow areas by the water level variations. Observations made during a period of 13 years have shown that the total population of trout has not dropped in number and that the population has even grown too big for the changed food conditions. With reference to spawning grounds, Runnstrom explains that char continued to spawn at the old spawning places during the first few years after the construction of the dam and that on the newly-flooded parts of the shore the stone and gravel bottom offered new suitable spawning places which were also occupied by the trout. Therefore the total area of suitable spawning grounds was considerably enlarged, permitting the spawners to disperse over the wide area and preventing over-crowding over a limited spawning ground. Runnstrom and also Fabricius, who made similar observations at Lake Storsjouten, Sweden, concluded that "it would seem that the spawning is more dependent on the nature of the bottom than on the depth".

Trout spawning in Lake Minnewanka appears to have considerably greater vertical distribution now than it had before 1941. When the draw-down occurs before the end of February, eggs then developing at depths of less than 15 feet fail to hatch; nevertheless, the rate of survival of eggs laid in deep water is so great that such losses are offset. It is therefore concluded that the construction of the dam in 1941 has not been detrimental to a potential production of an adequate lake trout population. It is also concluded that plantings of lake trout are not required.

Size Distribution and Growth of Lake Trout

Samples collected in 1936, 1938, and 1941 at Lake Minnewanka, by standard netting operations, indicated a normal population of lake trout where individuals of all sizes were well represented. In the 1943 sample, a scarcity of lake trout between 10 and 15 inches was noted. In the same sample the number of lake trout between 7 and 10 inches in length was greater than in previous samples, indicating that they had increased considerably. Since 1943, the increase in the number of fish of that size in the gill net catches has become more and more pronounced, and the catch of individuals of larger size has continuously decreased. In 1941, lake trout between 8 and 12 inches in length represented 17·6 per cent of the total catch by gill nets. In 1947 lake trout of that size range represented 65·1 per cent. For those between 16 and 20 inches in length the percentage dropped from 38·9 in 1941 to 6·7 in 1947. From samplings carried out during 1952, lake trout of the 8 to 12-inch length range represented 91 per cent of the total catch made by standard gangs of gill nets.

A detailed study of the length distribution of the gill net catch made in 1943, with poor representation of fish between 12 to 15 inches, seemed to suggest that there had been a failure in spawning and in survival of eggs. However, later samplings showed the same gap between an increasing proportion of small fish and a decreasing proportion of large fish. This supports the concept that spawning is successful, but the survival rate of young trout after they have reached an average length of 12 inches is very low. This critical stage in the life history of the lake trout at Lake Minnewanka coincides with the age of 4, 5, and 6 years.

The growth in length and in weight of the young lake trout in Lake Minnewanka is much slower than the growth of the same species of fish in the Waterton Lakes. Table 2 gives the average weights, for various ages, of the lake trout from these bodies of water.

Table 2

Age	Average Weights of Lake Trout		
Years	Lake Minnewanka	Lower Waterton Lake	Upper Waterton Lake
	lbs.	lbs	lbs
3	0·2	—	0·3
4	0·4	1·8	0·8
5	0·6	2·8	1·3
6	0·9	3·9	1·9
7	1·5	5·5	3·7
8	6·1	8·2	5·0
9	9·2	11·8	12·1
10	12·7	16·4	15·7
11	17·5	22·0	17·1

It should be noted that after the sixth year of life, the growth in weight increases at a high rate, even in Lake Minnewanka. It is among the small lake trout that the marked difference in rate of growth between Lake Minnewanka and the Waterton Lakes is significant and apparently of great importance. It seems that some limiting factors affect most of the young fish during their first five or six years of growth and that the heavy mortality occurs when the lake trout have reached five years of age. Sexual maturity has been found among 12 to 15-inch lake trout, which is normal as far as age is concerned, but seems abnormal when considering the length and weight of the fish.

The question is, then, if adult lake trout spawn, if a large proportion of eggs hatch, and if young lake trout are abundant, why is the growth so slow among young lake trout and why are there so few lake trout over 15 inches in length? The answer seems to be related to a change in the feeding habits of the young trout as a result of construction of the dam in 1941.

Food of Lake Trout

In his 1937 report, Dr. Rawson showed that amphipods, chironomid larvae, and forage fish occurred in 34 per cent, 26 per cent, and 19 per cent, respectively, of the stomachs of lake trout he examined. This food study was based, however, on only 21 specimens, without considering the size of the fish in the analysis.

The food of 116 lake trout taken in 1941 and analysed by Dr. Rawson, according to size groups, was as follows:

(1) Among lake trout ranging from 6 to 12 inches in length, chironomids and fish were reported from 22 per cent and 40 per cent of stomachs, respectively.

(2) Among lake trout with lengths greater than 12 inches, only 7 per cent contained chironomids, and 74 per cent contained fish in their stomachs.

In 1943, 380 lake trout, of which 169 had food in their stomachs, were examined by Dr. Rawson. This material permitted a more detailed break-down of the specimens into size groups. The results of this analysis were as follows:

Table 3

Food of lake trout—Lake Minnewanka—1943

Length Range	Number of Specimens	Percentage of Occurrence				
		Chironomids	Fish	Plankton	Amphipods	Others
		%	%	%	%	%
6-7	26	41	—	26	13	20
8-9	34	65	trace	—	17	18
10-14	26	32	53	—	—	15
15-20	65	14	78	—	—	8
Over 20	18	—	100	—	—	—

From this table it is noted that chironomid larvae constitute the main source of food of lake trout during their first years of life, that is, until they have reached lengths of about 10 inches. Beyond a length of 10 inches, the take of chironomids decreases and fish start to appear in the stomach contents. As the lake trout grow, the importance of forage fish in their diet increases until it constitutes 100 per cent of the lake trout diet.

The lake trout study carried out in 1951 at the Waterton Lakes gives approximately the same picture concerning lake trout feeding habits with regard to chironomid larvae and forage fish, mostly common whitefish. The results of that analysis are summarized in the following table:

Table 4

Food of Lake trout—Waterton Lakes—1951

Length Range (inches)	No. of Specimens	Percentage of Occurrence	
		Chironomids	Fish
		%	%
6-9	6	67	33
10-14	15	53	53
15-20	78	28	81
Over 20	99	36	81

This study indicated that the percentage of occurrence of chironomids in the stomachs of lake trout decreased as the size of the lake trout increased. On the other hand, the occurrence of fish as food increased as the size of the lake trout increased. The utilization of fish as food by young lake trout less than 15, even less than 10, inches in length is of importance.

During 1952, the stomach contents of 139 lake trout from Lake Minnewanka were analysed. This study, which includes specimens taken at various periods of the summer, reveals a drastic change in the feeding habits of the lake trout when the results are compared with previous data obtained from this lake, and when compared to data on lake trout from the Waterton Lakes. The data for 1952 are summarized as follows:

Table 5

Food of lake trout—Lake Minnewanka—1952

Length Range (inches)	Number of Specimens	Percentage of Occurrence				
		Chironomids	Fish	Amphipods	Molluscs	Others
		%	%	%	%	%
6-7	6	67	—	33	17	33
8-9	23	87	—	22	48	—
10-14	96	90	—	26	51	15
15-20	5	80	60	40	—	20
Over 20	9	11	89	—	—	11

The astonishing fact revealed by this study is the complete absence of fish in the diet of lake trout less than 15 inches in length. Those above that size, few in numbers, were feeding on forage fish, which behaviour seems to be related to their survival.

From the above reported data and from a survey made through published studies of lake trout from various waters, it seems obvious that the problem concerning lake trout at Lake Minnewanka is related to the feeding habits of this fish since the construction of the dam in 1941. Conditions are such that the lake trout, particularly at immature stages, are somewhat separated from their food requirements, even though cisco and Rocky Mountain whitefish are still present in the lake, apparently in fair numbers. Would conditions change with the years? Not likely, since the separation is probably related to a combination of factors, among which depth is considered the most important. To support this point the writer recalls the catch made by one gill net set in about 200 feet of water. The catch included 151 lake trout all ranging between 7 and 12 inches in length, and one small Dolly Varden. No cisco or Rocky Mountain whitefish were caught. The stomachs of these lake trout contained some plankton forms, but mostly chironomid larvae and sphaeriids. It seems, therefore, that small lake trout inhabiting the deep section of the lake do not find in this environment the forage fish to feed upon and that the cisco and Rocky Mountain whitefish are not adapted to the new environment created by the rise in water level. To improve conditions for lake trout, it seems desirable to introduce a species of fish closely associated with lake trout, utilized elsewhere by lake trout for food, and not ecologically separated from the lake trout in the lake by depth or other environmental factors.

Proposed Management Plan

Among the species of fish which are native to waters of North America where lake trout are found are the following: the ling (or burbot), the sculpin, the northern sucker, and the common whitefish. An examination of a distribution map of these species and a review of their life history indicate that they have similar requirements, particularly with respect to water temperature and depth. Geologically, it seems that these species, under conditions created by the last glaciation, have invaded streams and lakes formed by the receding glaciers. Along the east slope of the Canadian Rockies, the association of the five species of fish listed above and the Rocky Mountain whitefish is found only in the Waterton Lakes. In the other waters where native lake trout are found, Lake Minnewanka and Glacier Lake in Banff Park and Moab and Pyramid lakes in Jasper Park, this association does not exist, probably because there were at one time obstacles to the migration of some of these species. These obstacles are unknown, but might have been falls, or even heavy silt in suspension in the water. This may explain the fact that the lake trout and the Rocky Mountain whitefish, but not the common whitefish, are found at the head of the watershed of the North Saskatchewan River in Glacier Lake, one of the most silty waters in the Rockies. The Bow Falls and the silty waters of the Bow River could have prevented the common whitefish, the sculpin, and the ling from reaching Lake Minnewanka.

Because the ling is considered a predacious fish with respect to lake trout and because the planting of sculpin, which in certain lakes is a favourite food item in the lake trout diet, is almost an impossibility considering the size of Lake Minnewanka, the alternative would appear to be the common whitefish. This bottom feeder was the dominant item in stomach contents of lake trout at the Waterton Lakes, and seems to be the species most closely related ecologically to lake trout. It would, therefore, seem logical to attempt its introduction into Lake Minnewanka, as a means of managing the lake trout population in this lake.

About one million and a half eyed eggs of the common whitefish, kindly supplied by the Provinces of Manitoba and Saskatchewan, were planted in Lake Minnewanka during the spring of 1953. It is planned to repeat such plantings, but it is too early to report on the results of the introduction.

Field Trials with "Fish-Tox" in Streams

by

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British Columbia Game Commission

During the 1951 summer season, the Fisheries Research Group of the British Columbia Game Department carried out eleven field trials with the commercial toxicant "Fish-tox", produced by the Standard Supply Distributors, Wenatchee, Washington, U.S.A. The field trials were conducted with a view to obtaining information on the following points:

(1) Combinations of concentration, their period of application and their effectiveness.

(2) Stream factors contributing to success of poisoning.

(3) Distance downstream to which poisoning is effective.

(4) Relative cost and efficiency of stream poisoning vs. operation of coarse fish traps.

The programme of investigation was largely empirical and was designed to indicate the problems that might be encountered in wide use of Fish-tox in streams.

"Fish-tox" is a "rotenone" base mixture. (Rotenone is an organic substance derived from derris, cube, and timbo root. Its chemical formula is $C_{23}H_{22}O_6$). Combined with this base is a special dispensing agent which facilitates rapid and uniform dispersion of the poison.

According to Leonard (1938), rotenone affects the respiratory system of fishes by preventing consumption of oxygen. The initial effect of rotenone is to cause degeneration of epithelium of the gill filaments. Such a disintegration of surface cells prevents normal respiratory action of the gill filaments.

Methods Used For Dispersion

In the first two trials Fish-tox was mixed into a paste and placed in a cheesecloth bag. This bag was then moved through the water until the paste was entirely dissolved. By this method it was difficult to ensure a uniform and rapid application. In addition, the person releasing the poison suffered from keeping his hands submerged in cold water for long periods.

In the latter nine trials, immediately before the application the poison was mixed with water to make a smooth soupy paste. This "soup" could be easily, equally apportioned over the period of application.

In field trials sections of stream were cut off by seine nets or metal screens and effectiveness of kill was estimated for each section.

Tests in Eleven Field Areas

Norman Creek (Cluculz Lake, Prince George)

May 14, 1951, temperature 48° F., flow 2,169 cu. ft.-min. Swift flow over coarse gravel bottom. Bottom vegetation sparse. Species of fish in order of abundance: fine-scaled sucker, (*Catostomus catostomus*) (spawning run), coarse-scaled sucker (*C. macrocheilus*), peamouth chub (*Mylocheilus caurinus*), redside shiner (*Richardsonius balteatus*), ling (*Lota lota*), squawfish (*Ptychocheilus oregonensis*), Kamloops trout (*Salmo gairdneri kamloops*).

A poison concentration of 2 p.p.m. applied over a period of 15 minutes was ineffective in this fast-flowing, cold stream. A concentration of 5 p.p.m. applied over a period of twenty-five minutes was highly effective, and well over a ton of fish was killed by the use of 21·5 pounds of poison.

Sob Creek (Cluculz Lake, Prince George)

May 23, 1951, temperature 54° F., flow 396 cu. ft. min. Slow-moving, bottom covered with up to two feet of decaying organic matter. Banks heavily overgrown, in many areas stream margin a low marsh. Many channels at creek mouth. Species of fish: ling, redside shiner, peamouth chub, squawfish, fine-scaled sucker. Kill did not extend far downstream. A concentration of 4 p.p.m. for 20 minutes killed for a distance of one quarter of a mile; a concentration of 12 p.p.m. for 30 minutes killed for a distance of less than one mile. Where the stream was divided into many channels, application of poison in the main stream above the channels did not produce an effective kill.

Inlet Creek to Shumway Lake (Kamloops)

June 28, 1951, temperature 60° F., 480 cu. ft. min. Bottom largely coarse gravel. Some slow-moving stretches with mud bottom and small amounts of vegetation.

Poison was applied at three points on a 1·75 mile stretch of stream in concentrations of 5 p.p.m. for 13 minutes, 3 p.p.m. for 15 minutes and 6·5 p.p.m. for 20 minutes respectively. A complete kill was obtained over the entire stretch of stream. Some fish were killed within 7 minutes after application started. High water temperature may have been a contributing factor to the rapidity with which fish reacted to the poison.

St. George Creek (Nadsilnich Lake, Prince George)

June 18, 1951, temperature 48° F., flow 153·6 cu. ft. min. Slow flowing, largely gravel bottom, many short pools. Species of fish in order of abundance: coarse-scaled sucker, fine-scaled sucker, squawfish, peamouth chub, redside shiner, sculpin (*Cottus asper*), ling, Kamloops trout.

In this trial observations were made on the order in which various species were affected by poison. The following order was indicated:—

1. Trout, ling, redside shiner and peamouth chub together.
2. Squawfish (only slightly more resistant).
3. Fine-scaled sucker.
4. Coarse-scaled sucker.

Observations were made on 1,150 feet of this stream to which a dose of 7·4 p.p.m. was applied for 14 minutes. Trout, ling, shiners, peamouth chub, and squawfish were killed over the entire length of stream during the twenty-four hour period after application. Most of the suckers in the upper sections of the stream were killed but in the lower one hundred feet a substantial survival was indicated (roughly 50 per cent of coarse-scaled suckers and 25 per cent of fine-scaled suckers). Only one pound of "Fish-tox" was used and roughly 2,000 pounds of fish were killed.

Kalamalka Lake (Vernon)

June 12 and 27, 1951. Kalamalka lake and Woods lake lie in Kalamalka valley between Kelowna and Vernon, B.C. A channel roughly 200 yards long, five to ten feet deep and forty to fifty feet wide connects the two lakes. Flow in the channel is preponderantly to Kalamalka from Woods lake but reversal in flow is commonly observed. In general, water temperatures in the channel are high, ranging from 50 to 70° F. over most of the summer period.

On June 12 the channel and adjoining portions of the two lakes were poisoned. There was little flow in the channel and poison was dispersed over the entire trial area to give a concentration of 1 p.p.m.

At the end of the period of application flow had begun from Woods to Kalamalka lake at a rate of 0·5 foot per second. Accordingly, poison was applied at the Woods lake end of the channel at a rate sufficient to maintain a concentration of 2 p.p.m. in the inflow. This treatment was continued until kill of fish was observed. Five hours after the beginning of the application large suckers, squawfish and carp were apparently unaffected. Estimated kill was: 1,000 squawfish, four to eight inches in length; 500 peamouth chub, four to six inches in length; 2,000 shiners, one to three inches in length; 100 coarse-scaled suckers, two to six inches in length.

In a second trial, June 27, flow was from Woods lake to Kalamalka lake at 0·5 feet per second. A concentration of 5 p.p.m. of poison was maintained for 78 minutes. The total kills included eight carp and many thousands of peamouth chub, redside shiners and squawfish. Some of the large carp were the only fish apparently not affected by the poison.

Niskonlith Creek (Kamloops)

June 28, 1951, temperature 62° F., flow 180 cu. ft. min. Moderate rate of flow over a clean gravel bottom. Occasional deep pools, little marginal or aquatic vegetation.

A dose of 1·8 pounds of "Fish-tox" was released over a 30-minute period (5·2 p.p.m.) at a point three-quarters of a mile from the creek mouth. In one hour and forty minutes, apparently all fish from the point of application to the creek mouth had been killed. The various species were affected in the following order: sculpin and trout, redside shiner, squawfish and ling.

Monte Creek (Kamloops)

June 27, 1951, temperature 62° F., flow 800 cu .ft. min. Fast-flowing, gravel and sandy mud bottom, little marginal or aquatic vegetation.

Over a 30-minute period, 8·25 pounds of "Fish-tox" was added to the water (5·5 p.p.m.) and two hours after application started Kamloops trout and fine-scaled suckers were killed one mile downstream from the application point.

57 Mile Creek (Caribou Highway)

June 29, 1951, temperature 58° F., flow 80 cu. ft. min. Swift flowing, gravel bottom, little aquatic or marginal vegetation.

A concentration of 2 p.p.m. of "Fish-tox" was maintained over a period of 15 minutes. One-third of a mile downstream a small seine placed in the stream took roughly 200 Kamloops trout within 30 minutes after the end of the application. A rapid and complete kill for at least one-third of a mile from the application was indicated. The local game warden reported that the kill extended as far as two miles.

83 Mile Creek (Caribou Highway)

June 29, 1951, temperature 65° F., flow 156 cu. ft. min. Slow-moving, occasional shallows between long deep pools. Dense growths of submergent and emergent aquatic vegetation.

One and one quarter pounds of "Fish-tox" was applied in 15 minutes, (8·5 p.p.m.). Two hundred yards down-stream, in heavily weeded pools, poison dispersed very slowly. Roughly 800 yards downstream no toxic effects were observed one hour after the operation started. Many thousand peamouth chub and small coarse-scaled suckers were killed in the short stretch of stream in which the poison was effective.

Cluculz Creek (Outlet Cluclulz Lake) Prince George

June 30, 1951, temperature 65° F., flow 4,500 cu. ft. min. Part of Cluculz creek flows rapidly over gravel beds covered with heavy growths of algae. In other sections of the stream, flow is moderately rapid in the main channel but slow through large swampy areas at the margins. Species of fish: fine-scaled sucker, coarse-scaled sucker, squawfish, redside shiner, sculpin, ling, peamouth chub, Kamloops trout.

A concentration of 14·3 p.p.m. was maintained for a period of 15 minutes. Kill extended for over two miles. The relatively large water volume in relation to the area of stream bottom may have been a contributing factor to the great distance over which poison was effective.

Collett Irrigation Diversion (Merritt)

September 19, 1951, temperature 58° F., flow 66 cu. ft. min. Slow flow, bottom muddy with heavy plant growth. This trial was done in conjunction with the Federal Department of Fisheries to assess the extent to which young salmon had passed into the diversion.

Several hundred Kamloops trout fry, suckers and squawfish and a few spring salmon fry were killed. Dead fish were seen 400 yards below the application point.

Summary

In eleven trial poisonings, concentrations used ranged from 1 p.p.m. to 20 p.p.m. and times for application from 14 to 90 minutes. Concentrations of 1 and 2 p.p.m. did not effect complete kill even when maintained for over an hour. More extensive kill was obtained with higher concentrations applied over short periods of 15 to 20 minutes. Increasing the application time to 30 minutes gave slightly greater distance of kill. As might be anticipated, length of stream affected is related to concentration applied and rate of flow in the stream. In fast-flowing streams 5 p.p.m. doses killed for distances up to one mile. Increasing the dosages to 15 to 20 p.p.m. extended kill to at least two miles. In slow-moving streams, doses of 5 p.p.m. killed for distances of less than one quarter mile and increasing concentrations to 8 p.p.m. was not noticeably effective in extending kill farther down-stream.

Several factors may contribute to short distance of kill in slow-moving streams. Aquatic vegetation provides large surface area for adsorption of poison and is conducive to production of large numbers of invertebrates that would remove poison from solution. Bottom sediments of slow streams are largely composed of fine silt and organic detritus and adsorption of poison would be correspondingly high. Portions of Cluculz creek are slow-moving and swampy but a kill was obtained for a distance of two miles with a concentration of 14·3 p.p.m. The relatively large volume of flow in relation to the area of bottom would be a contributing factor in this situation.

Some species of fish are considerably more resistant than others to "Fish-tox" and concentrations of 5 p.p.m. were largely ineffective for large suckers and carp. In situations where these species are abundant further field trials using high concentrations might be planned.

It is suggested that the following general practices should be adopted in stream poisoning to ensure effective kill:

1. "Fish-tox" should be applied to provide a concentration of at least 4·5 p.p.m., and maintained for at least 15 minutes.
2. In small slow-moving streams repeated application at one-quarter mile intervals is preferable to increasing concentration.
3. In larger and faster streams application points could probably be one mile apart if concentrations of 5 p.p.m. are used. Higher concentrations do not give a proportionately greater distance of kill.
4. Poison can be conveniently applied in streams by preparing a poison and water paste which is dispensed uniformly over the application period.
5. Where large fine-scaled or coarse-scaled suckers, or carp are present, concentrations above 5 p.p.m. may be necessary to obtain a complete kill.

On the basis of the field trials the efficiency, cost and convenience of stream poisoning can readily be compared with the operation of coarse fish traps. First, poison kills resident stream fish in addition to spawning fish. This is a great advantage because a large fraction of the predation on sport fish may occur on or near the spawning grounds. Cottids, for instance, are predators of young fry, but coarse fish traps are ineffective in removal of Cottids. The efficiency of the poison in killing spawning fish is undoubtedly higher than that of traps. A trap must be in operation before runs start and must operate until runs are over, and in almost all instances this ideal is not realized. With a small number of poisonings a far more effective coverage of a spawning run could be obtained.

Comparison of costs is strongly in favour of poisoning. "Fish-Tox" costs roughly 30 cents per pound and on most small spawning streams the dose necessary is usually not over 50 pounds. Labour costs could be negligible for application of poisoning, because it could be done in conjunction with routine patrols and surveys. Opposed to this is the large expense involved in construction of traps and the necessity for daily inspection. If disposal of dead fish is necessary then traps are much more convenient but probably more expensive than poisoning. Traps take fewer fish in smaller lots and mink ranchers and farmers can conveniently use them. There is no problem of collecting carcasses. Poisonings kill more fish, generally in large lots, and the majority of the dead fish are not put to good use. Collection of carcasses can be partially effected by screens and nets, but it would be expensive and probably impractical to attempt complete recovery. Obviously, in stream poisoning, only perfunctory collections of dead fish are advisable.

This aspect of poisoning is important also from the viewpoint of public relations. Dead fish soon produce offensive odors and no amount of assurance that it is in a good cause makes the odor any more tolerable. Many local residents fear that the carcasses will pollute the water for domestic use, and while this fear is not well grounded it is a widespread conviction. Some apprehension is voiced when poison kills large numbers of trout in addition to coarse fish. These problems imply the need for a public relations programme and emphasize the importance of discretion in the use of poison.

It might well be recommended that poisoning should not be an indiscriminate procedure but that it should be used under proper direction and only after careful consideration and adequate publicity. Similarly, it is emphasized that it should not be used merely for the sake of killing coarse fish but that like all coarse fish control practices it should be used only when and where there is satisfactory evidence that its use will contribute to production of desirable species.

Literature Cited

LEONARD, J. W., 1939. *Notes on the use of derris as a fish poison.* Trans. Amer. Fish. Soc. 68:269-280.

Ulcer Disease and Furunculosis in a Quebec Trout Hatchery[1]

by

L. Margolis

Pacific Biological Station, Fisheries Research Board of Canada, Nanaimo, B.C.

Ulcer disease (Snieszko, 1952) and furunculosis (McCraw, 1952) are two of the most destructive diseases of hatchery trout. The etiological agent in each disease is a specific bacterium. Infection with *Hemophilus piscium* Snieszko, Griffin and Friddle, 1950, causes ulcer disease of trout and *Bacterium salmonicida* (Emmerich and Weibel, 1894) is the causative agent of furunculosis.

Ulcer disease of brook trout (*Salvelinus fontinalis*) is known to have been endemic in hatcheries in the Northeastern United States for at least fifty years. The original source of infection is unknown. Reports of *H. piscium* infection in nature are as yet lacking. However, ulcerative diseases of fish, some of which might possibly be due to infection with *H. piscium*, are not uncommon in natural bodies of water.

Furunculosis was first described from brown trout (*Salmo fario*) in hatcheries in Germany and subsequently in natural trout rivers in Germany and other countries of central and western Europe. It was believed to have been transmitted from central Europe, via infected brown trout, to hatcheries in Great Britain, from where it was spread to natural rivers through stocking with infected trout. The disease was reported from United States hatchery trout in the early part of the twentieth century, presumably the source of infection again being European brown trout. Furunculosis is now endemic in trout hatcheries in many parts of the United States, where brown and brook trout are principally infected. It has also appeared in natural waters in the United States. In Canada, furunculosis has been reported from British Columbia in the Elk River, at a salmon rearing pond at Cultus Lake (Duff and Stewart, 1933) and in a trout and salmon hatchery at Lake Cowichan (Carl, 1939).

First Report in Canada

This communication constitutes the first report of ulcer disease of trout (known to be caused by *H. piscium*)[2] in Canada, and the first report of furunculosis in Eastern Canada. Fish of all ages in a trout hatchery in the Province of Quebec, were afflicted with ulcer disease at the time of examination in October, 1952. Furunculosis was not as evident as ulcer disease, although present in the same group of fish. All fish showing furunculosis were also afflicted with ulcer disease. Diagnosis was confirmed by bacteriological examinations.

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[1] *Contribution from the Institute of Parasitology* (*McGill University*), *Macdonald College P. O., Quebec.*

[2] *Reed and Toner* (*Can. J. Res. D20, 161-166*) *reported* Pseudomonas hydrophila *as the probable cause of an ulcerative disease of brook trout in an Ontario hatchery.*

The hatchery, in operation for more than twenty years, has always been free from furunculosis and ulcer disease. Recently yearling brook trout, which previously had been mixed with brook trout received from a Northeastern United States hatchery, were introduced into the ponds at the Quebec hatchery. Furunculosis and ulcer disease are endemic in certain hatcheries of the Northeastern United States and it thus appears that the imported trout were the source of infection of the Quebec hatchery trout. As fish in the natural rivers and lakes in the vicinity of the hatchery show no evidence of either of these diseases, the water supply can be eliminated as the source of infection.

A second trout hatchery in the Province of Quebec was found to be free of ulcer disease and furunculosis. Foreign trout had not been introduced to this hatchery for at least two years.

This report is designed to emphasize the dangers involved when introducing alien stock to a trout hatchery.

Literature Cited

CARL, G. S., 1939. *Furunculosis and another case of ichthypohthiriosis.* Prog. Fish-Cult., No. 45, 47-50.

DUFF, C. B. and STEWART, B., 1933. *Studies on furunculosis of fish in British Columbia.* Contrib. Can. Biol. and Fish. 8, 103-122.

McCRAW, B. M., 1952. *Furunculosis of Fish.* U. S. Dept. Int., Fish and Wildlife Service, Special Scientific Report: Fisheries No. 84, 1-87.

SNIESZKO, S. F., 1952. *Ulcer disease in brook trout* (Salvelinus fontinalis): its economic importance, diagnosis, treatment and prevention. Prog. Fish-Cult. 14 (2), 43-49.

Aerator for Fish Hatchery Transport

by

A. H. Berst and J. W. Anderson[1]

During the past five years several papers dealing with various type of aerators for fish hatchery transports have been published. Most of the units at present in use employ one of the following methods of restoring dissolved oxygen to the water in the tanks:

(1) Forcing air through the water.

(2) Allowing pure oxygen to bubble up through the water.

(3) Re-circulation of the water and spraying it on the surface in fine droplets.

(4) Re-circulation of the water and pumping it through a "mixing chanber" where air and water are mixed by venturi action, then returning the water to the tanks.

Fish distribution units employing any one of the above methods are able to carry several times as many fish per load as transports which are not so equipped, and in addition to this advantage, prolonged stops for releasing fish, etc., can be made without worrying about "sick" fish due to depletion of dissolved oxygen in the tanks.

This paper, which describes an aerator built by the authors, is written as a result of several requests by persons concerned with the distribution of live fish. The unit was built in March and April of 1952 by the hatchery staff at a cost of less than $500.

The forced air system is employed to replenish the supply of dissolved oxygen to the water in the tanks. One of the chief reasons for selecting this type of system was that we were fortunate enough to be able to experiment with a commercial fish transport owned by the Krestel and Wrighton Fisheries of Port Rowan, Ontario, which used the same type. This transport was hired for several transfers of trout from the Lake Erie district to the Parry Sound area which involved trips of over 300 miles and proved to be quite satisfactory. We found that the aerator was relatively simple, practical, and inexpensive to build and operate.

The aerator which we built is an adaptation of the commercial unit. It was completed in time for the distribution of yearling trout from the Normandale Hatchery during May and June 1952. Approximately 125,000 speckled trout, 16,000 Kamloops

[1] *Respectively, Department of Lands and Forests District Fisheries Biologist, Aylmer, Ontario, and Department of Lands and Forests Hatchery Manager, Normandale, Ontario.*

trout and 8,000 brown trout were released in excellent condition and with practically no mortality en route, even though the fish were held in the tanks for as long as 48 hours on some of the northern trips. The increased capacity of the load from 2,000 to 15,000 yearlings made possible significant reductions in distribution costs. The average annual mileage for fish distribution dropped from about 32,000 to 10,400 miles as soon as the aerator was put into operation. In addition, restocking was carried out in record time, which is a definite advantage because it is necessary to clear the rearing ponds of yearlings as early as possible each year in order to make room for the growing stock of fingerlings. This also results in savings in fish food costs, since the large fish are disposed of early in the summer.

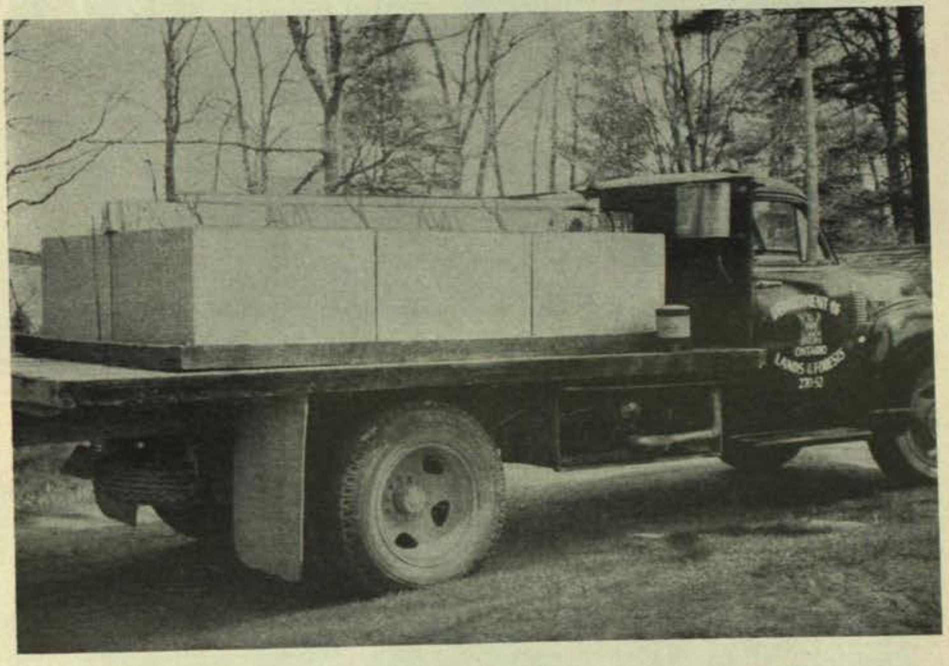


Figure 1—Fish distribution truck.

Construction of the Aerator

Fish Tanks

Use was made of the six metal fish tanks which had previously been used on our fish transport. The tanks are 3′x3′ and 2′ in height. Metal splash deflectors are installed near the top of each tank. The tanks are held in place by oak 4″x4″ bolted to the floor of the truck. Each tank is equipped with a wooden top which is divided into two parts; a fixed portion and a hinged portion. The fixed portion, which is the smaller, holds the air outlet tube and valve and the hinged portion contains a metal "well" which holds a 50-pound cake of ice.

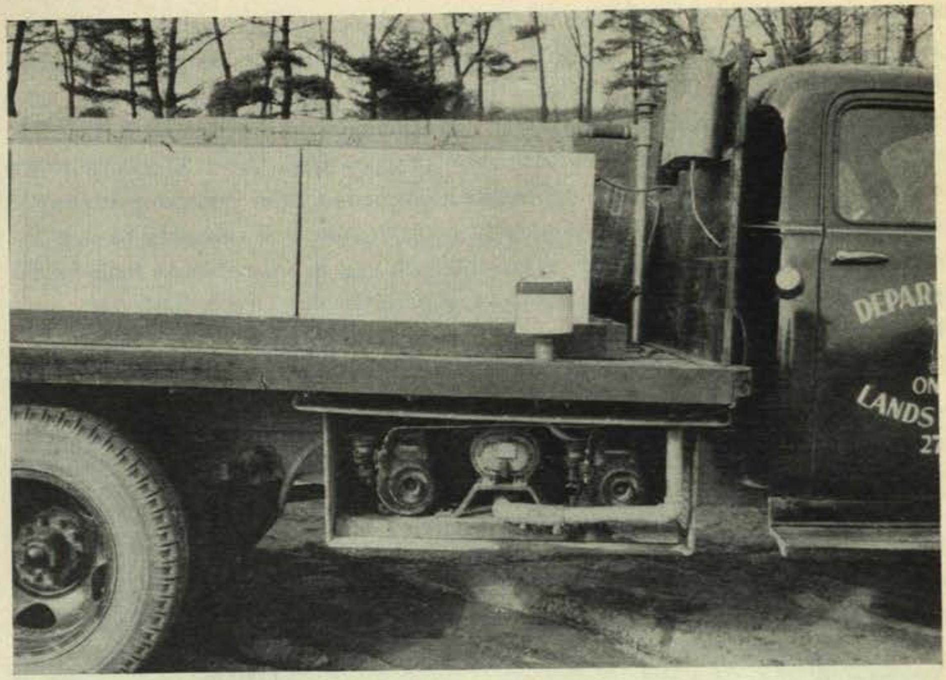


Figure 2—View of tanks and aerator.

Airblower and Motors

The main part of this unit is a rotary positive air blower which runs at approximately 1,200 r.p.m. and moves about 30 cubic feet of air per minute. It forces the air under a pressure of one pound into the water of each of the six 95 gallon tanks on the rack of the transport, through a system of tubing. The air blower is powered by a $1\frac{1}{2}$ to 2 H.P. Briggs and Stratton gasoline engine. A spare engine is mounted in such a position that it can be brought into operation in a matter of minutes if the first engine fails. Exhaust from the engines is carried away by flexible exhaust tubes. (Otherwise the hot exhaust fumes tend to heat the airblower).

The airblower and motors are bolted to a 2″ oak plank which in turn rests in a large steel support hanging from 2 bed pieces under the floor of the truck. In order to reduce the possibility of road dust and exhaust gases passing through the system, the air is drawn into the blower through a filter which is fastened to the end of an upright intake pipe extending above the rack of the truck. The outlet of the airblower is located in the bottom of the blower casing. For this reason, the airblower was raised about $4\frac{1}{2}$″ on a steel stand in order to let the outlet pipe (made of $1\frac{1}{2}$″ galvanized iron pipe) pass above the upper surface of the plank. This leaves the bottom of the frame free from any pipes or other parts which might be damaged when travelling through bush trails or over rough ground.

A 7″ V type pulley is used on the airblower and a 3″ pulley is installed on each of the motors. A Raybestos No. 64 fan belt connects the pulleys of the motor and the airblower.

Gasoline is supplied to the motors through $\frac{1}{4}''$ copper tubing from a Coleman fuel tank which is located on the upper front section of the truck rack. A 3-way cock in the fuel line permits the operator to shut off the gasoline supply to either or both engines when they are not operating.

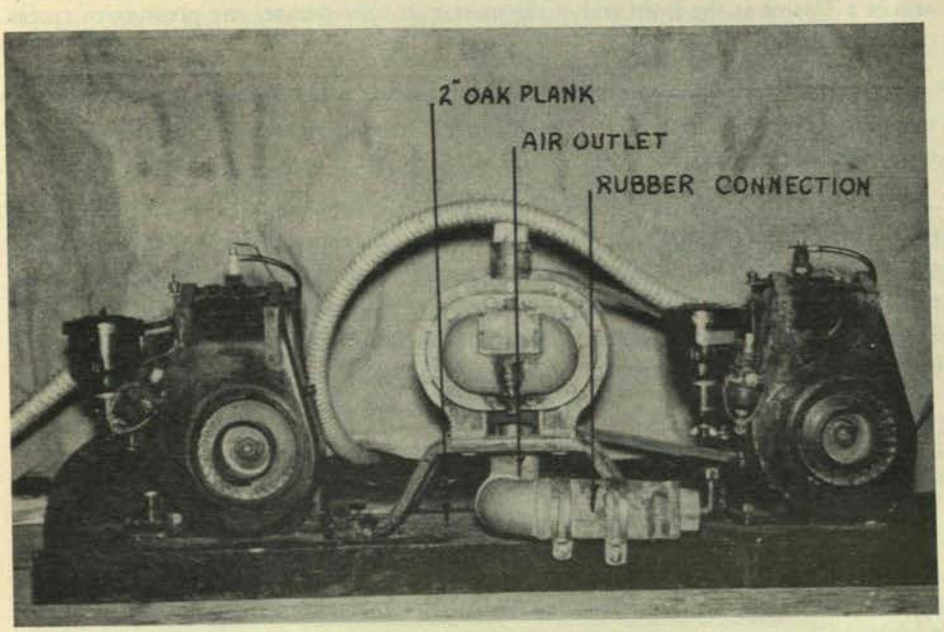


Figure 3—Front view of airblower and motors.

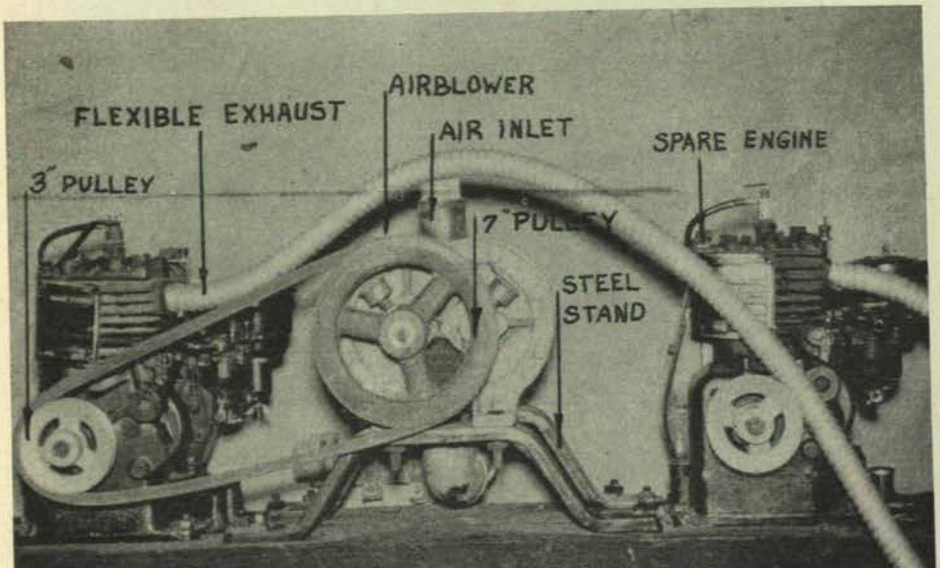


Figure 4—Rear view of airblower and motors.

Tubing System from Airblower to Tanks

After leaving the airblower, the outlet pipe passes laterally, under the floor of the truck, then up through a hole in the centre of the floor and then into the master air tube which lies along the centre of the tanks. A relief valve situated on the top arm of a T joint at the front end of the master air tube releases any pressure in excess of one pound.

There is a ½″ copper outlet from the master air tube for each tank on the truck which is connected to the corresponding tube in the top of the tank by a short piece of rubber hose.

A manually operated outlet valve is located in this tube, just below the wooden cover of the tank. It regulates the amount of air passing into the water of the individual tanks. Two rubber tubes lead from the outlet valve to a grid made of 6 pieces of copper tubing, which covers most of the bottom of the tank. Sixteen air holes, each 1/32″ in diameter, were drilled in each arm of the grid, making a total of 96 small openings in the grid of each tank through which the air passes into the water.

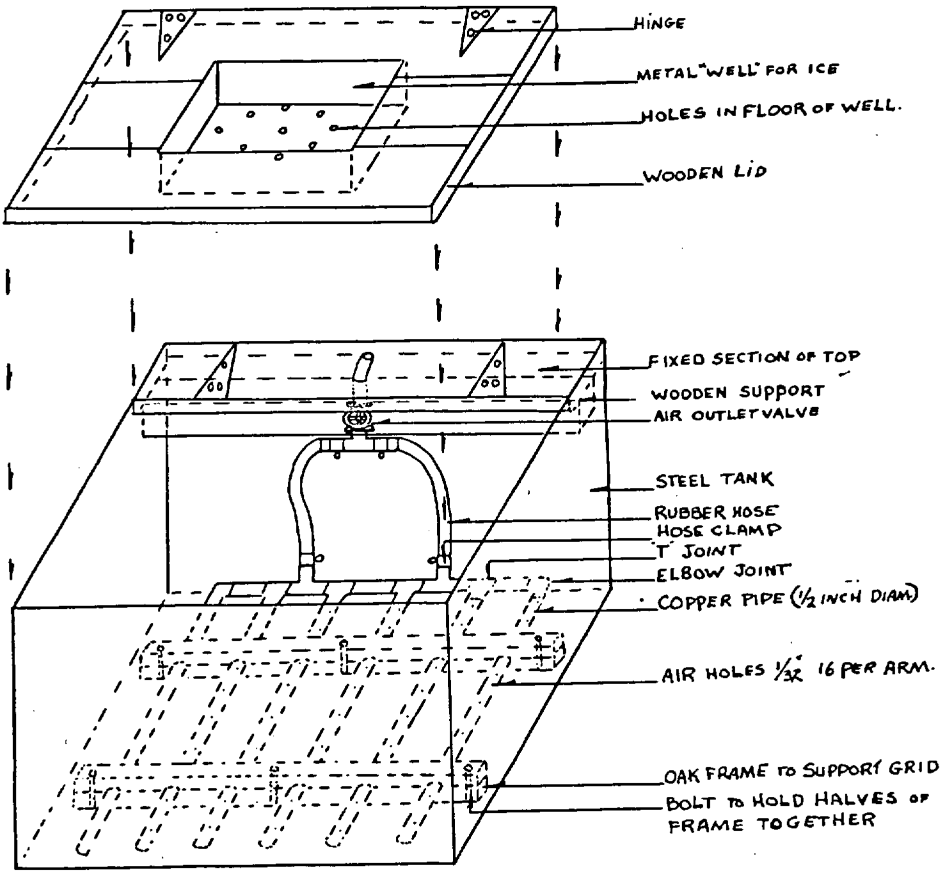


Figure 5—View of tank, grid and outlet valve.

Operation of the Aerator

Water Temperature Control

Cool temperatures are maintained by placing a 50 pound cake of ice in the metal "well" in the lid of each tank. As the ice melts the cold water drips through holes in the floor of the "wells" to the surface of the water in the compartments.

On long trips a tarpaulin is used to cover the tanks which acts as an insulator and serves two purposes; first, to reduce the rate of melting of the ice and, secondly, to help maintain cool and stable water temperatures.

A gauge in the cab of the truck shows the operator the air pressure in the system and the temperature of the water in the tanks without stopping the vehicle.

One of the disadvantages of this type of aerator is the fact that the water temperature is significantly affected by the temperature of the air which is pumped through the system. On extremely hot days this would be a problem. This is one reason why we try to distribute the bulk of our trout during April, May and the first part of June when temperatures in this latitude are not usually excessively high and so far we have had no difficulties in this regard.

Air Pressure Control

The relief valve at the front of the master air tube is always set at one pound pressure. Before loading the fish at the hatchery, the required amount of water is run into the tanks and the outlet valve in each tank is fully opened. The engine of the aerator is then started and the r.p.m. regulated by adjusting the throttle setting until the air output of the airblower is just sufficient to cause a small amount of air to continually escape from the relief valve.

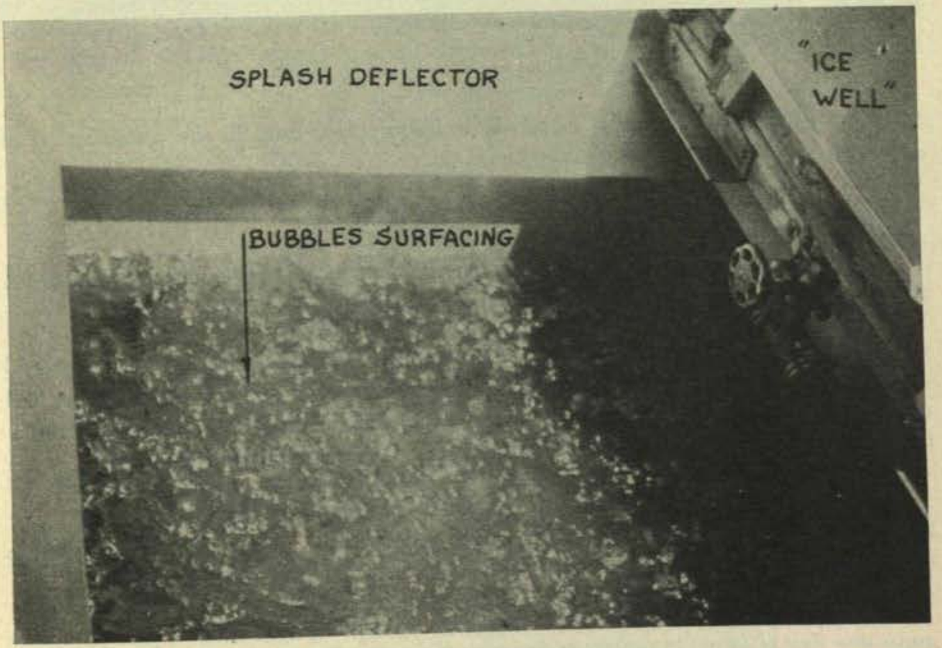


Figure 6—Fish tank with lid raised showing bubbles at surface of water.

The desired amount of air passing through the holes in the grid of each tank[1]. (which can be estimated by the amount of bubbles surfacing) is selected by adjusting the air outlet valve in the lid of the tank. When the truck reaches the stream or lake where the fish are to be released, the lid is lifted, the air outlet valve completely closed, and the grid lifted and hooked on the lid, as shown in photograph below. This allows the operator to dip the fish out of the tank without obstruction by the grid.

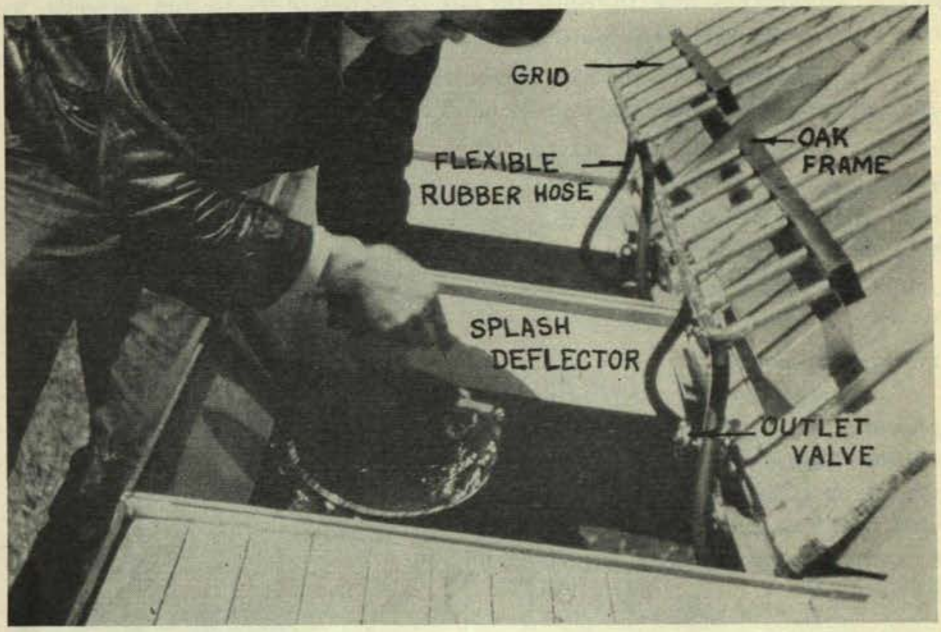


Figure 7—Dipping water from fish tank to fill tub.

The following is a list of materials and equipment used in the construction of the aerator:—

Truck—Two-ton stake truck with $7\frac{1}{2}'$x12′ floor.

Tanks—6 steel tanks 3′x3′ and 2′ in height, with hinged wooden tops in which are metal "wells" for ice. (Each well is 15″x15″x4″).

Airblower—1 Rotary Positive Airblower 24AF, with standard discharge and drive shaft, without base and pulley. 1 P.W. relief valve. 1 inlet muffler filter and two flexible connectors. (The airblower, plus attachments, approximately $100). One—7″ V type pulley (purchased locally). 1—Raybestos 64 Fan belt.

Motors—Two—1-1/2 to 2 H.P. air cooled gasoline motors (about $65 each). 2—flexible exhaust pipes (To carry heat away from blower). Two—3″ V type pulleys (purchased locally).

[1] *Air supply is reduced for Kamloops and brown trout yearlings. If outlet valves are fully opened, both species show signs of distress by jumping at the surface of the water in the tanks. Yearling speckled trout will take full pressure at all times.*

Gas Tank and Fittings—One—gas tank, 3-gal. capacity. One—41x6 Weatherhead fitting. One— 3200x2 Weatherhead fitting. Four 68x4 Weatherhead fittings. One—6737 Weatherhead fitting. One—68x6A Weatherhead fitting. Two feet of 3/8 copper tubing. Eight feet of 1/4 copper tubing.

Tubing and Fittings—Air System—20 feet—1-1/2″ galvanized pipe (Master air tube, air intake tube, air outlet from airblower). 1-1/2 feet—car radiator hose (For flexible connections in 1-1/2 piping). Six—1-1/2″ Galvanized Iron Elbows. (For right-angle bends in iron tubing between airblower and master air tube). 120 feet—1/2 inch copper tubing. (For grids). 42—copper 1/2″ T's. (For grids). 12—copper 1/2″ Elbows. (For grids). 6—Outlet Valves—Stop and Drain 1/2″ Bronze Valves (one for each tank). Six—1-1/2″ galvanized T's. (Master air tube to outlet for each tank). Six—1-1/2″ to 1/2″ Reducers. (Master air tube to outlet for each tank). Six—1/2″ copper to iron adapters. (Master air tube to outlet for each tank). 42 feet—car heater hose. (For flexible connection from outlet valves to grids). 36—Clamps to fasten hose to grids, etc.

Gauge—Air pressure and water temperature (both on same gauge with thermocouple). 12 feet—wiper hose for pressure gauge.

Acknowledgment

The authors wish to thank the staff of the Ontario Provincial Fish Hatchery at Normandale for their co-operation in the construction and operation of the unit.

Valuable suggestions on the design were made by Mr. D. N. Omand, who also helped in critical reading of the manuscript.

We are also grateful to Mr. John Krestel, Port Rowan, Ontario, who gave us a great deal of valuable information and advice on the construction and operation of the equipment.

A Device for the Controlled Drainage of Hatchery Troughs

by

H. H. MacKay

Ontario Department of Lands and Forests

After feeding trout fry or fingerlings in hatchery troughs, it is necessary to remove waste by sweeping down the debris to the outlet without injury to the fish. To do this effectively it is necessary to lower the water in the troughs.

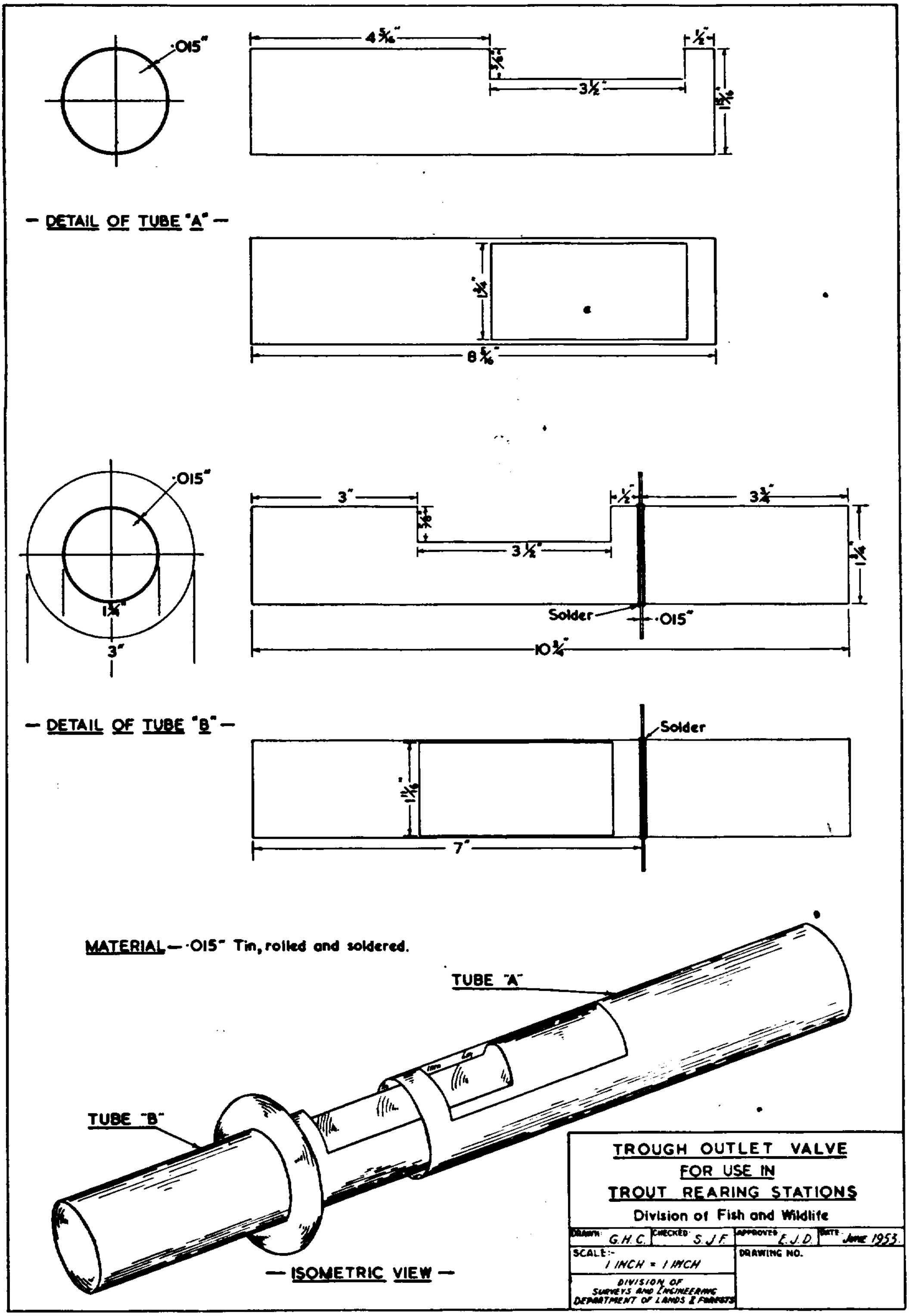
Several methods are in use, for example, by the partial removal of the plug at the outlet of the trough, by changing the level of the overflow pipe, or by slitting the bottom of a small tin can and inverting the can over the outlet. These methods are somewhat cumbersome and have been known to create considerable suction against the screen near the lower end of the trough causing small fry to be drawn against the screen. A controlled amount of suction speeds up the cleaning process without injury to the fish.

Mr. T. Marston, manager of the Pembroke Trout Rearing Station, Pembroke, Ontario, has devised a novel valve by which the flow of water against the screen may be regulated.

The valve can be made by a tinsmith to fit a drainage outlet of any practical size. It consists of two parts made of ·015 inch tin rolled and soldered. Tube A in the illustration is $8\frac{5}{16}$ inches long and $1\frac{15}{16}$ inches in diameter. From this tube an opening $3\frac{1}{2}$ inches long by $1\frac{3}{4}$ inches wide is cut. This opening is $\frac{1}{2}$ inch from one end of the tube.

The inner Tube B is $10\frac{3}{4}$ inches long by $1\frac{3}{4}$ inches in diameter. The opening of this tube is the same size as the opening in the outer tube A. The inner tube B has a flange around its circumference and $\frac{1}{2}$ inch from the bottom of its open section.

Tube A may be turned until it closes the opening of Tube B. The drainage plug or overflow pipe at the end of the trough may be removed and the new valve inserted in the hole until the flange rests on the bottom of the trough. Tube A is then turned until an opening is provided between the two open sections. This opening may be adjusted in such a way that the amount of suction against the screen is increased or decreased at will, and in such a way that the fry or fingerlings are not drawn against the screen.



·015"
4 5/16"
1/2"
3 1/2"
— DETAIL OF TUBE "A" —
8 5/16"
·015"
3"
3 1/2"
3 3/4"
Solder
·015"
10 3/4"
3"
— DETAIL OF TUBE "B" —
Solder
7"
MATERIAL — ·015" Tin, rolled and soldered.
TUBE "A"
TUBE "B"
— ISOMETRIC VIEW —
TROUGH OUTLET VALVE
FOR USE IN
TROUT REARING STATIONS
Division of Fish and Wildlife
DRAWN G.H.C.
CHECKED S.J.F.
APPROVED E.J.D.
DATE June 1953
SCALE:- 1 INCH = 1 INCH
DRAWING NO.
DIVISION OF SURVEYS AND ENGINEERING
DEPARTMENT OF LANDS & FORESTS

The Education of Undergraduate and Graduate Students in Fish and Fisheries Biology*

by

W. A. Clemens

University of British Columbia

It seemed desirable in considering the above topic to indicate my conception of the meanings of some of the terms used. In a broad sense, education consists in imparting knowledge in such a way as to lead to an understanding of the universe. This may be done on the basis of what I may call the Pyramid of Knowledge (Fig. 1). The base consists of data or so-called facts. These, when systematized and analyzed, lead to the development of generalizations or principles which in turn, when synthesized and resynthesized, provide a concept of the universe.

Education, then, consists in imparting information or data (too often teaching stops here) and then leading the student through the logical process of analysis, generalization and synthesis. The end result should be an individual who has some appreciation of his place in the "scheme of things" and who will think and act accordingly.

Much the same idea is expressed by G. E. Hutchinson (Amer. Scientist, Vol. 38, No. 1, 1950): "The pleasure in analysis and intellectual resynthesis of experience is one of the mainsprings of our culture, and therefore one of the primary functions of the university is to encourage the appreciation of this pleasure." Again, "In a general sense, it is the basic function of the university to emphasize, as vigorously as possible, that intellectual activity is one of the great pleasures of life, for in so doing the university performs the fundamental duty of encouraging us to know enough to implement the will to set our house in order."

Research consists in visualizing a problem, instituting pertinent observations and experiments, analyzing the data and, when the solution is achieved, developing generalizations. The education objective is to lead a student to understand this logical process and to train him in a special field so that he may make a contribution to knowledge, that is, add a splinter to the Pyramid of Knowledge and perhaps become a leader in advanced thought and synthesis.

Fish biology has to do with the morphology, physiology, growth, reproduction, taxonomy and ecology of fishes, that is, with the general biology. On the other hand, fisheries biology involves fish populations and the relation of exploitation to the stocks. Research in this field requires a sound, broad background of biological knowledge including reproductive potential, natural mortality, distribution, movements, migrations, etc., and the use of statistical procedures. The results should make it possible to inform the fishermen and others concerned at any time of the distribution and composition of the stock and of the amount of the stock which may be taken, not only as to time and place but as to age.

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* *A contribution to a conference held under the auspices of the Committee on Biological Investigations of the Fisheries Research Board of Canada.*

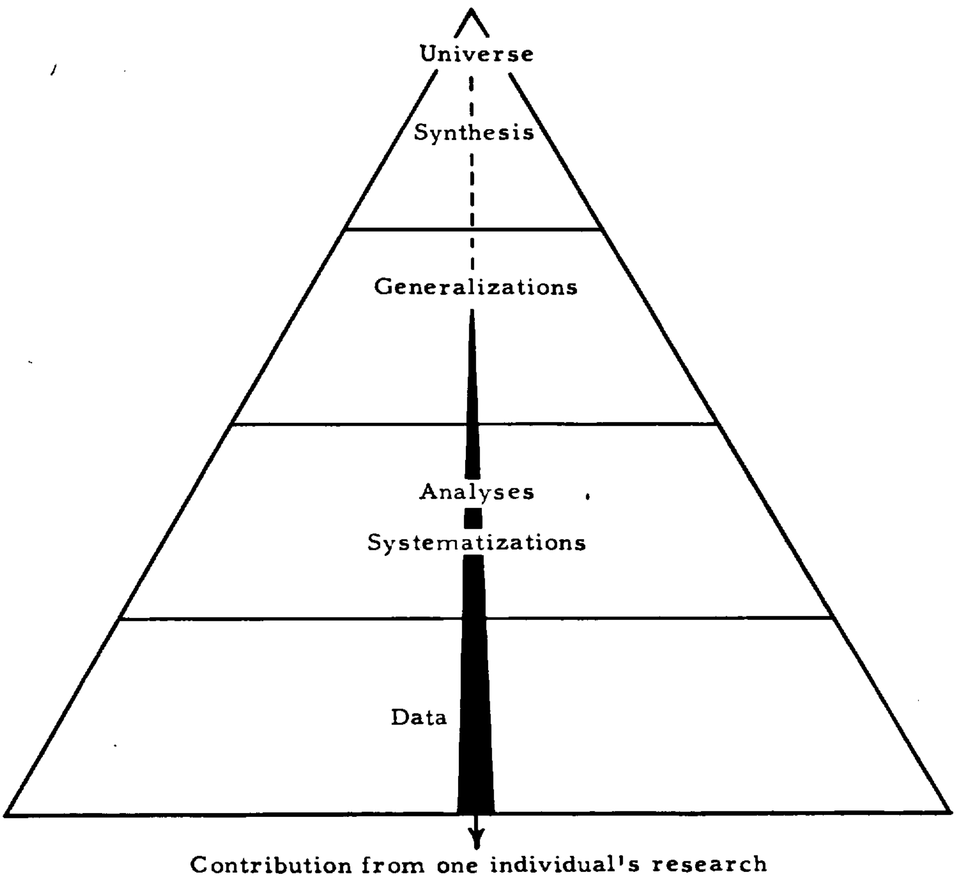

Figure 1—Pyramid of Knowledge.

Undergraduate Education

On the basis of what I have outlined, I believe that the undergraduate years should be a time for the acquisition of a broad, sound education. For the biologist I would suggest five divisions from which the student should make a judicious selection of courses:

a) Humanities:— English, Modern Language, Philosophy, Logic, Economics, Sociology, Political Science, etc.

b) Physics:— General, Physical Optics, Electricity and Magnetism, Biophysics.

c) Chemistry:— General, Analytical, Organic.

d) Mathematics:—General, Calculus, Statistics.

e) Biology:— Botany, including Morphology, Systematics. Zoology, including Morphology, Embryology, Physiology, Genetics, Systematics, Ecology. General Biology in the fourth year. An introduction to the student's speciality ex. Biology of Fishes.

The end product should be a student who thinks logically and biologically.

In the biological field I think there is some need for a revision in the "set-up" of instruction based upon:

a) a broader vision of the objective in biological education.

b) more attention to the animal kingdom as a whole,

c) some shift of emphasis from the static to the dynamic aspects.

Figure 2 illustrates the content of biology and the focus of its various divisions which, of course, are all interrelated.

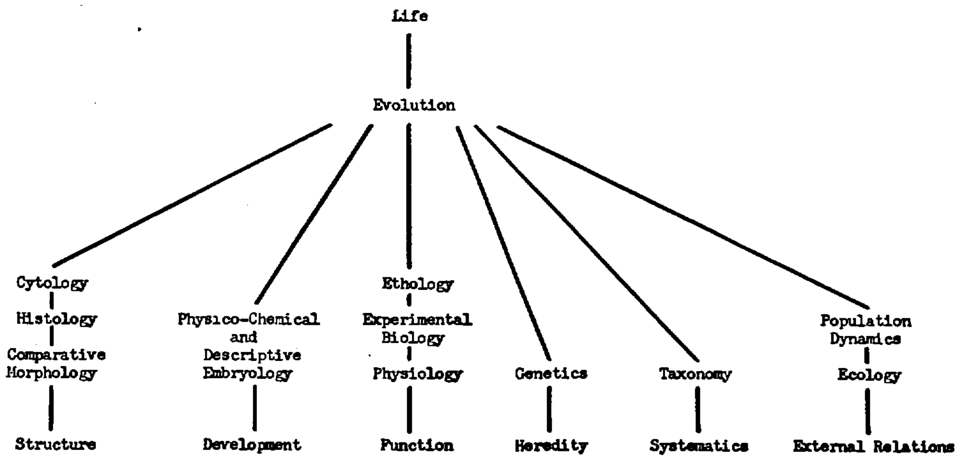

Figure 2—Content of Biology.

Graduate Education

The fifth and sixth years should be a period of specialization and of training in research, culminating in the award of the Master's degree. With reference to fish and fisheries biology, courses such as the following might be available:

Ichthyology, Fisheries Biology and Management, Population Dynamics, Oceanography, Limnology.

In addition, courses which might appear desirable to "round out" the student's field of knowledge might be selected from among the following:

Entomology, Marine Zoology, Meteorology, Law, Geology, Parasitology, etc.

Some of the instruction should be tutorial. Considerable attention should be given to directing the student in research and in the preparation of a thesis.

Very many courses have been mentioned in connection with the undergraduate and graduate years to the Master's level. It is not suggested that all of these should be covered in formal course work. The student should select with advice and he should be encouraged to develop the reading habit by which he may obtain knowledge in fields outside those of formal instruction.

The Doctorate period should follow the Master's and in it there should be:

a) Emphasis and concentration on independent research,

b) a minimum of instruction, most or all of which should be tutorial,

c) some time given to the development of a cultural field.

The objective should be the development of the student in the realm of productive scholarship.

It is not expected that any set programme of instruction will produce an educated and trained fishery or fish biologist. But if the teacher has, and the student gains, a vision of the objectives, the end result should be most satisfactory. In the final analysis very, very much depends upon the qualities of both teacher and student.

The Toxicity of Heavy Metals to Fish, With Special Reference to Lead, Zinc and Copper[1]

by

E. H. Vernon

British Columbia Game Commission, Vancouver, B.C.

Salts of heavy metals such as lead, zinc, copper, iron, manganese, cobalt, nickel, and cadmium may be discharged into natural waters as waste effluents from mines, chemical plants, steel plants, pigment works or other industrial processes. Because salts of heavy metals are very toxic to aquatic organisms, this paper was written as an outline of information for fisheries biologists, indicating the effects of heavy metals on fish, some toxicity levels, some relations with water chemistry and a partial introduction to literature on the subject.

Action of Heavy Metals on Fish

Salts of heavy metals combine chemically with proteins in the mucus secreted by the fish's skin, mouth parts and gills, forming insoluble compounds which prevent aeration of blood and lead to acute respiratory distress and death.

If the pollutant be sufficiently dilute, or if the supply of pollutant be intermittent, the secretion of additional mucus may wash away the precipitated compound as it is formed, or may carry away the larger masses of the precipitate before serious damage to the fish results. If, however, the concentration is large enough and the exposure time long enough the precipitated insoluble compound covers the body, lining of the mouth and the gills. Ellis (1937) states that the precipitate caused death by a combination of three conditions which individually or collectively disturbed the proper functioning of the respiratory and circulatory mechanisms.

(*a*) In the weaker concentrations, the precipitate coated the gill filaments and filled the filament interspaces so that water pumped through the mouth and onto the gills for aeration of the blood could not reach cells of the gill filaments. Aeration of the blood was prevented and death followed from anoxemia and carbon dioxide retention.

(*b*) In stronger concentrations, larger masses of flocculent precipitate formed on the gills, clogging the interlamellar spaces and preventing movements of the gill filaments. This condition affected circulation of blood in the gills, in that stasis of blood in the gill capillaries usually followed cessation of movements of gill filaments.

[1] *Derived from a Literature Review.*

(c) Gills of fresh water fishes are extremely important excretory structures, removing from six to ten times as much nitrogenous wastes as the kidneys. Special chloride-secreting cells are also present in gills of fresh water fishes. Therefore even weak solutions of heavy metals which do not damage the gills rapidly enough to cause speedy respiratory or circulatory failure can result in impairment of other functions, particularly those of salt-balance and excretion.

Apparently the outer epithelial tissues of fishes effectively block the penetration of heavy metals to the internal tissues. Chemical analyses and tests with isotopes have failed to detect traces of heavy metals in the internal organs of fish killed by these metals.

Some Effects of Natural Waters on Effective Concentrations of Metallic Salts

Variation in physical, chemical and biological conditions in natural waters has a very great effect on the concentration of metallic salts in solution. These salts must be in solution or in colloidal suspension to be effective as toxic agents.

Fluctuations in stream flow may radically change the concentrations, if an effluent is discharged at a uniform rate. In some cases (Jones, 1940) where pollutants are reaching waters from old mining refuse dumps, these pollutants may be washed into a stream in much greater amounts during periods of heavy rainfall. Periods of maximum concentration should be determined. These periods, even if of short duration, may be limiting factors in the survival of fish.

Salts of heavy metals are largely precipitated by carbonates so that, in general, "hard" waters with a high pH tend to greatly reduce effective concentration of metallic ions. With reference to copper, Smith (1935) finds that in hard waters a basic copper carbonate is formed:

$$2\,CuSO_4 + 2CaH_2\,(CO_3)_2 \rightarrow CuCO_3 \cdot CuO_2H_2 + 2\,CaSO_4 + 3\,CO_2 + H_2O$$

which hydrolyses to copper hydrate and precipitates:

$$CuCO_3 \cdot CuO_2H_2 + H_2O \rightarrow 2\,CuO_2H_2 \downarrow + CO_2$$

In hard waters no trace of copper salt remains in solution after 24 hours, but in acid waters hydrolysis does not occur and much copper remains in solution.

Moore and Kellerman (1904) also working with copper, suggest that the minimum lethal concentration of copper sulphate is increased 0·5% for each 10 p.p.m. of temporary hardness.

Ellis (1937) warns that even though precipitated out, compounds carrying heavy metals, as long as they remain in the stream, are subject to ingestion by fish and other animals, and, if water conditions change, are subject to re-solution.

The toxicity of metals increases with temperature and Moore and Kellerman (1904), using copper sulphate for the control of algae, suggest the following procedure to adjust a minimum lethal concentration to various temperatures. Fifteen degrees centigrade is taken as standard and 2·5% copper sulphate is added for each degree below standard temperature. Conversely 2·5% copper sulphate is subtracted for each degree above 15°C.

Heavy metals are removed from solution by combination with organic matter. All plants and animals contain proteins which combine with, and precipitate metallic ions. Smith (1935) cites the case of an *Anabaena* scum which was found to contain 11·25% metallic copper two hours after copper sulphate was applied to a lake. Only traces of copper could be found in the water at this time. In lake waters particularly, dissolved proteins and amino acids also remove metallic ions by precipitation. Moore and Kellerman (1905), using copper sulphate for algae control, suggest a 2% increase in $CuSO_4$ for each 10 p.p.m. organic matter.

These considerations indicate some of the difficulties of making accurate predictions of resultant metallic ion concentrations when measured quantities of metallic salts are added to known volumes of natural waters.

Some Toxicity Levels for Fish

Many records of toxicity to fish of heavy metals exist in the literature but most are of no practical value because conditions have not been accurately defined or natural situations have not been considered in designing laboratory experiments. Application of results to particular situations is rendered impossible. However, the following records are considered by the writer to be among those of practical value and will serve to indicate some toxicity levels for copper, lead and zinc. Jones (1938), using very soft water with calcium at about one p.p.m., found the following minimum lethal concentrations for the three-spined stickleback, *Gasterosteus aculeatus*:

0·3 p.p.m. of $Pb(NO_3)_2$ fatal in $4\frac{3}{4}$ days.
0·4 p.p.m. of $ZnSO_4$ fatal in 6 days.
0·04 p.p.m. of $Cu(NO_3)_2$ fatal in $5\frac{1}{2}$ days.
All concentrations are of metal—not salt.
Temperatures varied from 14° to 17°C.
pH was 6·4 to 6·6. Survival times are the means of four fish.
Volume of each solution was 2000 c.c. and was renewed daily.

Goodman (1951) found the following concentrations of zinc to be critical and cause some mortality in rainbow trout of various sizes:

10 to 14 day-old	— ·3 p.p.m.
4 weeks	— 2 p.p.m.
8 weeks	— 4 p.p.m.
3 inch fingerlings	— 6 p.p.m.
5 inch fingerlings	— 6 p.p.m.
10 weeks old	— 6 p.p.m.

All concentrations are of zinc. Temperature was 11°C. and pH 7·4 to 7·8. Tap water was used. These experiments were terminated after 48 hours and it is mentioned that some survivors died subsequently. It is very likely that much lower critical concentrations would have been found if fish had been exposed to the zinc for longer periods of time.

Compounds of various metals may have a cumulative toxic effect. Ellis (1937) found that goldfish kept in glass containers, with very insoluble lead sulphide ore on the bottom, suffered some mortalities after 61 days exposure. Jones (1938) found that three-spined sticklebacks were killed after 14 days exposure to 0·1 p.p.m. of lead. He concluded that for sticklebacks, critical lethal concentrations were: Pb— ·01 p.p.m., Zn— 0·3 p.p.m., Cu— 0·01 p.p.m.

Ellis (1937) lists the experimental results of many workers, a few of which follow:

Copper

0·143 p.p.m. $CuSO_4$—maximum concentration tolerated by brook trout in hatchery water. (Moore and Kellerman, 1905)

1 p.p.m. $CuSO_4 \cdot 5\,H_2O$ killed perch, catfish, suckers and trout in 10 hours. (Smith, 1935).

Lead

0·33 p.p.m. Pb. lethal to fresh water fish (Carpenter, 1936).
10 p.p.m. $Pb\,(C_2H_3O_2)_2$ killed yearling trout in stream water.
10 p.p.m. $Pb(NO_3)_2$ killed trout in stream water in 2½ hrs.

Zinc

100 p.p.m. $ZnSO_4$ killed goldfish in 5 days.

Jones (1938) has shown that apart from the precipitation reaction of $Ca(HCO_3)$ on metallic ions, there is also a direct antagonistic effect of calcium on the protein precipitation reaction. Even when no apparent precipitation occurs in a solution of metallic salt, calcium prevents the precipitation of mucus on the gills and reduces toxicity. This was checked (*in vitro*) on mucus of an eel, which precipitated with metal salts only in the absence of calcium. Jones (1938) also experimented with a running supply of "hard" water containing approximately 50 p.p.m. calcium as $Ca(HCO_3)_2$ and containing the maximum amount of lead it could hold in solution (0·7 p.p.m.). This solution proved harmless to the minnow *Phoxinus phoxinus* and to the stickleback *Gasterosteus aculeatus*, although a similar concentration of lead in "soft" water was fatal to sticklebacks. Ellis (1937) presents similar data which show that sodium also has an antagonistic effect on the precipitation of proteins by heavy metals.

Some Toxicity Levels for Other Aquatic Organisms

Toxic action of heavy metals has been utilized for many years in control of undesirable aquatic plants such as algae and pond weeds. An extensive literature on the subject exists including: Moore and Kellerman, 1904; Speirs, 1948; Hasler, 1949. Copper sulphate has been the metallic salt most generally used, and concentrations of approximately one p.p.m. are highly toxic to plants.

Newton (1944) describes the toxic action of zinc and lead on aquatic plants in a river. Because of the greater solubility of zinc she found that it had a greater toxicity and that this increased sharply with concentrations from 1 to 10 p.p.m. *Ranunculus aquatilus* was found to be most sensitive to lead and zinc and disappeared first, after pollution occurred.

Newton (1944) also found the highest concentration of zinc which the following aquatic animals could withstand:

Pond snail (*Limnaea pereger*)—0·2 p.p.m.
Fresh water limpet (*Acylastrum fluviatile*)—0·2 p.p.m.
Shrimp (*Gammarus pulex*)—0·3 p.p.m.
Mayfly nymph (*Chloeon simile*)—0·2 to 0·5 p.p.m.
Planarian (*Polycelis nigra*)—30 p.p.m.
Water boatmen (Corixidae), stonefly nymphs (Plecoptera), Dragonfly nymph (Anisoptera), Caddis larvae (Trichoptera)—500 p.p.m.

Suggestions for Control and Standardization of Procedures

The chemistry of natural waters is complex and extremely variable. To define the relationship of heavy metal toxicity with all the chemical variables, and to formulate general rules for application to any specific situation, would require extensive and fundamental research. The fisheries biologist will be forced to make decisions for many years without benefit of this research, but perhaps much may be accomplished without it if intelligent use is made of what is already known.

When considering an already polluted stream, the complexities of water chemistry are largely excluded. The usual procedure of chemical analyses of filtered water from the stream gives the effective concentration of metallic ions in solution. While some very small colloidal particles may be included in such analyses these probably contribute to the effective concentration. These colloidal particles may well go back into solution in the higher carbon dioxide concentrations adjacent to gill membranes of fishes.

While a good approximation of effective concentration of toxic metals in a polluted water may be made, the interpretation of results by comparison with experimental toxicity assays is, in many cases, impossible. In most toxicity tests, concentrations have been estimated by adding known amounts of metallic salt to a measured amount of water of unknown chemistry. The effective concentration is unknown and the results can have no application except to that particular water. If effective concentration of test solutions is measured by periodic chemical analyses the results can have far more general application.

As the antagonistic effects of calcium and sodium reduces toxicity of heavy metals, the concentration of these ions in test solutions should be known. If this proves impossible, some measure of their concentration such as pH or total alkalinity may be a useful approximation.

Temperature has an effect on toxicity of heavy metals and therefore should be controlled.

In attempting to predict the effects of a polluted water on aquatic organisms the fisheries biologist must know the maximum concentration which a particular species can tolerate, usually for considerable periods of time. Many experiments have not attempted to define these limits but have merely resulted in records of animals dying a short time after immersion in a single test solution. To find the minimum lethal concentration a series of solutions of increasing concentration should be tested over a period of at least 96 hours. To test for possible cumulative effects, experiments may have to extend over several weeks.

To establish the toxicity of a polluted water by reference to experimental results of other workers may be difficult, and such a procedure may merely indicate the nature of the problem. The concentrations found in a polluted stream may be of such magnitude that an immediate decision is possible. However, if concentrations are close to critical values found by other workers, bio-assays using the water in question may be necessary to establish whether toxic pollution is occurring.

Since this paper was written a valuable additional paper on the subject of metal toxicity has come to the writer's attention: Doudoroff, P. and Max Katz. 1953. Critical review of literature on the toxicity of industrial wastes and their components to fish. II. The metals as salts. Sewage and Industrial Wastes. 25 No. 7: 802-839.

Appended is a partial list of pertinent papers on the subject of heavy metal toxicity. The literature cited in the present paper is included in this list.

References

CARPENTER, K. E. 1925. *The biological factors involved in the destruction of river fisheries by pollution due to leadmining.* Ann. Appl. Biol. 12:1-13.

——— 1926. *The lead mine as an active agent in river pollution.* Ann. Appl. Biol. 13:395.

——— 1927. *The lethal action of soluble metallic salts on fishes.* Brit. Jour. Expt. Biol. 4:378-390.

——— 1930. *Further researches on the action of metallic salts on fishes.* Jour. Expt. Zool. 56:407-422.

CATT, JAMES. 1934. *Copper sulphate in the elimination of coarse fish.* Trans. Amer. Fish. Soc. 64: 274-279.

DOUDOROFF, P. et al. 1951. *Bio-assay methods for the evaluation of acute toxicity of industrial wastes to fish.*

ELLIS, M. M. 1937. *Detection and measurement of stream pollution.* Bull. 22, U. S. Bur. Fish. 48: 365-437.

GOODMAN, J. R. 1951. *Toxicity of zinc for rainbow trout.* Calif. Fish and Game. 37: No. 2, 191-194.

HASLER, A. D. 1949. *Antibiotic aspects of copper treatment of lakes.* Trans. Wisc. Acad. Sci., Arts & Letters. 39: 79-103.

JONES, J. R. E. 1938. *The relative toxicity of salts of lead, zinc and copper to the stickleback and the effect of calcium on the toxicity of lead and zinc salts.* Jour. Expt. Biol. 15: 394.

——— 1940a. *A study of the zinc polluted river Ystwyth in North Cardiganshire, Wales.* Ann. Appl. Biol. 27: 368.

——— 1940b. *The fauna of the River Melindwir, a lead polluted tributary of the River Rheidol, North Cardiganshire, Wales.* Jour. Anim. Ecol. 9: 188.

——— 1941. *The fauna of the River Dovey, West Wales.* Jour. Anim. Ecol. 10: 12.

LAURIE, R. D. and J. R. E. JONES, 1938. *The faunistic recovery of a lead-polluted river in North Cardiganshire, Wales.* Jour. Anim. Ecol. 7: 272.

MOORE, G. T. and K. F. KELLERMAN, 1904. *A method of destroying or preventing the growth of algae and certain pathogenic bacteria in water supplies.* U. S. Dept. Agr., Bur. Plant Ind., Bull. 64: 1-44.

NEWTON, LILY, 1944. *Pollution of the rivers of West Wales by lead and zinc mine effluent.* Ann. Appl. Biol. 31: 1-11.

REESE, M. J. 1937. *The microflora of the non-calcareous streams Rheidol and Melindwir with special reference to water pollution from lead and zinc mines in Cardiganshire.* Jour. Ecol. 25: 385.

SMITH, G. M. 1924. *Ecology of the plankton algae in Palisade Interstate Park, including the relation of control methods to fish culture.* Roosevelt Wildl. Bull. No. 2, 2: 93-195.

SMITH, N. W. 1935. *The use of copper sulphate for eradicating the predatory fish populations of a lake* Trans. Amer. Fish. Soc. 65: 101-114.

——— 1936. *Copper sulphate and the destruction of undesirable fish in lakes.* Biol. Bd. Can. Prog. Rept. Atl. St. No. 17: 8-9.

SPEIRS, J. M. 1948. *Summary of literature on aquatic weed control.* Can. Fish. Cult. 3: 20-32.

THOMAS, A. 1915. *Effects of certain metallic salts upon fishes.* Trans. Amer. Fish. Soc. 44: 120-124

EDMOND CLOUTIER, C.M.G., O.A., D.S.P.
QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1954

CJA

ISSUE SIXTEEN
AUGUST - 1954

THE CANADIAN FISH CULTURIST

Published at Ottawa by
The Department of Fisheries of Canada

Oct 5/54

CONTENTS

The Canadian Fish Culturist is published under the authority of the Minister by the Department of Fisheries of Canada as a means of providing a forum for free expression of opinion on Canadian fish culture. In the areas of fact and opinion alike, the responsibility for statements made in articles or letters rests entirely with the writers. Publication of any particular material does not necessarily imply that the Department shares the views 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. Those who may wish to discuss articles which have been published in The Canadian Fish Culturist are encouraged to do so and space will be made available.

Correspondence should be addressed to the DIRECTOR, INFORMATION AND EDUCATIONAL SERVICE, DEPARTMENT OF FISHERIES, OTTAWA, CANADA.

Published under Authority
of
HON. JAMES SINCLAIR, M.P.,
Minister of Fisheries

Planting Hatchery Stocks of Speckled Trout in Improved Waters*

by

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The planting in natural habitats of fish hatched and reared under artificial conditions is one of the oldest procedures designed to maintain and improve sport fishing. The procedure is based upon the assumption that there are deficiencies in nature that man may overcome. Specifically, there is the assumption that, for whatever reasons, naturally-reared stocks of game fish, such as the speckled trout, are insufficient to utilize fully the productive capacities of many of our fresh waters. However, we have progressed in fish-cultural matters to the realization that we are indeed fortunate if any one procedure by itself gives anticipated results. The planting of hatchery stocks of speckled trout is no exception, and the history of the procedure discloses more failure than success when data have been available for assessment. Rather, we have seen that benefits from fish-cultural procedures have been most frequently obtained when two or more actions have been taken consecutively or concurrently. It is the intent of this paper to show that when the trout-producing capacity of a natural lake was increased by fertilization and mortalities were reduced by control of predatory mammals, birds and fish, the planting of hatchery stocks proved to be an integral part of the programme and contributed strongly to the improved angling that was realized.

Fertilization and Predator Control at Crecy Lake

Creel censuses conducted for a number of years on eight lakes of southwestern New Brunswick disclosed low yields of speckled trout to the fishermen (Smith, 1952a). The average yield from the lakes per season amounted to only 0·6 pound of trout per acre (0·08 to 2·1 pounds). On the average it took a person three hours to capture a trout.

Associated with the low yield of trout was a low mineral content in the water of these lakes, in keeping with drainage from an area of igneous rocks. Believing that the infertility of the waters was the basic reason for the low yield of trout, Crecy Lake, one of those on which creel censuses were made, was fertilized in 1946 to determine if the level of trout production could thereby be substantially improved. Crecy Lake has an area of 50 acres and mean depth of 7·8 feet. Sufficient ammonium phosphate and potassium chloride were added to the lake to provide 6·5 pounds of the fertilizer per acre-foot.

As previously reported (Smith, 1952b), the fertilization resulted in an improved growth rate of trout to the extent that introduced fingerlings were of suitable size for

**The first four papers in this issue were presented at the meeting of the Canadian Committee on Fresh water Fisheries Research held at Ottawa in January, 1954. A fifth paper, "The History of Lake Minnewanka with Reference to the Reaction of Lake Trout to Artificial Changes in Environment" by Jean-Paul Cuerrier, Canadian Wildlife Service, which was also presented at the meeting, was published in Issue No. 15 of The Canadian Fish Culturist.*

angling during the year after planting—a situation not previously encountered in lakes of the region. Fingerling trout planted at mean fork length of 8·2 cm. in early September, 1946, were taken by anglers at a mean length of 21·7 cm. during the following May and June. A definitely better yield of trout to the anglers resulted (Table I).

Table I

Yield of trout to anglers from Crecy Lake

	Number caught	Number per rod hour	Pounds per acre	Pounds per acre produced in lake*	Pounds per acre of native trout
1943	166	0.5	2.2	2.2	2.2
1944	148	0.5	1.5	1.5	1.3
1946	139	0.6	1.4	1.1	0.7
1947	425	1.0	3.6	2.8	0.5
1948	110	0.3	1.6	1.4	0.3
1949	39	0.2	0.9	0.8	0.2
1950	264	0.6	2.9	2.2	0.2
1951	1,441	1.4	6.4	5.3	0.4
1952	2,418	1.6	11.4	5.5	0.1
1953	3,276	1.9	18.1	8.7	0.1

*Calculated from the weight increase while in the lake of the captured planted trout plus the weight of native fish.

The improvement did not persist, however, for in 1948 and 1949, notwithstanding that the growth continued to be as good and even better, the catches of planted and native trout declined to below pre-fertilization levels. Coincident with this decline there appeared to be an increase in the number of fish-eating birds and mammals frequenting Crecy Lake, probably attracted by a consistent annual introduction of hatchery trout. Attempts to reduce the number of these predators were initiated in 1949 and became more fully effective in 1950 and later. A programme of trapping eels, which are the only predatory fish in the lake aside from possibly the trout themselves, was also undertaken in 1950. There followed in 1951 a yield of 1,441 trout, captured at a rate of 1·4 per hour as compared to a previous high, with comparable stocking, of 425 trout at 1·0 per hour in 1947, the year after fertilization (Table I).

The growth rate of the trout was slower in 1950 and 1951 when, as indicated by larger yields, there was a greater population of trout in the lake. These findings prompted a second comparable fertilization in 1951 to establish whether both growth and survival could be improved by concurrent application of fertilization and predator control. To ensure adequate stock of trout to capitalize fully upon any increased production that might be occasioned by the second fertilization, the number of introduced trout was also doubled in 1951. The results of these and previous actions are summarized in Tables I and II and are shown to be favourable.

Contribution of Naturally-Reared Trout to the Anglers' Catches

Crecy is a headwater lake which has no permanent tributary streams. At low-water levels drainage into the lake is by seepage from a contiguous swamp area. Spawning facilities for trout are accordingly limited and practically all of the spawning that does occur is confined to the shallow littoral area where seepage enters the lake and suitable bottom is to be found. The outlet streams present few opportunities for spawning, nor does it provide favourable conditions for the survival of small trout, especially in late summer.

As shown by the records for the early years of the investigation, natural propagation provided a yield to the anglers of about one and a half pounds of trout per acre (Table I). However, with persistent and increased fishing effort, the yield of naturally-reared trout became less through the years, although the conditions for growth and survival of trout in the lake improved. Netting and observations at the time of spawning corroborated the results of the creel censuses to the effect that there were few native trout remaining in the lake. Apparently the naturally-reared stock of trout was not able to utilize at all fully the productive capacity of the lake.

Table II

Survival of planted trout to anglers' creels

Year planted	Average length, cm.	Number planted	Number angled	% survival
I—Planted as fingerlings				
1946	8.2	6,701	288	4.3
1947	7.4	6,674	52	0.8
1948	6.1	6,575	26	0.4
1949	6.6	6,633	129	1.9
1950	8.4	6,750	1,338	19.8
1951	7.9	14,160	1,650	11.7
1952	6.7	13,438	1,746	13.0
II—Planted as yearlings				
1944	28.3	665	6	0.9
1945	19.2	812	82	10.1
1946	21.3	659	111	16.8
1947	21.4	675	26	3.9
1948	16.2	675	12	1.8
1949	18.7	674	193	28.5
1950	18.5	675	306	45.3
1951	17.3	675	244	36.2
1951	24.8	674	552	81.9
1952	20.8	675	597	88.4
1952	26.0	675	574	85.0

Contribution of Planted Trout to the Anglers' Catches

Introduced hatchery trout contributed 89 per cent by number and 78 per cent by weight to the greater yield experienced in 1947, the year following fertilization. Of the fingerlings planted in 1946, 4·3 per cent survived to the anglers' creels (Table II). As previously noted, predation apparently masked the beneficial effects of fertilization, and in 1947 and 1948 stocking was quite ineffective in maintaining, let alone increasing, the yield, although in those years it was the planted trout that provided most of the catch, even if much reduced. Following the inception of predator control in 1949 and with a second application of fertilizer in 1951, the yield of trout steadily rose to a comparatively high level in 1953 (Table I). In this period almost 100 per cent of the trout captured came from planted stock. Of fingerlings planted in 1950, 19·8 per cent entered the anglers' catches of the next two years. Of the yearlings introduced in 1952, 87 per cent were taken by the fishermen during 1953. The important role played by the planted trout in the improved condition of the angling in Crecy Lake is self-evident. Yet it is also evident that the procedure of planting hatchery trout became effective only when applied in conjunction with fertilization and predator control, and in a situation where the supply of naturally-reared trout was too poor to turn the improved trout-carrying capacity to profitable account.

The investigation at Crecy Lake has been concerned with bettering a sport fishery and not with providing food in a commercial sense. However, it is pertinent to inquire what net return in trout flesh has been realized from the plantings of hatchery trout. In Table III the total weight of each planting of trout is compared to the total weight of trout from each planting subsequently captured by the anglers. It may be seen that only when the survival of the introduced trout to the anglers' catches was relatively high was there a net gain in weight.

Table III

Relationship of total weight of trout when planted to total weight of recoveries by anglers from Crecy Lake

Year of planting	Total weight of planted trout		Net gain or loss in weight (lb.)	% survival by number
	When planted (lb.)	When angled (lb.)		
	Planted as fingerlings			
1946	103.0	95.9	− 7.1	4.3
1947	83.0	33.8	− 49.2	0.8
1948	47.7	8.7	− 39.0	0.1
1949	61.6	57.0	− 4.6	1.9
1950	108.9	229.5	+120.6	19.8
1951	262.5	259.4	− 3.1	11.7
1952	124.9	217.5	+ 92.6	13.0
	Planted as yearlings			
1944	435.9	4.5	−431.4	0.9
1945	149.1	43.7	−105.4	10.1
1946	169.7	67.8	−101.9	16.8
1947	176.2	22.0	−154.2	3.9
1948	71.6	10.1	− 61.5	1.8
1949	115.2	138.1	+ 22.9	28.6
1950	127.9	127.3	− 0.6	45.3
1951	376.1	348.1	− 28.0	63.8
1952	528.2	556.8	+ 28.6	86.8

A more detailed account of these investigations is in preparation. This paper is published with permission of the Fisheries Research Board of Canada.

Summary

The planting of hatchery-reared speckled trout, fingerlings and yearlings, to provide better angling was effective in Crecy Lake, New Brunswick, when conditions for growth and survival of trout in the lake were made more favourable by fertilization and predator control, and where the supply of naturally-reared young trout was insufficient to utilize an improved trout-carrying capacity.

Literature Cited

SMITH, M. W., 1952a. *Limnology and trout angling in Charlotte County Lakes, New Brunswick*. J. Fish. Res. Bd. Can., Vol. 8(b): 383-452.

1952b. *Fertilization and Predator Control to Improve Trout Production in Crecy Lake, New Brunswick*. Canadian Fish Culturist, No. 13: 33-39.

Pacific Salmon for Atlantic Waters?*

by

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There is a striking contrast between Canada's Atlantic and Pacific fisheries. The Atlantic industry depends heavily on a large volume of relatively low-priced cod, while the Pacific gets most of its income from relatively high-priced salmon. Some approximate figures for 1948 Canadian production, including Newfoundland, are as follows (1):

	Total marketed value (exports only, for Nfld.)	Round weight
Atlantic—		
All fishery products...........	$65,364,000	
Salmon only.................	$ 1,995,000	4,873,000 lbs.
Pacific—		
All fishery products...........	$58,704,000	
Salmon only.................	$36,671,000	145,168,000 lbs.

The year 1948 was fairly representative of recent years on both coasts. The Atlantic salmon catch, though it fluctuates a lot, has only once been more than 10,000,000 pounds.

However, even these figures do not do justice to the greater abundance of salmon in the Pacific Ocean, because while practically all of the new world's Atlantic salmon production is Canadian, we take much less than half of its Pacific production. The latter amounted to 798,000,000 pounds a year in the early 1940's, of which Canada's share was 167,000,000 pounds (2).

The first thing to remember, in comparing Pacific with Atlantic figures, is that the word "salmon" does not mean the same thing on the two coasts. The Atlantic salmon are all of one species, *Salmo salar*. This is a rather large fish of good quality, sold mainly in the fresh market. The Pacific "salmon" include five different species of *Oncorhynchus*, each distinct from one or more of the others in respect to length and place of freshwater life, size and age at maturity, behaviour and feeding habits in the sea. Some of these differences are shown in Table I. In value, the Pacific salmon tend to fall into two groups: pinks, chums and the white-fleshed variety of spring salmon bring only about half as much to fishermen as do red springs, coho and sockeye. There is also in the west a steelhead "trout", which in appearance and habits is more closely allied to the Atlantic salmon than is any species of *Oncorhynchus*. Like the Atlantic salmon too, the steelhead supports only a minor commercial fishery.

This brief survey of well-known facts leads directly to some familiar but difficult questions: Are salmon (in the inclusive sense) more numerous on the Pacific coast because of the greater variety of species present? Would it be possible to build up a major salmon fishery in the Atlantic by introducing the Pacific species? Could this

**Presented at the meeting of the Canadian Committee on Freshwater Fisheries Research held at Ottawa in January, 1954.*

Table I

Characteristics of American species of Pacific salmon (*Oncorhynchus*)

Name	Chinook (spring)	Coho	Sockeye	Pink	Chum
Scientific name	*tshawytscha*	*kisutch*	*nerka*	*gorbuscha*	*keta*
Approximate maximum size, lbs	100	25	15	12	35
Average commercial size (B.C.)	18	9	8	6	13
Usual age at maturity[a]	3-8	3-4	4-6	2	3-6
Usual growth in fresh water[a]	A few months, in rivers	1-2 years, in rivers	1-2 years, in lakes	None	None
Food in the ocean	Mostly fish	Mostly fish	Plankton, small fish	Plankton, small fish	Plankton, small fish
Commercial fishery	Trolling and nets	Trolling and nets	Nets only	Nets only	Nets only
Average landed value, cents per lb. (B.C., 1951-52)	Red, 21-24 White, 12-15	15-21	25	8-10	7-9

[a]The older ages and the longer periods of freshwater life are characteristic of more northern stocks.

be done without harm to stocks of native Atlantic salmon? What would the effect be, upon Canadian economy, of having a major supply of salmon in the east—particularly around Newfoundland, Labrador and the St. Lawrence estuary? Answers to these questions must determine whether or not new attempts to transplant Pacific salmon should be made.

Natural Distribution

The Pacific salmons occur naturally in the north Pacific, south to Japan and California. They are taken commercially as far north as the Bering Sea and somewhat beyond. In the Arctic Ocean pink and chum salmon occur as far as the Lena River to the west, while chums are known in the Mackenzie to the east (3, 5). However, salmon are not abundant in either of these rivers, and there seems to be no important fishery north of Bering Strait, off either continent.

Within their native range Pacific salmon tolerate a wide range of ocean temperatures and salinities; these have been summarized by Davidson and Hutchinson (4). Excluding the Arctic, summer surface temperatures up to at least 15° C. and down to at least 5° are found along coasts where they occur; temperatures at 200 meters vary from about 8° to less than 0°. Temperatures within these ranges abut most of Canada's Atlantic coast, so the most obvious preliminary condition for successful transplantation is satisfied. It is not possible to go farther than this with any confidence. A detailed comparison of the oceanography of the Atlantic and the Pacific, and of the rivers available and accessible, might permit a more confident prediction of success or failure, but only actual trials are likely to supply a final answer.

As far as the ocean is concerned, our Atlantic coast resembles the Asiatic side of the Pacific far more closely than it does the American side. Along both these shores a massive body of Arctic water moves a long way southward before becoming mixed and dispersed; while the Sea of Okhotsk, like the Gulf of St. Lawrence, is at least partly ice-covered in winter. What then is salmon production in Asiatic waters? The most readily available estimates are given in Table II, and compared with figures for the whole of North America and for British Columbia (5, 6). In Asia, as in America, chums and pinks are the principal commercial species; in fact their estimated catches considerably exceeded the American catches in the years tabulated. Sockeye, coho and

Table II

Asiatic, North American, and British Columbia production of Pacific salmon, in millions of pounds. Data for 1936-39 are from (5), the figures for Asia including both USSR and Japanese catches. The Canadian figures are for the first two years of the improved statistical system (6).

Kind of salmon	Asia 1936-39	North America 1936-39	Canada 1951-52
Chum	370–480	140–190	32–63
Pink	330–750	290–420	51–60
Coho	11–22	44–59	22–35
Sockeye	66–88	220–290	30–31
Chinook (spring)	2–5	44–58	13–14
Cherry (*O. masu*)	about 28	0	0

chinook, on the other hand, are all much less numerous in Asia than in America, though the Kamchatka sockeye catch is quite respectable—about twice that of British Columbia.

A comparison of ocean conditions is of course only half of the picture, and in any event the analogy between Siberian and Canadian Atlantic waters cannot be pushed too far. But as far as it goes, it suggests that pinks and chums, at least, have a good chance of becoming abundant in the western Atlantic.

Earlier Transplantations of Pacific Salmon

A review of past attempts at introduction of Pacific salmon outside their native range has been made by Davidson and Hutchinson (4). After correcting some of their errors, Huntsman and Dymond (7) conclude that there is only one fully-documented successful experiment, that of chinook salmon transplanted to New Zealand. One success is of course sufficient to show that Pacific salmon *can* be acclimatized outside of the north Pacific, but the total score is certainly not impressive. Several other attempts "succeeded" temporarily, in that adult fish returned to the stream where eggs or fry had been liberated, but no permanent self-sustaining run was established. This occurred, for example, on the Dennys River of Maine, where pink salmon persisted for several generations with the help of artificial propagation. An experiment is still in progress on another Maine river, the Ducktrap, where there may now be an "established" run of 100 or more cohoes from plantings made in 1943-48. Native-born non-hatchery adults were seined there in 1952, but it is too soon to say whether the run will persist indefinitely (8, 9).

In Canada there has been relatively limited activity in transplantation, done principally during the period 1919-25. Most of it consisted of an attempt to introduce chinook salmon in Lake Ontario streams as a substitute for the Atlantic salmon which had disappeared 35 years earlier. A compilation of these introductions by Mr. J. A. Rodd has been published (10). Though adult chinooks were caught in the lake, and a few returned to the rivers and were observed building redds (11), no permanent runs were established. One substantial shipment of chinook eggs also went to the Grand Falls hatchery, New Brunswick, again without permanent results. In all, about 1,700,000 eggs were involved in these transfers.

Considering that the chinook is the least common salmon in the Pacific and, apart from sockeye, the most "choosy" one in respect to the streams it ascends, it is perhaps not surprising that these efforts failed. In the Ontario work, the large lake which the young fish had to traverse before getting to salt water was something absent from the environment of chinooks of the stock used (autumn-spawning white springs from the Harrison River rapids in British Columbia). And in fact it is not known whether the adult fish observed in Lake Ontario had been to sea, or whether they grew up in the lake.

Difficulties of Salmon Transplantation

The lack of success which has usually been experienced in transplanting anadromous salmon, even to apparently suitable waters, may call for special explanation. It contrasts with the quick success which has often been achieved with non-anadromous salmonids, and also with the immediately-successful acclimatization of anadromous striped bass and shad in California waters. These latter species, however, do not necessarily go far out to sea; a large fraction of the bass, for example, may from the beginning have remained in or near San Francisco Bay and hence close to suitable spawning grounds, as they do to-day. What is known of the ocean life of both Pacific and Atlantic salmon suggests, on the contrary, that they usually travel far afield. Chinook and coho salmon have often been found to go hundreds of miles along the coast after tagging (12), while Japanese pelagic fishing shows that large numbers of pinks, chums and sockeye are present far out at sea, over deep water much beyond the limits of the continental shelf (13). Under these conditions, the "homing" of a sufficient number of newly-introduced stock to their adopted stream, or to *any* single stream, may be fraught with hazards. This would be especially true if a salmon's ability to home to and become established in a new site depended partly on hereditary factors, and hence only partly on the individually-acquired response which has frequently been demonstrated. In the west there are indications that transplanted stocks of salmon commonly return to a stream less completely than native stocks. Furthermore, for sockeye there is one experiment suggesting that the more closely the habitat of a donor race resembles that of the locality to which it is transferred, the better the survival (4).

If this hereditary component in homing ability does exist, then the process of establishing a new run becomes an example of speeded-up adaptation by natural selection. The most obvious by-product of this selection is a poor rate of return during the first few generations. This suggests two desirable characteristics for any programme of transplantation:

1. Relatively large plantings should be made to one or a few sites, at first, so that there will be an adequate expendable surplus while the selection process is weeding out genes whose effects are in poor adjustment to the new situation. Reasonably large plantings may also provide greater percentage survival because of less predation (15).

2. Donor stocks should be carefully selected in order to match up the freshwater and marine conditions of existence of the old and the new sites as closely as possible. For example, if a lake is to be stocked with sockeye, and the only suitable spawning beds are in the outlet, we should select a donor race which has the habit of outlet spawning, and one which spawns at the time of year at which this outlet water becomes of suitable temperature. Also, if the neighbouring sea is cold, fish from the northern part of the native sockeye range would probably take hold most quickly. For more northerly introductions in Newfoundland and Labrador it might even be wise to try to obtain eggs from Bering Sea stocks of all species used.

Only experience will show how careful it is necessary to be in these and other respects. Most of the rather sketchy information available on transplantation in the west concerns chinooks and sockeye, and it may be that the other species will more readily become adapted. However past efforts to establish "off"-year runs of pink salmon are not reassuring (16), though in that there may be other factors involved. Either disappointing results, or unnecessary trouble, might be avoided by a preliminary series of experiments in British Columbia, designed to compare the ocean survival and return of native runs with that of transplanted stocks from different types of environment.

Effects upon Atlantic Fishes

Considering the freshwater habits of the five Pacific salmons (Table I), only the coho seems a possible significant competitor of Atlantic salmon. Coho spend a year or two in a river before going to sea, and might compete then with Atlantic salmon parr. Detailed study and comparison of the stream habits of the two species could indicate whether this competition would be serious. In British Columbia, coho and steelhead seem to live together happily enough. However, it would be well to defer any attempt to transplant cohoes until their relation to native salmon can be clarified. The Maine experiments may provide some of the necessary information. The introduction of cohoes there was made in the hope that they would occupy many streams which have too little water to maintain Atlantic salmon through the summer.

As regards eastern marine fishes, the picture cannot be assessed very clearly without better knowledge of where the various Pacific salmons go in the sea. If sockeye, pinks and chums are really mainly pelagic, then much of their feeding would be done in waters whose food supplies are scarcely touched by any commercial fish in the Atlantic at the present time. If salmon ever became really abundant on the banks, they might to some extent displace cod and certain other commercial species, though any significant reduction is difficult to imagine. (The 1951 catch of cod alone, from northwest Atlantic waters, is given as 1,829 million pounds (7).) In any event no one would be apt to object if cod, hake or pollock were to be partially replaced by salmon, because salmon are so much more valuable.

Can Native Atlantic Salmon be Increased?

Important developmental and research programs in the eastern provinces to-day are devoted to learning how best to increase the supply of native salmon. Several promising lines of attack are being tried, for example, bird control, water control, opening up of new nursery grounds by fishways or by continuous artificial propagation, better spawning escapements in some areas, and so on. These efforts should be and undoubtedly will be continued and intensified. Nevertheless, even the most optimistic will scarcely expect such measures to do more than double or triple the supply of salmon on the Atlantic coast as a whole, in any foreseeable future. And whether the supply is increased or not, it is likely that anglers will wish to take a larger and larger share of it as time goes on. Thus, although the largest possible production of *Salmo salar* should certainly be promoted, a major commercial salmon industry in the east could only be based upon western species.

It seems fairly clear why the Atlantic salmon has always been, and will always be, a relatively uncommon fish by commercial standards. The trouble is that it makes very heavy demands upon fresh waters, of which the supply is limited. A river must support each Atlantic salmon for two or three years of its life. Past fluctuations in Canadian Atlantic salmon supplies have been laid largely to fluctuations in the volume of the eastern rivers, and a short-term correlation of Margaree commercial salmon catches with summer discharge of that river has been documented (18). (There are also strong indications that river volumes mainly limit the commercial stock of the coho salmon, which has similar requirements (19, 20).)

In sharp contrast, the two most abundant Pacific species, pinks and chums, are relatively free of freshwater shackles. Of rivers they require only suitable spawning gravels—their food comes exclusively from the rich pastures of the ocean.

Sport Fishing

Although the introduction of Pacific salmon seems attractive mainly as a commercial venture, it might also pay dividends to anglers. Chinook salmon and (if they prove admissible) coho salmon both provide excellent salt-water sport fishing, while pink salmon also are sometimes taken by trolling. To introduce this diversion in the east would increase the attractiveness of the Maritimes area to residents and visitors alike. Even though chinook and coho were never to become generally abundant, they might be so locally, under favourable conditions. St. Andrews, for example, standing by a bay that is filled to overflowing with young herring on which these salmon should prosper, might possibly become as famous a sport fishing center as Wedgeport or Campbell River.

Coho and chinook salmon can also be taken by rod after they enter fresh water, but they do not provide the excellent warm-weather river angling for which Atlantic salmon are so famous. Even so, improvement of river salmon angling might be an important by-product of successful transplantation of Pacific salmon. For if a large commercial fishery for some of the Pacific species develops, it may become possible and desirable, by careful regulation of kinds of gear and places and times of fishing, to spare for anglers many Atlantic salmon that are now taken in nets.

The Economic Picture

Western fishermen and processors, faced with difficulty in marketing their present salmon packs, may look askance at any proposal which might increase competition from eastern waters. Certainly if our Atlantic coast were producing to-day the 700 to 1,000 million pounds of pinks and chums which are taken on the corresponding stretch of Asiatic coast, the salmon market would be considerably "softer"—that is, more favourable from the consumer's point of view. Obviously, however, there is no prospect of a sudden production of this magnitude, or of any other magnitude. Even with the best of luck, it would be 10 or 12 years before significant commercial production from new transplantations could begin. Only after about 25 years might the fishery start to be of real importance, while the first 100 million pounds a year would be in sight only after perhaps 40 to 60 years, if ever. During the intervening years the western and eastern fishing industries alike would have time to make gradual investment and personnel adjustments necessary to meet the new situation.

It is for economists to assess the probable long-term effects of successful salmon introductions upon the general economy and standard of living of the eastern provinces. The committee which recently reported on Newfoundland's fisheries recommends both increased output and greater diversification (21), both of which would be provided by an expanded salmon industry. However, the final decision should be made by representatives of the people concerned.

To a non-economist, it seems likely that in the world of 25 or 50 years from now there will still be a scarcity, not a surfeit, of first-class protein foods. Perhaps Canada herself will have felt the pinch. From a national point of view, salmon have the advantage that for the most part they must come back near the three-mile limit before they can be caught easily. It may even be possible to establish a proprietary interest in anadromous fishes, on the basis of investments in their conservation in fresh water. Thus a Canadian fish supply might be assured even if the day comes (let us hope it is far distant) when our eastern offshore banks will be so continuously scoured by the trawls of competing nations that good-quality bottom fish can no longer be taken in paying quantities.

Summary

The commercial salmon fishery of the west Atlantic takes about 5 million pounds a year, as compared with about 150 million pounds in British Columbia and about 1,000 million pounds on the Asiatic side of the Pacific. The difference probably stems mainly from the fact that the two most numerous Pacific salmons live in rivers only during the spawning and incubation periods, and do not require the freshwater food or living space which appears to limit the supply of Atlantic salmon. Attempts at transplantation of Pacific salmon to other waters have only once been permanently successful—in New Zealand. However, Canadian effort along this line has been limited, and further trials would be warranted if the possibility of a major salmon industry in the east seems attractive to everyone concerned.

Literature Cited

(1) CANADIAN FISHERIES ANNUAL, 1952. Gardenvale, P.Q.

(2) Anon. 1945. *Fishery resources of the United States.* 79th Congress, 1st Session, Senate Doc. No. 51, Washington.

(3) J. R. DYMOND and V. D. VLADYKOV. 1934. *The distribution and relationship of the salmonoid fishes of North America and North Asia.* Proc. 5th Pac. Sci. Congress, pp. 3741-3750.

(4) F. A. DAVIDSON and S. J. HUTCHINSON. 1938. *The geographic distribution and environmental limitations of the Pacific salmon* (Genus Oncorhynchus). Bulletin U.S. Bureau of Fish., Vol. 48, No. 26, pp. 667-692.

(5) L. S. BERG, A. S. BOGDANOV, N. I. KOZHIN and T. S. RASS (editors). 1949. *(Commercial fishes of the USSR.)* Vsesoiuznyi N.-I. Institut Morskovo Rybnovo Khoziaistva i Okeanografii, Moscow.

(6) BRITISH COLUMBIA CATCH STATISTICS, for 1951 and 1952. Canada Dept. Fish., Pac. Area, Vancouver, B.C.

(7) A. G. HUNTSMAN and J. R. DYMOND. 1940. *Pacific salmon not established in Atlantic waters.* Science, Vol. 91, No. 2367, pp. 447-449.

(8) G. A. ROUNSEFELL and L. H. BOND. 1949. *Salmon restoration in Maine.* Atlantic Sea-Run Salmon Comm., Res. Rep. No. 1, 52 pp. Augusta, Maine.

(9) J. E. MASON. 1953. Personal communication. (Atlantic Sea-Run Salmon Commission.)

(10) J. R. DYMOND, J. L. HART and A. L. PRITCHARD. 1929. *The fishes of Lake Ontario.* Univ. Toronto Studies, Biol. Ser. No. 33, pp. 1-35. Pub. Ontario Fish. Res. Lab. No. 37.

(11) H. H. MACKAY. Personal communication.

(12) W. A. CLEMENS, R. E. FOERSTER and A. L. PRITCHARD. 1939. *The migration of Pacific salmon in British Columbia waters.* Publ. Am. Assn. Advancement Sci., No. 8, pp. 51-59.

(13) F. M. FUKUHARA. 1953. *Japanese 1952 North Pacific salmon-fishing expedition.* U.S. Fish and Wildlife Serv., Comm. Fish. Rev., Vol. 15, No. 2, pp. 1-17.

(14) R. E. FOERSTER. 1946. *Restocking depleted sockeye salmon areas by transfer of eggs.* J. Fish. Res. Bd. Canada, Vol. 6, pp. 483-490.

(15) F. NEAVE. 1953. *Principles affecting the size of pink and chum salmon populations in British Columbia.* J. Fish. Res. Bd. Canada, Vol. 9, pp. 450-491.

(16) A. L. PRITCHARD. 1938. *Transplantation of pink salmon* (Oncorhynchus gorbuscha) *into Massett Inlet, British Columbia, in the barren years.* J. Fish. Res. Bd. Canada, Vol. 4, pp. 141-150.

(17) INTERNATIONAL COMMISSION FOR THE NORTHWEST ATLANTIC FISHERIES, 2nd Ann. Rept., 1952, Table 2a.

(18) A. G. HUNTSMAN. 1937. *The cause of periodic scarcity in Atlantic salmon.* Trans. Royal Soc. Canada (V), Vol. 31, pp. 17-27.

(19) F. NEAVE. 1948. *Game fish populations of the Cowichan River.* Fish. Res. Bd. Canada, Bull. No. 84, 32 pp.

(20) W. A. SMOKER. 1953. *Stream flow and silver salmon production in western Washington.* Washington Dept. Fish., Fisheries Res. Papers, Vol. 1, No. 1, pp. 5-12.

(21) REPORT OF THE NEWFOUNDLAND FISHERIES DEVELOPMENT COMMITTEE. 1953. St. John's, Newfoundland.

Introductions of the Kamloops Trout in British Columbia Lakes

by

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British Columbia, like the rest of the North Western slope of the North American continent has a meagre fresh water fish fauna. This consequence of recent extensive montane glaciation has set the background for many of the problems of fresh water fish culture in the province today. The majority of lakes utilized in the widespread but light sport fishery contained no fish as little as 50 years ago. By far the most spectacular results of fish cultural practice have resulted from introduction of fish into these "barren" lakes, and there are undoubtedly still several hundred more which as yet contain no fish. In most drainage systems tributary to major river valleys in British Columbia, upstream migration of fish has been obstructed and in consequence the only species which frequently occur above natural obstructions are those which have been introduced by man. It is thus apparent that introduction of fish into lakes and streams of British Columbia has been and will continue to be a prominent feature in development of its sport fish culture.

British Columbia lakes and streams thus provide many types of localities in which the effects of both natural and man-made introductions can be observed. The situations which occur are so simplified that rare opportunities are provided for study. The kamloops trout (*Salmo gairdneri kamloops*, Jordan) is the most important species of sport fish in British Columbia and some features of its ecology and management in barren lakes are discussed below as an example of the results of introductions.

I. Introduction of Kamloops Trout in Barren Lakes

The Kamloops trout has been widely introduced into many different types of barren lakes in British Columbia. Figure 1 is an attempt to classify these situations from a management point of view. The material from which this summarization was derived, was obtained from surveys during the last five years of approximately 200 lakes in the province. The subject matter of Figure 1 is enlarged below.

Kamloops trout were planted in many barren lakes in the early part of this century and the history of the resulting fisheries is fairly well known. Usually the first introduction was a success and Kamloops trout up to five and six pounds were common three years after stocking. Paul, Pinantan, Salmon, Peterhope and Knouff lakes (Kamloops district) could be cited as a few examples. In recent years the same growth rate has been observed on Johnson, Andy, Jacko and Pass Lakes (Kamloops district). Because growth rates and population phenomena in the early years following introduction may reflect stocking schedules (for example, Rawson, 1947) the conclusions

*Presented at the meeting of the Canadian Committee on Freshwater Fisheries Research held at Ottawa in January, 1954.

Figure I

A summary of the results of introductions of Kamloops trout in British Columbia lakes

A. Favourable conditions (no summer or winter kill)			B. Unfavourable conditions
(i) Good spawning facilities	(ii) Poor spawning facilities	(iii) No spawning facilities	Summer kill Winter kill
Generally become overpopulated with large number of small trout. Common in small lakes.	Population size and growth rate vary in relation to changes in spawning grounds from year to year.	Population size and growth rate determined by artificial stocking.	Partial or complete kill in most years. Stocked artificially but usually population size low and growth rate high.
Need improvement.	Artificially stocked when necessary.	Artificially stocked.	Stocked with surplus. Usually no fishery but occasionally temporary good fishing.
"Poor fishing"	"Good fishing".	Good fishing.	

Some factors modifying growth rate of Kamloops trout in lakes.

A. Primary factors determining lake productivity,—morphometry, climate, geology.
B. Secondary factors determining lake productivity,—mineral content, glacial flour, etc.
C. Efficiency of utilization of food resources by Kamloops trout.
D. Absence of some types of organisms in lake fauna.

that can be drawn from results of initial plantings are limited. Consideration of the several courses of events which can ensue several years after initial introductions, contributes more to appreciation of the advisability of the introductions. For this reason, Figure 1 classifies results of introductions after there has been adequate time allowed for adjustment of the trout populations to the new environments.

Ecological factors affecting growth rate and population size of established populations of Kamloops trout in barren lakes can be classified into three groups:

1. Limnological conditions at the height of winter or summer stagnation.
2. Extent and permanence of natural stream spawning facilities.
3. Ecological conditions largely associated with lake productivity.

A classification of these three groups of factors is schematically suggested in Figure 1.

(A) *Favourable conditions for Kamloops trout*

Where summer or winter kill does not occur (see section I B for discussion of unfavourable conditions) a Kamloops trout population is affected most profoundly in its ecology by the nature and permanence of natural spawning facilities accessible to a lake.

Because Kamloops trout spawn in streams, and the eggs may incubate for several weeks before emerging as fry, "natural spawning facilities" is defined as the environment for deposition of eggs, incubation of eggs and provision of access for fry to the lake. Ostensibly, all sustained artificial stocking of lakes that contain only Kamloops trout can be justified only on the grounds that natural spawning facilities are inadequate, unless the water is to be used only as a medium for transferring legal size fish from a hatchery to an angler's catch. Spawning facilities are thus a feature of lakes of primary significance to the fish culturist.

(i) *Good Spawning Facilities*

Many lakes in British Columbia that were once barren provide excellent natural spawning facilities in most years, and are not subject to either "winter kill" or "summer kill". These generally support a large population of small trout which seldom exceed 12 inches fork length. A few examples are Lemon, Cottonwood and Plaid Lakes (Nelson district), Penask, Hull and Rhoda Lakes (Kamloops district), Loon Lake (Clinton district, may be a naturally established Kamloops trout population), Lequime, Divide and Norman Lakes (Penticton district). Growth rate is commonly lowered in these lakes by overpopulation to such a degree that a management problem is posed. Anglers are discouraged by the small size of the fish and the fishery may become non-existent. For example, in 10 lakes of this type, of a total of 306 fish taken by common angling methods, only 98 were above the legal size of eight inches, and none exceeded 12 inches. As a general rule, the most striking examples of overpopulation occur in small lakes. There are few bodies of water in the province over 100 acres in surface area in which it occurs. (Loon Lake mentioned above is a notable exception.) The introduction of Kamloops trout into lakes with good spawning facilities might be termed premature because the trout populations may quickly degenerate to the point where no fishery is supported. There are no examples known in British Columbia where increased intensity of fishing in these lakes has caused any noticeable improvement in growth rate, although in several instances anglers have been encouraged to try to thin out the population (six inches size limit, unofficial and official).

In their natural condition small lakes with good spawning facilities for Kamloops trout are apparently unsuitable for supporting a satisfactory fishery for Kamloops trout. The most direct solution of their management problem would appear to be obstructing spawning grounds, but this may pose practical problems. Other species of fish might be better suited to this type of lakes.

(ii) *Variable Spawning Facilities*

In the arid interior areas of British Columbia, spawning streams are often small and intermittent and their yield of fry from deposited eggs depends on the wetness of the spring and early summer season. Accordingly, the size of the population of trout and the growth rate of its individuals fluctuate from year to year. Larkin et al (1950) describe annual variations in growth rate and abundance of Paul lake trout associated with flood years in the inflowing spawning streams. Similarly, Peterhope Lake has a single inflowing tributary stream which at low flows becomes entirely subterranean over a short portion of its length near the mouth. In dry years this is an effective mechanism for preventing most of the newly hatched fry from reaching the lake. In the past 15 years the abundance and size of trout in Peterhope Lake have varied markedly depending on the nature of the spring runoff. Paul and Peterhope lakes are typical of several dozens of lakes in the Kamloops district, which periodically contain relatively large populations of relatively small sized fish.

Scientific management of lakes which have intermittent spawning grounds requires quite precise annual information if artificial stocking is to be used primarily as a varying supplement to annual natural spawning. However, there is no doubt that even if there is only scanty information available on which to base annual stocking, lakes of this type are put to effective use in the culture of Kamloops trout, and the introductions should be termed successful from a management viewpoint. In addition, overpopulation from excessive artificial stocking is rectified naturally within a few years. Consequently, many of the famous Kamloops trout lakes of British Columbia have maintained a good fishery in spite of uninformed but enthusiastic and often unnecessary hatchery practice. Needless to say these same lakes are often cited as examples of good management.

(iii) *No Spawning Facilities*

Some lakes have virtually no spawning facilities even in wet years and these ostensibly provide the fish culturist with the opportunity for close regulation of abundance and size of trout to a desired level. In these bodies of water the trout may become less attractive to fishermen when they reach maturity and become "spawn-bound". Female fish may carry eggs from previous maturations until they are reabsorbed, and both males and females may retain year round the dark coloration, leathery skin and singularly tasteless flesh characteristic of the spawning adult. Jacko and Pass lakes (Kamloops district) are examples.

These lakes provide excellent fisheries for young Kamloops trout which may attain substantial size. Annual artificial stocking is essential, but the resulting fisheries are not only satisfactory, but readily regulated.

(B) Unfavourable Conditions for Kamloops Trout

The smaller and shallower bodies of water by virtue of their productivity have generally yielded the highest growth rates in Kamloops trout, but in many instances introductions into them have been a partial or complete failure because of periodic summer or winter kill. Lac du Bois, Shumway and Disdero lakes (Kamloops district) have been stocked with Kamloops trout but during midsummer, low oxygen concentrations in both the hypolimnion and the epilimnion in association with heavy algal blooms have apparently caused mortality of trout. This was observed experimentally in several lakes of the Kamloops area in 1952. Edith, Tunkwa and Leighton lakes (Kamloops district) have experienced "winter kill" in recent years and accordingly present a risk as possible sites for introductions.

There are literally hundreds of small lakes on the central interior plateau which are in this category and their future improvement and management poses a challenging problem to the fish culturist. Those which are extremely shallow and small can be readily classified as unsuitable for most species of fish. However, for the remainder, there has not been devised as yet any simple method of detecting that they will not support a trout population the year around. In consequence, each year of hatchery operations sees several thousand Kamloops trout fry sacrificed in attempts to bring such lakes into production.

II. Lake Productivity and Growth of Kamloops Trout

Most of the foregoing presentation has dealt with qualitative aspects of the introduction of Kamloops trout, i.e. the distinction between favourable and unfavourable limnological conditions, the relation between extent of natural spawning grounds and the problems posed to the fish culturist. As a refinement to the scheme of classification indicated in Figure 1 and to indicate the complexities of trout culture in barren lakes it is necessary to consider some of the relationships between lake ecology and growth of trout.

Growth rate and size attained by Kamloops trout are related to lake productivity as well as to population size. Thus lakes with unfavourable features of climate, morphometry and surrounding geology or any combination of these factors show lower growth rates on the average than lakes which combine favourable features for productivity. Lakes in the coastal areas commonly have a large inflow in relation to their size, in spite of having relatively small drainage areas. Lower Campbell Lake in its natural condition (it has recently been dammed) could have had its entire volume of water replaced in only 30 days at average inflow (McMynn and Larkin, 1952). According to Mottley (1936) the large inflow of Jones Lake was an important factor in limiting productivity. Small bodies of water may have their entire volume replaced in less than seven days. In addition, in coastal areas the surrounding surface geology is commonly dominated by relatively insoluble and relatively recent volcanic and igneous rocks. It is not uncommon to observe total dissolved solids measurements of less than 50 p.p.m. in coastal lakes and several have been surveyed in which total dissolved solids are probably less than 25 p.p.m. In these lakes resident trout (cutthroat trout, *Salmo clarki clarki*, and Kamloops trout) seldom exceed three pounds and growth rates are low even when population size (as reflected by catch per unit of effort) is low. Small coastal lakes are particularly subject to stunting in trout populations although spawning facilities may not be extensive.

Interior lakes at low to moderate altitudes generally combine more favourable features of morphometry, climate and geology than the coastal areas. The well known Kamloops trout lakes of the south central interior which are capable of producing good fishing for fish up to five pounds (for example, Paul, Knouff, Lac le Jeune, Island, Stake, McConnell, Beaver, Echo, Peterhope, Glimpse, Pillar lakes) are almost all characterized by at least two of three favourable features, i.e. mean depth of less than 30 metres, total dissolved solids in excess of 100 p.p.m. or relatively warm and dry summers. The high altitude lakes of the interior with their short summer season commonly support large populations of small trout where spawning facilities are good, or variable populations of trout which may attain weights of up to 10 pounds where spawning facilities are poor or intermittent.

Secondary factors of lake productivity may often play important roles in local situations. Coastal lakes, while low in total dissolved solids, may be either rich or poor in calcium. Many coastal lakes receive large quantities of allochthonous organic matter because of the relatively large inflow and the heavy terrestrial plant cover. It is possible that low growth rate in some coastal lakes may be a consequence of qualitative deficiencies in mineral content of the water. At high altitudes in many parts of the province, lakes may be heavily silted in certain seasons with "glacial flour". Excessive alkalinity may be a factor which renders many lakes of the arid interior unsuitable for trout.

There are also features of lake ecology which influence the efficiency with which Kamloops trout utilize food resources in a lake. For example, Mottley (personal communication) observed that during the height of midsummer stagnation Kamloops trout had slower growth rates than in the spring and autumn months and this caused the not uncommon "summer check" on the scales. This same feature of Kamloops trout scales has been observed by the writer and associates in samples from Paul Lake and other interior lakes. Early and severe stratification which causes a relatively long period of summer stagnation may be a feature in the ecology of small lakes in which growth rates do not appear to be commensurate with productivity.

Large bodies of water, say those over 100 acres in surface area, are seldom observed to attain the same degree of relative overpopulation so characteristic of small lakes. There is some suggestion that in larger lakes, competition for food (or possibly other factors which may contribute to stunting) may be manifested by decrease in survival rather than by lowering of growth rate. This is a subject much in need of study since it relates to the often repeated speculations concerning "space factors" in growth phenomena.

There are some lakes in British Columbia which apparently have not as yet been colonized by the usual complement of fresh water invertebrates. Thus Clearwater Lake (Hedley district) is one of many interior lakes where *Gammarus* was alleged to be absent and which was planted with *Gammarus* by local anglers. There is some evidence that this introduction may have resulted in increased growth rate of trout.

Similarly, *Mysis* and *Pontoporeia* which are important elements in the fauna of oligotrophic lakes of Eastern North America do not occur naturally west of the continental divide except possibly in the Arctic. *Neomysis* occurs in some coastal lakes but is not widespread in its distribution. Where it occurs it is a common and no doubt important food item.

Added to this complex of ecological factors which describes the environment of the fish and the interaction of the fish with its environment are the possibilities of genetic differences in strains of trout from different localities. These possibilities are commonly the basis for speculation but have not been demonstrated for British Columbia Kamloops trout.

III. Introductions of Forage Fish for Kamloops Trout

The success attending initial introduction of Kamloops trout into a lake was quite frequently followed by a gradual decline in the size attained by the trout as natural spawning and artificial stocking increased the size of the population. Although this evolutionary process would be condoned by a biologist as more efficient utilization of food resources it was frequently deplored by the more intrepid anglers who yaerned for the "big fish of yesteryear". It had long been common knowledge that the large Kamloops trout of such lakes as Kootenay and Okanagan fed extensively on kokanee (*Oncorhynchus nerka kennerlyi*). It was also known that in eastern North America, combinations of predator and forage species commonly occurred and were often manipulated with considerable success by fish culturists. It was to be expected that introductions of "forage" species would be attempted and fortunately several such efforts are now known well enough that their results can be applied to future practice. The examples discussed below serve to emphasize the complexity of the subject of introductions.

(a) Kokanee

The kokanee is primarily a plankton feeder and its ecological niche parallels that of the ciscoes (genus *Leucichthys*) of eastern North America. Like its anadromous counterpart, the sockeye salmon *Oncorhynchus nerka*, the kokanee generally attains maturity at three, four or five years of age, and it dies after spawning. In most lakes in British Columbia in which it occurs naturally with the sockeye salmon it seldom attains a maximum fork length in excess of 12 inches. It also occurs in lakes that once supported anadromous populations of sockeye but which have become inaccessible to sea-run fish. (Kootenay Lake, Arrow Lake, Okanagan Lake, Christina Lake, Eutsuk and Ootsa lakes, etc.). In these lakes also it seldom attains a maximum fork length over 12 inches. Wherever kokanee occur naturally, Kamloops trout are usually present, and it is common to observe that kokanee make an important contribution to the diet of large Kamloops trout.

Kokanee have been planted in several lakes in British Columbia which previously contained only Kamloops trout. The results of some of these introductions were not anticipated and management problems were multiplied rather than lessened by the introductions. In Jones Lake (Hope district) the size of trout deteriorated with increase in population size (Mottley, 1936) until in 1938 kokanee were experimentally planted as forage fish. At the present time the lake supports a kokanee fishery almost as much as a trout fishery. Trout do not eat the kokanee extensively and large trout (over five pounds) do not occur. In the first few years following the introduction, some kokanee attained weights of two and three pounds, and while this is not the case today, kokanee still contribute directly to the fishery more than to the improvement of the trout population. Almost the same pattern of events transpired in Premier Lake (Cranbrook district) which at one time was famous for its trout of from 10 to 20 pounds, subsequently became populated with large numbers of trout of about one pound, and is now ignominious as a producer of kokanee of about three quarters of a pound and occasionally trout up to 10 pounds. The interaction between kokanee and Kamloops trout in small bodies of water that contain only these two species has not been studied intensively. However, in a study of Borgeson Lake (Princeton district), which was experimentally poisoned in 1948 (McPhee, unpublished) it was concluded that of the eight species of fish, excluding Kamloops trout, which occurred in the lake, the kokanee was not only the most intensive competitor of the trout, but was more efficient than the trout in utilizing food resources available to both species. In consequence when the lake was poisoned, several hundred kokanee but only two Kamloops trout were recovered. Kamloops trout had been stocked in the lake for several years prior to the poisoning with no apparent success, yet stocking afterwards resulted in a catch on the opening day of fishing of almost 700 Kamloops trout averaging one pound.

Kokanee would thus seem to be unsuitable as a forage species for Kamloops trout in small lakes. However, their contribution to the fisheries of the lakes into which they have been introduced is significant and to a fish culturist this gain may outweigh the depreciation of the trout fishery.

(b) *Redside Shiner*

Richardsonius balteatus, the redside shiner, is a small Cyprinid which seldom attains an adult length over 10 centimetres. It occurs naturally throughout the Fraser and Columbia drainages, but like other minnows has no natural distribution in alpine and semi-alpine lakes in British Columbia. Where it occurs in lakes it is usually extremely abundant in the littoral zone and is easily caught by dip-net, seine or trap. It is a popular bait in trout fishing which largely explains the number of occasions on which it has been introduced into new areas.

The introduction of redside shiners has usually been followed by a disastrous decline in trout fishing. Jewel Lake (Greenwood district) once produced Kamloops trout weighing over 50 pounds; in later years it was populated by large numbers of small trout, but after the introduction of shiners the trout fishery is alleged to have declined seriously. Wilgress Lake (Grand Forks district), Stevens Lake (Cranbrook district), Hyas, Pinantan and Paul lakes (Kamloops district) are other examples where trout populations have exhibited a similar reaction to the introduction of shiners. Paul Lake has been studied closely since 1946 when shiners were probably first becoming established and in a forthcoming publication (Larkin and Smith, in press) the effect of the shiner population on the trout as evidenced by stomach content and growth rate analyses is described in some detail. Shiners prey on trout fry, compete with trout when the latter are changing from a plankton diet to a mixed diet of predominantly bottom organisms, but may in turn provide food for large trout. In consequence of these interactions the trout population exhibits the following features:

1. Reduced population size, possibly from shiner predation.
2. Reduced growth rate between fork lengths of 7 to 20 centimetres, corresponding approximately to age I to II.
3. Accelerated growth rate from age III onwards, presumably from consumption of shiners.

In 1946, the annual catch of Kamloops trout in Paul Lake exceeded 10,000 individuals, while in 1952 it was probably less than 3,000. It is apparent that the trout population was adversely affected by the shiners. It is concluded that competition of shiners with small trout together with the unexplained failure of trout to prey on any but the larger shiners are the important factors determining the deterioration of the trout fishery. The solution to the management problem posed by these lakes appears to lie in the planting of trout that are roughly 20 centimetres fork length. Catches of marked fish released in Hyas and Pinantan lakes as yearlings and the reported recovery of the fishery in Wilgress Lake as a result of similar plantings substantiate this argument. Experimental plantings of various sized fingerlings in Paul Lake are now being conducted.

Discussion

The planting of Kamloops trout into barren lakes of British Columbia has provided opportunity for studying the most simple type of introduction, one in which a single species of fish is utilizing the food resources. Nevertheless, the results of the introductions have been so varied that there can be no doubt that this "simple" subject is highly complicated, and it is both difficult and misleading to summarize "typical" results. This is particularly true if the subject is looked at from a management viewpoint, where the criterion of success of an introduction is the maintenance of a perennial fishery which is satisfactory to anglers with respect to both numbers and size of fish. Many of the introductions that have been attempted have failed to establish trout populations. These are a distinct failure by any criterion. Other introductions have resulted in the establishment of large populations of extremely small fish and while these were successes for the species, they remain failures to the fish culturist until remedial measures can be taken. In between these two extremes, introductions have resulted in various degrees of success as measured by abundance and growth rate of the trout and hence the suitability of the established population as a basis for a fishery. The extent of natural spawning facilities is one of the most important factors in determining the nature of the fishery and the management problems it poses, but there are many other features of lake ecology which assume significance in local situations. The individuality of lakes predestines the singularity of their trout populations, and thus while Figure 1 attempts to classify results, it describes the "average lake" of a group rather than a type which is frequently closely replicated.

The difficulty of categorizing types of established trout populations, in lakes which contain only trout, is abundantly reflected in the dilemma of the management biologist when he is asked to decide if a barren lake will be suitable for trout. Even at an expense out of proportion to the situation it is doubtful if he could predict except in the most general terms, what type of trout population would eventually develop. In some recent situations in British Columbia it would have been difficult even to predict whether Kamloops trout would survive in a lake. Thus the fish culturist does not as yet have sufficient knowledge of the limnological and physiological requirements of Kamloops trout to make a rapid and inexpensive evaluation of the potentialities of a barren lake. Considering the complexity of the problem, he is not likely to have such knowledge for some time to come. In consequence, the cheaper and more direct alternative of experimental introduction is most frequently employed, despite the possibilities of failure. The guiding principle has been and will probably continue to be for some time, that it is better to get something done and perhaps guess wrongly than to be overcautious and to accomplish nothing.

The introduction of forage fish for Kamloops trout has emphasized the same principle. Despite the fact that some of the introductions were considered by trained men they did not develop as was expected and usually the results were unsatisfactory. Nevertheless, they have given some indications of the advisability of some types of management and in this respect alone could probably be justified. One might say that the lakes unfavourably affected were inadvertently sacrificed in a good cause.

It is concluded that the study of Kamloops trout in barren British Columbia lakes emphasizes the complexity of even simple aquatic communities, and thus the difficulty of predicting results of introductions of fish. Consequently, if the practical fish culturist wishes to improve fisheries he must be prepared to make frequent, bold and what may subsequently turn out to be ill-advised experiments if he is going to accomplish anything by introductions. However, where a particularly valuable sport or commercial fishery already exists, introductions of species of fish new to a lake should probably be discouraged on the grounds that their results could not be foreseen with sufficient confidence to warrant the risk of jeopardizing the status of the existing fishery.

Literature Cited

LARKIN, P. A., G. C. ANDERSON, W. A. CLEMENS and D. C. G. MACKAY. 1950. *The production of Kamloops trout* (Salmo gairdnerii kamloops Jordan) *in Paul Lake, British Columbia.* B.C. Game Dept., Sci. Publ. No. 1: 1-37.

LARKIN, P. A. and S. B. SMITH. (In press.) *Some effects of introduction of the redside shiner on the Kamloops trout in Paul Lake, British Columbia.* Trans. Amer. Fish. Soc. for 1953 (in press).

McMYNN, R. G. and P. A. LARKIN. 1952. *The effects on fisheries of present and future water utilization in the Campbell River drainage area.* B.C. Game Commission, Manag. Publ. No. 2: 1-61.

McPHEE, C. (Unpublished.) *A limnological study of a series of five lakes in the interior of British Columbia and the effects of rotenone on the fauna of two of these lakes.* Univ. B.C. M.A. Thesis. 1949.

MOTTLEY, C. McC. 1936. *A biological survey of Jones Lake.* B.C. Game Commission Report for 1935: 27-30.

RAWSON, D. S. 1947. *Deterioration of recently established trout populations in lakes of the Canadian Rockies.* Can. Fish Cult., 2: 14-21.

Introduction of Anadromous Fishes on the Pacific Coast*

by

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Although Canadians were not responsible for the introduction of the shad (*Alosa sapidissima*) and the striped bass (*Roccus saxatilis*) on the Pacific coast, and have not received significant benefit from their advent, it is appropriate to mention these quite unusual success stories in a symposium dealing with the problems and results of transplanting fish. This brief account is compiled from sources indicated at the conclusion of this paper.

Shad

Six plantings of shad fry, totalling 621,000, were made in the Sacramento River between 1871 and 1880, the fish being transported across the continent by rail under very difficult conditions. Further shipments amounting to 910,000 fry were planted in the Columbia River system in 1885-86. The part played by these later introductions in augmenting the west coast stocks is not known, since shad derived from the previous Sacramento plantings had reached the mouth of the Columbia by 1880 or earlier.

Marketable quantities of shad were obtained at San Francisco by 1879 and the species increased rapidly in availability thereafter. 10,000 lb. was marketed from the Columbia River in 1888.

The increasing abundance was not always reflected in the quantities sold. Both in California and on the Columbia River prices were at times so low that shad were not fished or were thrown away after being caught.

In recent years the total commercial shad catch has been about 3,000,000 to 4,000,000 lb. per annum. The fishery is mainly concentrated between San Francisco and the Columbia River, although shad are known to occur from the Mexican border to Cook Inlet, Alaska—a north-south range of about 27 degrees of latitude. Throughout much of this vast area the shad is still an uncommon fish.

Perhaps the best testimony to the fact that the shad is reacting like a native fish is to be found in recent complaints of depletion in the Columbia River, accompanied by requests for appropriate investigation of its status.

Striped Bass

In 1879, one hundred and thirty-two small striped bass were brought by rail from the Atlantic coast and released in the "Delta" area of the Sacramento River. Another shipment of about 300 was planted in 1882.

By 1899 the commercial net catch of the Delta area was over 1,000,000 lb. per annum and the known range of the species had extended northward into southern

**Presented at the meeting of the Canadian Committee on Freshwater Fisheries held at Ottawa in January, 1954.*

Oregon. The striped bass is more restricted in range and more local in occurrence than the shad, apparently in part because it requires extensive tidal estuaries for nursery grounds and for wintering. It has been recorded from points between the southern boundary of California and the Columbia River—about 14 degrees of latitude. Although there is a small commercial fishery at Coos Bay, Oregon, the main centre of abundance is the area in which the original plantings were made, namely, the Delta area of the Sacramento River. Since 1935 commercial fishing for striped bass has been prohibited in California, the species being reserved for sporting operations. The annual catch in this state since 1942 has been stable at about 1,500,000 fish. It has been estimated that $10,000,000 is spent annually on bass fishing trips and that the species provides 2,000,000 man-hours of recreation per annum.

Summary

The success which attended the transplantation of striped bass and shad was in each case initiated by small or very small plantings. It seems remarkable that these unprotected populations could find opportunities for such rapid expansion in such an unrestricted and presumably highly competitive ecological environment as the ocean. As far as is known their expansion has not been at the expense of other species, or at least of species in which man is economically interested. If we had to initiate these experiments today I doubt whether we would be as sanguine of success as were our predecessors of 80 years ago. In some respects our ignorance of population dynamics is demonstrated as effectively by these successes as by the failures which have frequently attended our efforts to introduce species into new environments.

Literature Cited

CALHOUN, A. J. 1952. *Annual migrations of California striped bass.* Cal. Fish and Game, 38, 391-403.

1952. *Striped bass fishing map.* State of California, Dept. Fish and Game.

CHAPMAN, W. M. 1942. *Alien fishes in the waters of the Pacific Northwest.* Cal. Fish and Game, 28, 9-15.

SMITH, H. M. 1896. *A review of the history and results of the attempts to acclimatize fish and other water animals in the Pacific states.* Bull. U.S. Fish Comm., 15, 379-472.

U.S. COMMISSION OF FISH AND FISHERIES. Report of the Commissioner, 1873-4 and 1874-5. Washington, D.C. 1876.

FISHERY STATISTICS OF THE UNITED STATES. Fish and Wildlife Service, Washington, D.C.

WELANDER, A. D. 1940. Notes on the dissemination of shad, *Alosa sapidissima* (Wilson), along the Pacific coast of North America. Copeia, 1940, 221-223.

A Weir for Adult and Fry Salmon Effective Under Conditions of Extremely Variable Run-off

by

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In the fall of 1947 the Fisheries Research Board of Canada extended its investigation of pink (*Oncorhynchus gorbuscha*) and chum (*O. keta*) salmon to the north central coastal area of British Columbia.

A study of the freshwater survival of these two species of salmon, as well as the sockeye (*O. nerka*) and coho (*O. kisutch*) salmon also present, called for the construction of both adult and fry collecting weirs.

The specific location chosen for this investigation was Hooknose Creek situated in Port John Bay on the northwest side of King Island. Hooknose Creek is approximately three miles long with a small lake (roughly 0·40 miles by 1·65 miles) at its headwaters. The creek has one main tributary which comes off the neighbouring mountains. The watershed is roughly 3·6 square miles in area and precipitation records taken at the mouth of the stream show a yearly rainfall of approximately 100 inches. Hooknose Creek ranges in volume from 10 cubic feet of water per second to 300 cubic feet per second, with flood levels usually occurring in the spring and fall.

The investigation is under the direction of Dr. Ferris Neave. The choice of fence design, the suggestions, the criticism and the encouragement he has given have done much to make the operation a success. Mr. R. C. Wilson along with numerous other technicians have aided in the installation and operation of these weirs.

Design and Construction of Weirs

Fences capable of handling this large volume of water were designed by Mr. G. B. Starr, engineer, and installed under the supervision of Mr. E. V. Epps. Adult and fry sections were made interchangeable in the same basic framework, thus eliminating the expense of construction and maintenance of two separate weirs.

The basic framework of these two fences was of the conventional type used extensively throughout in similar installations. A platform floor, 12 feet wide and 90 feet long, was installed on the creek bottom. This floor was made of boards (2″ x 12″) fixed to five sills (4″ x 6″) which in turn were secured to small hand-driven pilings. Every six feet across the length of this floor two timbers bolted together at the top and reinforced by a brace at the middle were fastened to the floor, thus forming "A" frames to which the rest of the fence and walk could be fastened. See Fig. 1. These "A" frames were held rigid in an upright position by two stringers bolted to the front or upstream member and extending the length of the fence.

Adult Weir

The adult weir consisted of panels of pickets placed between the "A" frames. These panels, set at an angle of 30°, were attached to the floor between the upstream legs of the "A" frames by simple screw hooks while the afterpart was held up by boards (2″ x 6″) which were fitted to the downstream leg of the "A" frames. The panels were two feet wide and made of boards (1″ x 4″) seven feet long set on edge and held $1\frac{1}{4}$ inches apart by wooden spacers. A flap built of 1″ x 4″ boards on their flat side and spaced $1\frac{1}{4}$ inches apart was hinged from the upper stringer with the lower end resting on the downstream end of the panels (Fig. 2).

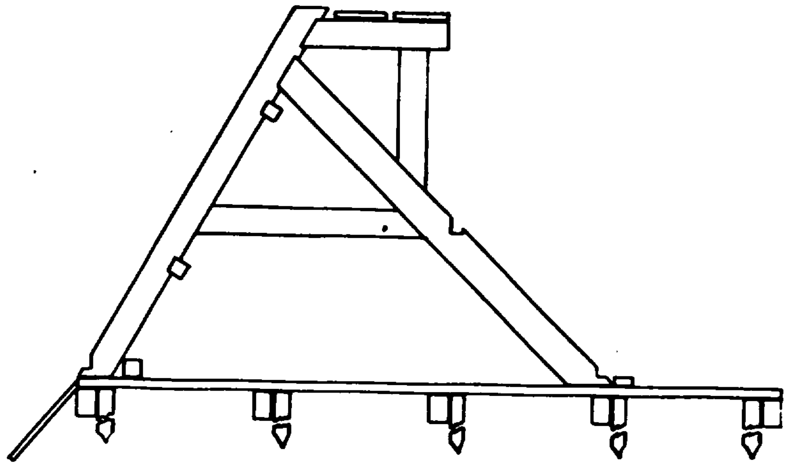

Figure 1. Cross sectional view of fence showing "A" frame and walk on floor in creek bottom.

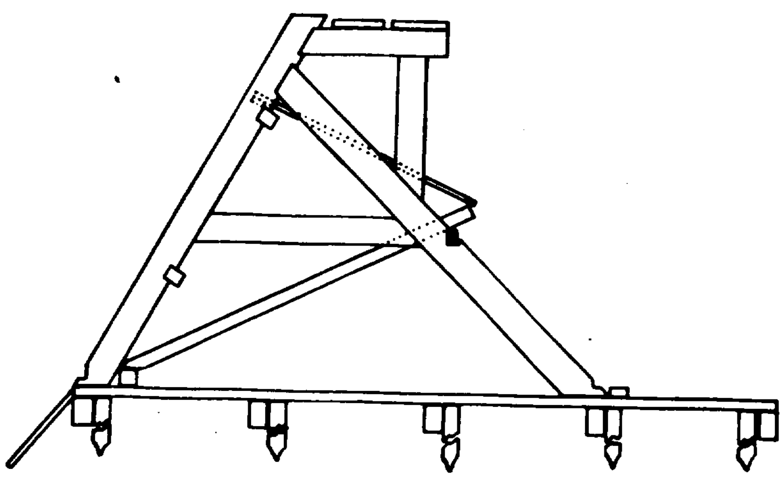

Figure 2. Cross sectional view of fence showing "adult" panels.

These flaps prevent any fish from jumping over the panels which at their highest point are only $3\frac{1}{2}$ feet above the floor of the fence, and at the same time they allow excessive flood waters to flow over the panels, lift the flaps and give the fence a self-cleaning feature at such times.

There are 14 sections or bays between 15 "A" frames in the weir at Port John. The trap section, located in the middle part of the creek where the greatest amount of water is moving, supports panels in the same plane as the front leg of the "A" frames.

In the centre of this section is the lead opening (2′ x 2′) by which the salmon enter a trap. This lead is 3′ long and enters a trap (6′ x 8′ x 5′) made of 1″ x 4″ boards. The lead itself upon entering the pen narrows down to an opening six inches wide and two feet high. One side of the pen has the upper two feet hinged to form a large gate. This gate is opened to facilitate the release of fish after examination.

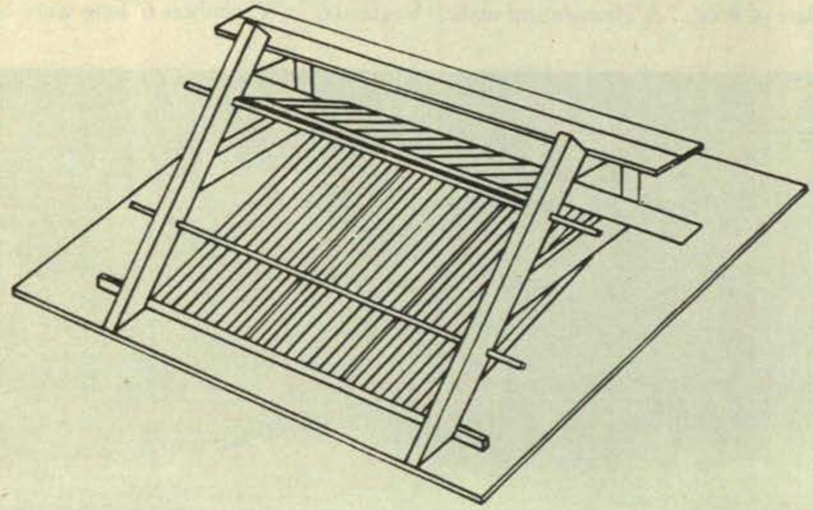

Figure 3. Frontal view of fence showing "adult" panels.

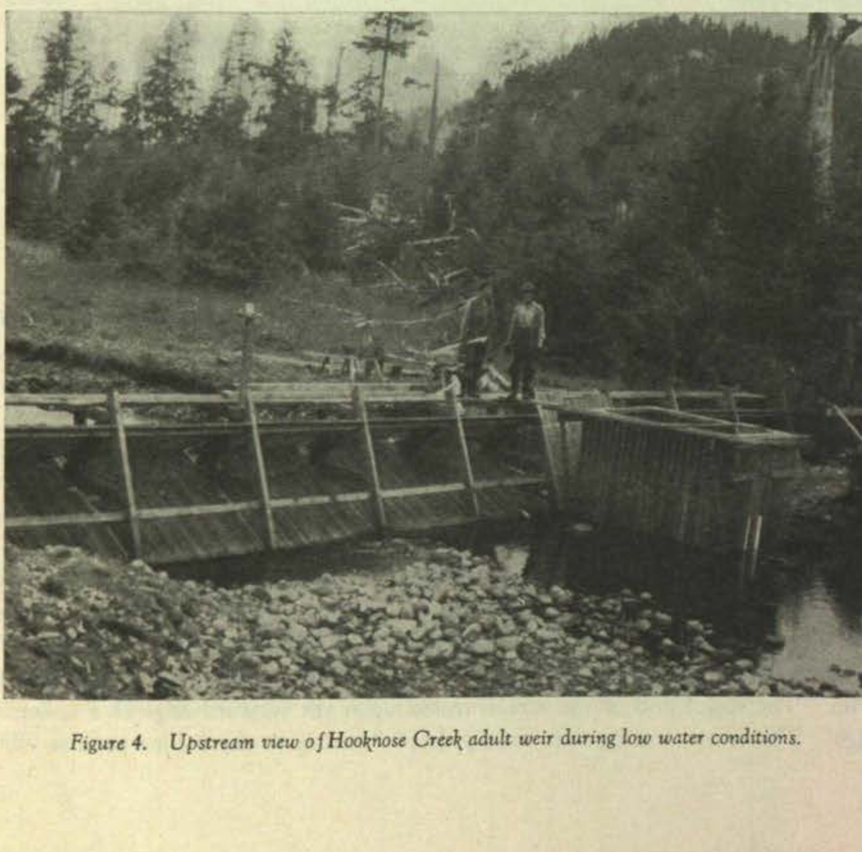

Figure 4. Upstream view of Hooknose Creek adult weir during low water conditions.

Fry Collecting Weir

The fry fence, a modification of that described by Wolf (1946), was installed in the spring of 1948 to capture the downstream migrants of the 1947 seeding.

The panels, flaps, and trap of the adult fence were removed leaving the basic structure of floor, "A" frames and walk. Vertical 6″ x 6″ timbers 6′ long were bolted

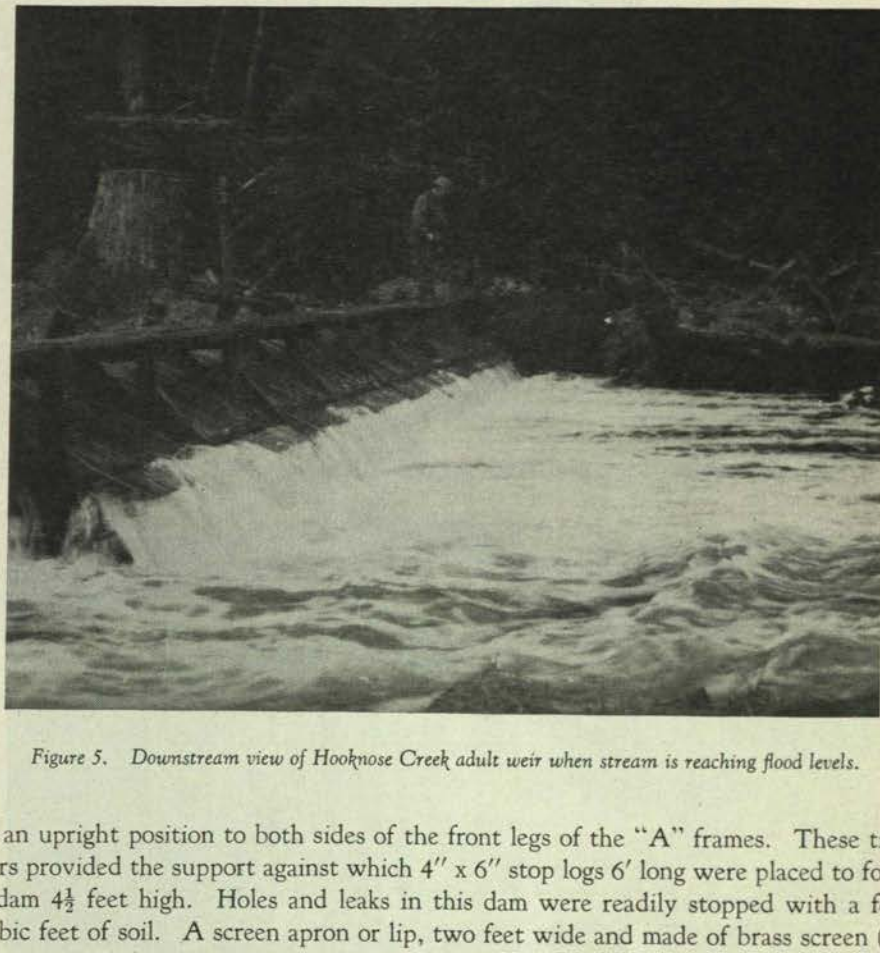

Figure 5. Downstream view of Hooknose Creek adult weir when stream is reaching flood levels.

in an upright position to both sides of the front legs of the "A" frames. These timbers provided the support against which 4″ x 6″ stop logs 6′ long were placed to form a dam $4\frac{1}{2}$ feet high. Holes and leaks in this dam were readily stopped with a few cubic feet of soil. A screen apron or lip, two feet wide and made of brass screen (16 gauge, 6 mesh/inch) attached to (2″ x 6″) boards at the leading and downstream edges permitted the straining of much water and carried the remainder over to fall 8 inches on to incline screens. A baffle made by placing a 2″ x 8″ board 6 feet long in front of the water flowing over the lip caused the water to be deflected more vertically on to the incline screens. This prevented loss of screen area by eliminating the arc which the water would take if allowed to flow freely over the lip. The brass incline screens, of 22 gauge and 10 mesh, were affixed to frames $4\frac{1}{2}$′ x 6′ made of 2″ x 4″ boards. The upper end of the incline screen was held in position by the same legs that supported the lip. The lower end of the screen rested upon the forward edge of a collecting trough. The water coming over the lip drops 8 inches to the incline screens which slope downstream 3° from the horizontal and leads into a collecting trough ten inches wide and six inches deep. The downstream side of the trough was faced with fine mesh screen to a height of 18 inches. The trough led into collecting pens $3\frac{1}{2}' \times 6'$

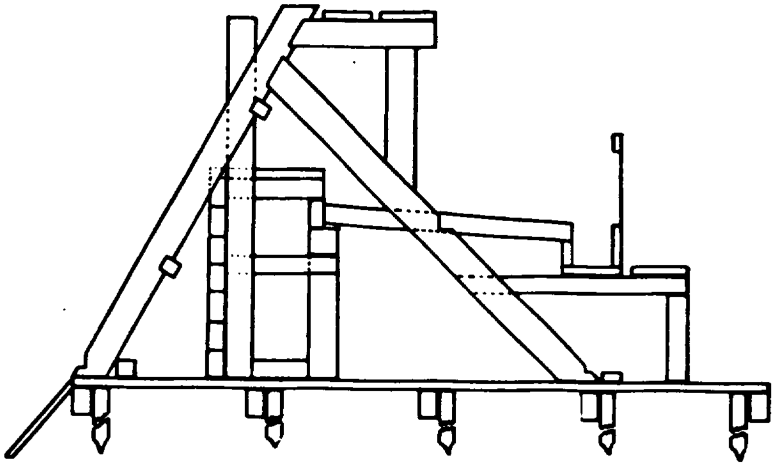

Figure 6. Cross sectional view of fence showing fry screens and collecting trough.

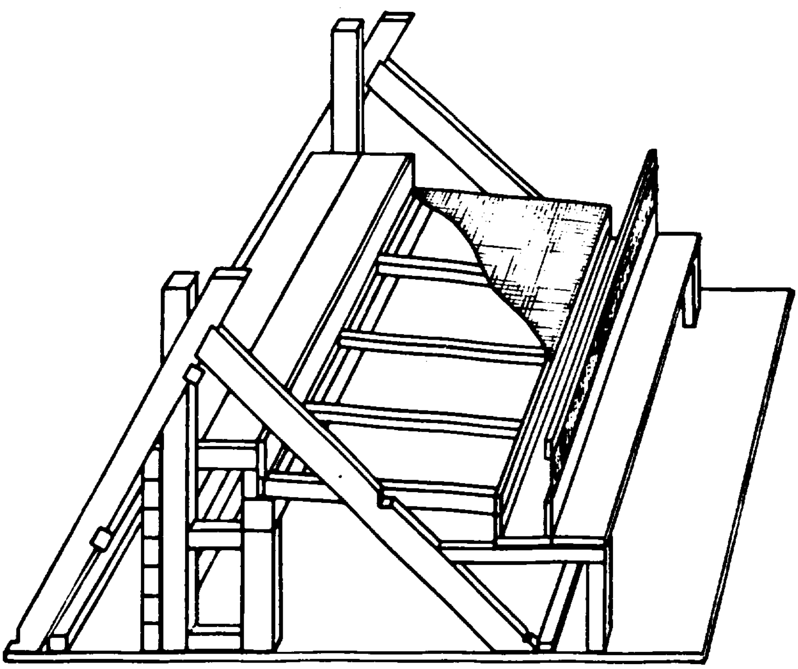

Figure 7. Dorsal view of fence showing fry screens and collecting trough.

in area and 2 feet deep, the lower six inches of which formed a watertight box while the upper part was faced with screen. Screen on the trough and collecting pen is used to prevent fish from jumping out into the stream below the weir. See Figures 6 and 7.

The water flowed on to the lip of the dam and that which did not pass through this screen dropped on to the incline screens. About 40 per cent of the water passed through the lip screen while of the remaining water 95 per cent passed through the incline screens leaving a small amount to carry the fish and debris along the incline screen and into the trough. A fall of 8 inches on to the screen was found to give optimum results. The screens were easily cleaned with a deck broom. Except in cases of high water most of the dirt, sticks, needles and leaves were cleaned by the water. In periods of high water the screens required frequent manual cleaning. An additional aid to keeping the screens clean was the settling pond formed by the dam. Here the stream velocity was greatly reduced and much of the debris settled to the bottom.

The pink and chum fry show behaviour patterns similar to those described for pink salmon at McClinton Creek (Pritchard, 1944). They begin their downstream migration at dark and continue until 1.00 a.m. They appear to be actively swimming downstream until they come in contact with the influence of the water falling over the dam. This current immediately causes them to head upstream and they are swept over the dam on to the incline screens in this tail first position. Usually they are forced down the entire length of the screens into the collecting trough but in many cases fall short of this objective. The fish that land short of the trough go through a series of movements and struggles. This activity is given direction by the gentle slope of the screens so that eventually the fish reach the collecting trough. Another aid to fish stranded on the screens are the spurts of water which are continually sprayed out from the point at which the main body of water strikes the incline screen. This water plays no small part in the success of fish thus stranded gaining the trough. Mortality or damage from failure to reach the trough is negligible, amounting to less than 2 per cent. The troughs empty into collecting pens from which the fish are taken for enumeration.

Modifications

A second weir of the type just described has been constructed on a tributary of Babine Lake. The principles of straining water and collecting fish remain unchanged, and only structural alterations have been made, these with a view to ease of installation and saving of building materials.

In this second weir of this type the floor structure remains unchanged while everything above this level requires modification. The front leg of the "A" frame is altered so that it stands vertically and thus eliminates the additional timbers for the dam. A separate construction assumes the task of supporting the panels at the back of the fence. The stop logs of the dam were changed to 2″ x 8″ planks 6 feet long. Subsequent operation of the fence suggested these stop logs be changed to 3″ x 12″ planks 12 feet long. The support for the lip and upper end of the incline screen is reduced to a 4″ x 6″ support bolted to the vertical leg of the "A" frame. The lower end of the incline screen, the collecting trough and walk are supported by a brace tying the adult framework to the back leg of the "A" frame (Fig. 8). Collecting pens are installed at intervals and these require additional supports. In the adult weir the panels are two feet longer and the flaps and walk have been eliminated (Fig. 8).

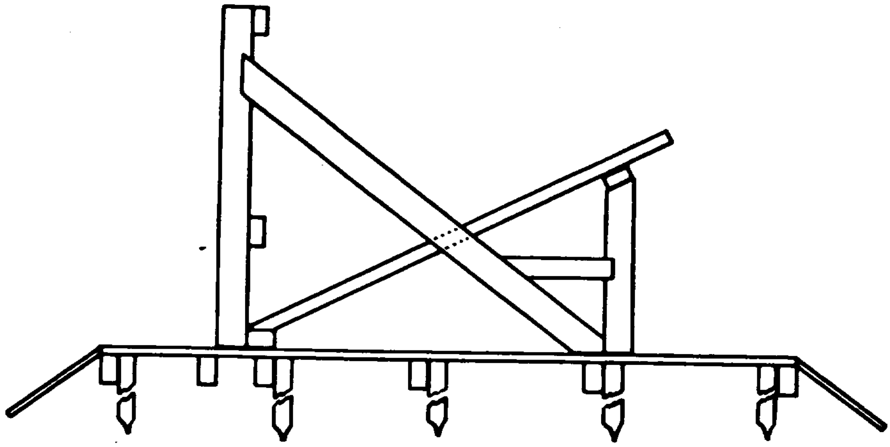

Figure 8. Cross sectional view of modified adult fence.

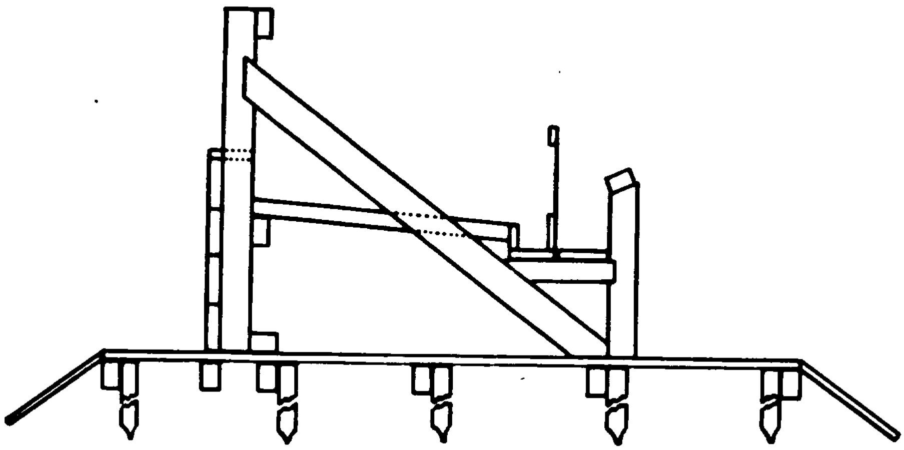

Figure 9. Cross sectional view of modified fry fence.

Summary

The enumeration of fry and adult migrants, in a stream which was subject to severe flash floods, called for the construction of weirs capable of capturing the fish during severe floods as well as normal stream levels. These weirs were designed to be interchangeable on the same basic framework. The adult weir was more or less typical of weirs used in other salmon investigations. The fry and smolt fence employed the technique of utilizing the pressure of the water as it flowed over the lip of the dam and again a pressure created by the water falling on to stationary incline screens. The utilization of two pressure "heads" of water lessened the amount of screen required to strain a volume of water and also helped to clear dirt and debris which is left from water flowing smoothly across a screen or straining surface.

Literature Cited

PRITCHARD, A. L. 1944. *Physical characteristics and behaviour of pink salmon fry at McClinton Creek, B.C.* J. Fish. Res. Bd. Can. 6(3).

WOLF, Ph. *Lax och laxöring i Kavlingean 1946* (Annual Report of Swedish Salmon and Trout Association).

Winter Studies on the Burbot, *Lota lota lacustris*, of Lake Simcoe, Ontario

by

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A winter study on the burbot, *Lota lota lacustris* (Walbaum) (see Speirs, 1952) in Lake Simcoe was carried out during January and February of 1954. Observations on the age, growth, food and spawning of the burbot, known locally as ling, which are presented in this paper have been made of fish taken in hoop nets. These nets were set in the mouths of several rivers tributary to Lake Simcoe for the purpose of coarse fish removal.

Lake Simcoe, one of the largest of Ontario inland waters with an area of 280 square miles, is situated in southern Ontario at Lat. 44°N., Long. 79°W. where it forms a part of the Trent Valley system of waterways which empties into Georgian Bay through the Severn river. This lake maintains an extensive sport fishery of which the important species include the lake trout, whitefish, cisco, smallmouth bass, pike, pickerel and perch. The burbot, which is widely distributed over the lake during the winter months, is not exploited except for those accidentally taken by fishermen while angling for other species. The characteristic movement of the burbot into the rivers beneath the ice during mid-winter has facilitated its capture by netting.

The failure of the burbot to form a significant part of the sport or commercial fishery has contributed towards only a limited knowledge of the ecology of this species. The purpose of this study has been to gain a better understanding of the burbot of Lake Simcoe.

Methods of Age Determination

Burbot used in the study were taken from hoop nets operated at seven locations on Lake Simcoe by personnel of the Ontario Department of Lands and Forests.

A comparison of possible methods for aging burbot was made. At the time that the fish were weighed and measured, otoliths and pectoral fins were removed. Samples of scales were collected. The otoliths were kept in a 3 per cent solution of the tri-sodium phosphate until examined under low magnification as described by Clemens (1951). Pectoral fins were air-dried, the large ray sectioned and cleared in xylene, and finally examined under a binocular microscope. Scales were studied by means of a scale projector.

The otolith method, as validated for this species by Martin (1941), provided the most readily workable and accurate means of age determination. While some pectoral ray sections could be aged, the younger age groups presented considerable difficulty. The scale method was least satisfactory for aging burbot.

Some 100 stomachs were opened and the contents examined and weighed. In addition, the stomach contents of other burbot caught at the various netting locations were examined for food items.

The studies on sexual maturity included an examination of reproductive organs with particular attention to the degree of development and to the time of spawning.

Growth of the Burbot

With the exception of Martin (1941) who examined 31 burbot in Lake Opeongo, Algonquin Park, and Clemens (1951) who made an extensive study of this species in Lake Erie, little investigation had been done on the growth of the burbot in Ontario.

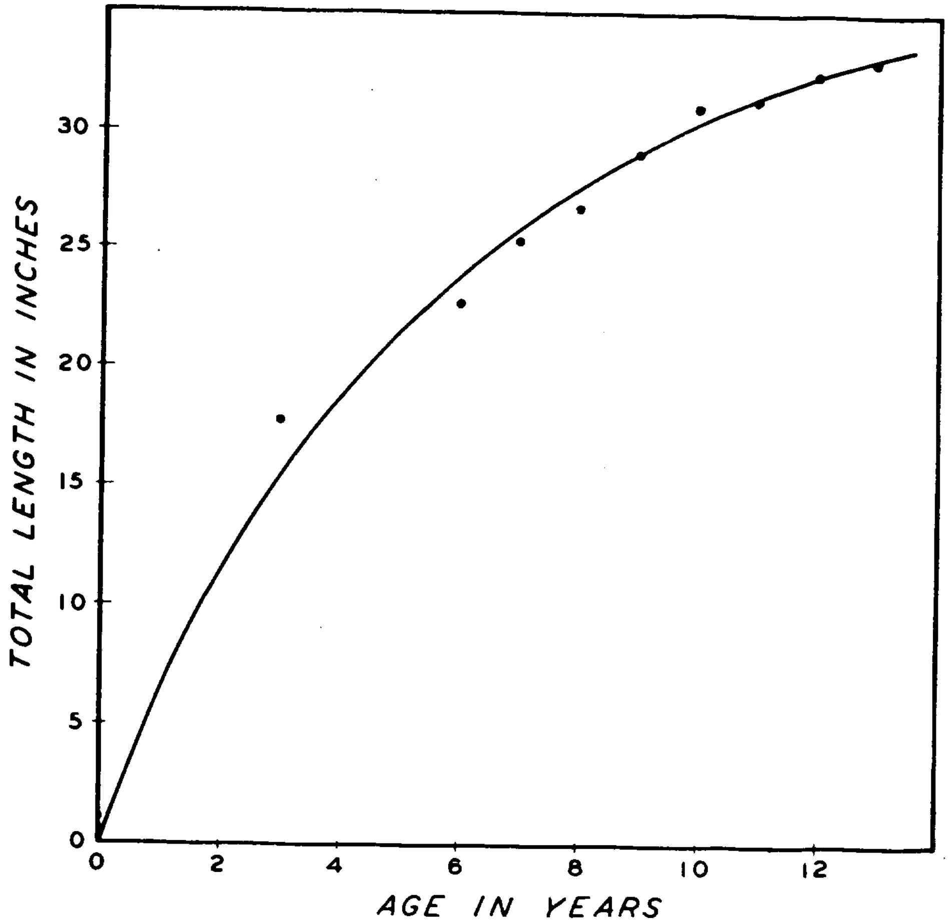

Figure I. Length to Age Relationship of Burbot (sexes combined) in Lake Simcoe, January-February, 1954.

Age determinations were made on a total of 130 burbot from Lake Simcoe. These fish were taken from a catch of 2,813 burbot netted during the months of January and February, 1954. This species attains a relatively rapid growth in length during the first four years of life with a gradual decrease in growth rate thereafter (Figure I). This growth curve (both sexes combined) was based on the average total lengths for each age group at time of capture. Otoliths collected varied in size from about 9·0 mm. x 4·0 mm. in the smaller fish to 18·5 mm. x 8·0 mm. in the larger fish. These were placed in a watch glass, covered with water and read under a low power microscope without cutting. All otoliths of fish over six years of age had a clear zone on the margin. In contrast the younger fish, up to at least three years of age, had an opaque zone on the margin. The significance of this latter observation is not apparent.

Table I

Catch of Burbot during Netting Operations in Lake Simcoe—January 6 to February 27, 1954

Jersey River	7
Sutton River	799
Pefferlaw River	349
Whitefish Creek	15
Talbot River	508
Trent Canal	459
Atherley Narrows	676
Total Number of Burbot	2,813
Estimated Poundage of Burbot	13,221 pounds

A comparison of growth rates of the burbot of lakes Opeongo and Erie with those of Lake Simcoe indicates that the Lake Simcoe burbot grow more rapidly than those in the aforementioned lakes (Figure II). The curves for lakes Opeongo and Erie are based on published data by Martin (1941) and Clemens (1951) respectively.

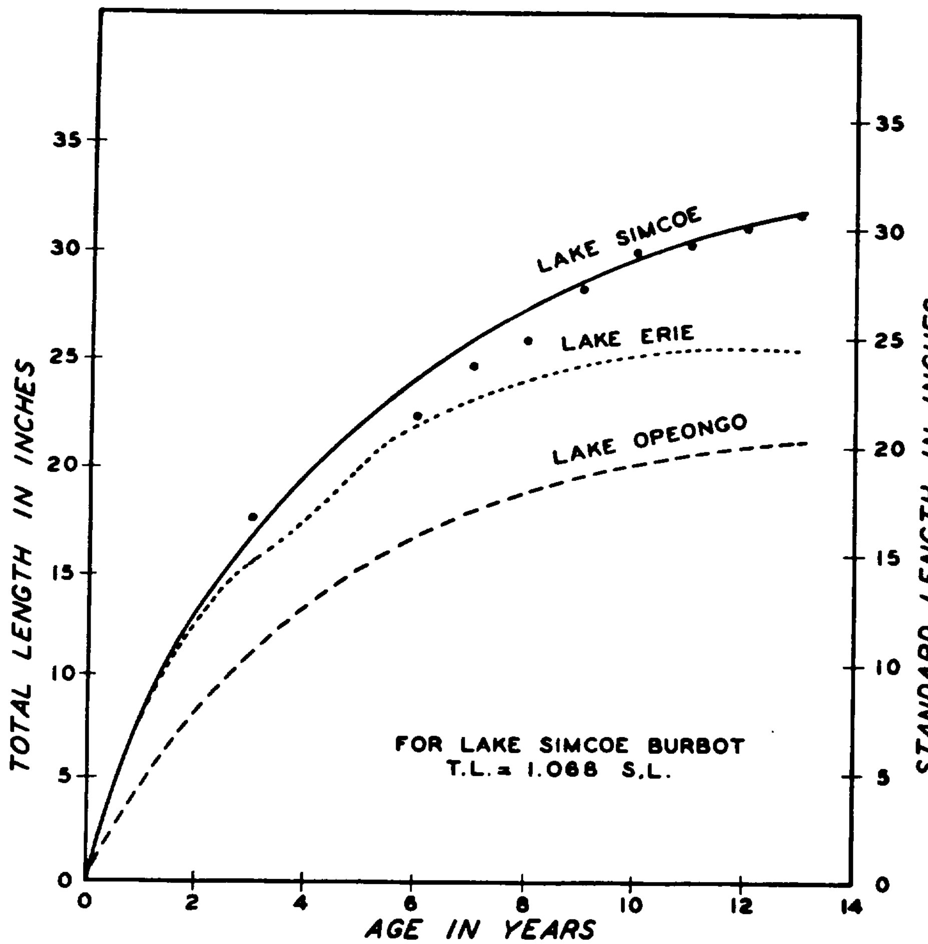

Figure II. Comparison of the Growth of Burbot in Lakes Simcoe, Erie and Opeongo.

Length-Weight Relationship

The length-weight relationship of Lake Simcoe burbot was based on data collected from 130 fish without regard to sex, date of capture, or state of maturity. The weights of burbot at various lengths are shown in Figure III.

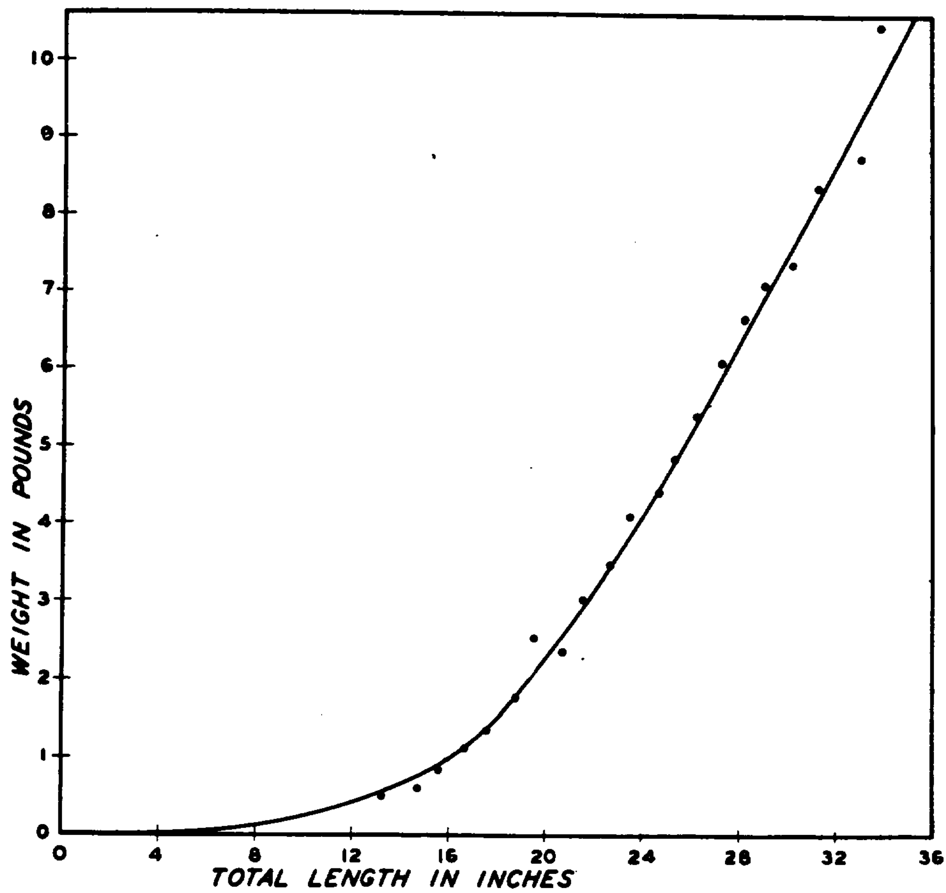

Figure III. The Length-Weight Relationship of Burbot (sexes combined) of Lake Simcoe, January-February, 1954.

Sexual Maturity and Spawning

The greater proportion of the male and female burbot of Lake Simcoe mature during the third year of life. Few fish were still immature by the fourth year. The smallest mature male captured measured 13·5 inches, weighed 9 ounces and contained 1·6 ounces of milt during early January. A mature female 16·5 inches in length and weighing 24 ounces, carried some 45,600 eggs before spawning. These fish were both three years of age.

The quantity of milt and roe increased considerably with the growth of the burbot. An eight-year old female, 28 inches in length contained 1,018,050 eggs which constituted 22 per cent of its pre-spawning body weight. A male of similar age and size held 13·8 ounces of milt, making up 10 per cent of its body weight. During the spawning period there is a significant loss in body weight between ripe and spent mature female of all ages caused by the release of such large quantities of eggs.

The time of spawning was determined through daily observations on the degree of ripeness of the male and female burbot taken in the hoop nets. During the pre-spawning and spawning period, male fish made up 57 per cent of those captured. Ripe male fish were observed first on January 14 at all netting stations. After this time the proportion of ripe males and females increased until nearly all fish exuded eggs or milt when handled. After January 25, the numbers of ripe fish decreased until only spent burbot appeared in the nets. All burbot taken on or after February 1 were spent fish.

In the immediate post-spawning period, the number of burbot taken daily in the nets increased abruptly and was accompanied by a notable change in the sex composition. The number of male fish decreased to only 16 per cent of the fish captured while many large females predominated. During the pre-spawning and spawning period 1,177 burbot, or 6·7 fish per hoop net-night, were taken in January. In contrast, 1,636 burbot were taken with less equipment during February and represented 16·7 fish per hoop net-night. Nearly half of the nets were removed from the water in early February when ice conditions became unsafe at the Atherley Narrows and Sutton River, both locations characterized by heavy runs of burbot. The nets at Talbot River, Trent Canal and Pefferlaw River were operated until the end of February when a prolonged thaw and accompanying flood conditions made further operation hazardous. Considerable quantities of burbot were still being taken daily when the work was discontinued.

While it is probable that a few burbot may spawn in the rivers, the comparatively small number of burbot which ascended the rivers prior to the post-spawning period suggests that the principal spawning grounds of this species lie in the open lake. Two of the spawning areas which have been located in Lake Simcoe, are near the Atherley Narrows at the north end of the lake, the other near Virginia Beach on the east shore. Here, the burbot spawn over a coarse gravel bottom where the water is five to ten feet in depth. Spawning occurs usually during the later part of January. Competent informants at Atherley report that spawning burbot have appeared on the spawning bed there on about January 22 for many years past. The statements of several local people have indicated the presence of additional spawning areas and it is probable that the burbot spawn in various other parts of the lake.

Food Items

The food of burbot in Ontario waters has received some attention by other investigators. The food of 100 burbot taken in January from Rideau and Otter lakes in Lanark and Leeds counties was found to be composed of fish exclusively (Prov. of Ont., 1932). Dymond (1928) found alewives, cottids and crayfish to be the food of 64 burbot from Lake Ontario. Clemens et al (1923 and 1924) found *Mysis* and ciscoes to be the principal items of food of 242 burbot in Lake Nipigon. Clemens (1951) in an extensive survey of the food of Lake Erie burbot found that fish and invertebrates, largely Percidae and crustaceans, constituted the major food items.

Figure IV. The stomach contents and quantity of eggs contained by a female burbot prior to spawning.

A study of the stomach contents of burbot taken in Lake Simcoe river mouths during January and February has shown that the yellow perch, the freshwater herring, and the emerald shiner form the main items of food; these species were found in 35, 34 and 27 per cent of the stomachs, respectively. The pumpkinseed and common white sucker occurring in 16 and 6 per cent of the stomachs, appeared less commonly while other species of fish, crayfish, and insects were items of food in only 2 per cent or less of the stomachs examined. Some 14 per cent of the stomachs examined contained no food which resulted from a definite curtailment of feeding during the time of spawning. The stomach contents of a female burbot prior to spawning is shown in Figure IV.

Table II

Frequency of Items Taken as Winter Food by Burbot in Lake Simcoe River Mouths

Items of Food	Percentage of Stomachs Containing Items	Average Number per Stomach	Greatest Number in One Stomach
Yellow Perch *Perca flavescens*	35	10·7	101
Freshwater Herring *Leucichthys artedi*	34	3·7	11
Emerald Shiner *Notropis atherinoides*	27	26·4	135
Pumpkinseed *Lepomis gibbosus*	16	1·8	5
Empty	14	....	....
Common White Sucker *Catostomus commersonnii*	6	1	1
Rock Bass *Ambloplites rupestris*	2	1	1
Crayfish *Cambarus bartoni*	2	1	1
Caddis-fly cases	2	1	1
Johnny Darter *Boleosoma nigrum*	1	1	1
Smallmouth Bass *Micropterus dolomieui*	1	1	1
Bluntnose Minnow *Hyborhynchus notatus*	1	2	2
Common Whitefish *Coregonus clupeaformis*	1	1	1

Previous to spawning during January, the stomachs of the burbot were found to contain all species of food itemized in Table II. It was not until the fish appeared ripe and in a spawning condition that a notable reduction in the amount of food was noticed. Immediately following spawning, the female burbot, in particular, consumed great quantities of whatever kind of food was readily available. One fish contained 101 perch, one lake shiner, one sunfish; another fish, 135 lake shiners, five sunfish, two perch. The individual stomachs of many of the burbot contained a variety of food items. For example, a large female fish taken in the Pefferlaw River on February 9 contained 31 yellow perch (2″-4″), 15 emerald shiners (1″-3″), three pumpkinseed (3″), one sucker (8″), and one smallmouth bass (8″).

As a result of the examination of food items in the stomachs and the degree of digestion, it would appear that the burbot move in and out of the river mouths, presumedly in search of food during the winter months.

Summary

A study of Lake Simcoe burbot was made in January and February, 1954, during coarse fish removal operations when 2,813 burbot were captured.

It was found that the otolith method offered the most satisfactory means of those investigated for the aging of burbot.

A comparison with the growth rates of the burbot of lakes Opeongo and Erie revealed that the Lake Simcoe burbot grew faster than those of the other two lakes.

The burbot of Lake Simcoe mature in their third and fourth years of life at lengths approximating 13 to 17 inches.

The spawning period usually occurs during the last two weeks of January. It is believed that spawning areas are restricted largely to the open lake.

The principal food items found in the burbot stomachs were the yellow perch, the freshwater herring and the emerald shiner. Other items such as the pumpkinseed, common white sucker, rock bass and crayfish occurred in lesser numbers.

The burbot is seldom recognized as a food fish by the fishermen of Lake Simcoe. A commercial market for this species is lacking at the present time.

Literature Cited

CLEMENS, HOWARD P. 1951. *The growth of the burbot* Lota lota maculosa *(Le Sueur) in Lake Erie.* Trans. Am. Fish. Soc., Vol. 80 (1950), pp. 163-173.

CLEMENS, HOWARD P. 1951. *Food of the burbot* Lota lota maculosa *(Le Sueur) in Lake Erie.* Trans. Am. Fish. Soc., Vol. 80 (1950), pp. 56-66.

CLEMENS, W. A., J. R. DYMOND, N. K. BIGELOW, F. B. ADAMSTONE and W. J. K. HARKNESS. 1923. *The food of Lake Nipigon fishes.* Univ. Toronto Studies Biol. Ser. No. 22, Publ. Ont. Fish. Res. Lab., No. 16, pp. 173-188.

CLEMENS, W. A., J. R. DYMOND and N. K. BIGELOW. 1924. *Food studies of Lake Nipigon fishes.* Univ. Toronto Studies Biol. Ser. No. 25, Publ. Ont. Fish. Res. Lab. No. 25, pp. 103-165.

DYMOND, J. R. 1928. *Some factors affecting the production of lake trout* (Cristivomer namaycush) *in Lake Ontario.* Univ. Toronto Studies Biol. Ser. No. 31, Publ. Ont. Fish. Res. Lab. No. 33, pp. 29-41.

MARTIN, WILLIAM R. 1941. *Rate of growth of the ling* Lota lota maculosa *(Le Sueur).* Trans. Am. Fish. Soc., Vol. 70 (1940), pp. 77-79.

PROVINCE OF ONTARIO. 1933. Twenty-sixth annual report of the Game and Fisheries Dept. 1932, pp. 1-32.

SPEIRS, J. MURRAY. 1952. *Nomenclature of the channel catfish and the burbot of North America.* Copeia, No. 2, 99-103.

The Effective Use of a Direct Current Fish Shocker In a Prince Edward Island Stream

by

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During the assessment of summer populations of trout and salmon in Ellerslie Brook, Prince Edward Island, electrofishing techniques were developed which can capture all or almost all the fish in the sample areas. These results were obtained with low voltage outputs.

Ellerslie Brook

Ellerslie Brook is a small spring-fed stream with an effective length for supporting trout of 4½ miles. The brook lies in an area of Permo-Carboniferous sandstones and the stream bottom consists of these sandstones or of soils weathered from them (Whiteside, 1950). The average width at summer levels is about four feet. In the lower reaches a maximum width of 20 feet is attained. Depths up to three feet are encountered in the larger pools but for the most part average only about six inches.

A small tributary, Hayes Brook, enters about one-half mile from head of tide. It has an average width of three feet and an average depth of five inches.

Electrofishing is the most effective means of capturing fish in Ellerslie Brook and its tributary because overhanging alders and frequent snags in the water make seining extremely difficult.

Summer water temperatures range from 10° to 20° C. The conductivity of the water, as determined by Dr. F. R. Hayes, is 168 reciprocal mega-ohms at 25° C. The hydrogen ion concentration, expressed as pH, ranges from 7·5 to 7·8. The brook water contains 45·2 ppm. of fixed CO_2 and has a total hardness, expressed as $CaCO_3$, of 93·9 ppm. (Leverin, 1947).

Apparatus

The complete fishing apparatus consists of an Onan portable lighting plant (Model 102AH-115 M) rated at 115 volts, D.C., 1200 watts; 75 yards of two-conductor wire leading to a control box which has outlets to the grounded negative electrode and to the commutator of the wire-reel; and a positive fishing electrode (Fig. 1).

The wire-reel consists of a light metal frame in which is set a fibre spool equipped with a commutator which turns as wire is pulled off. It carries 200 yards, or more, of 650 volt, no. 14 stranded (flame-sealed) wire which weighs only 5½ pounds per 100 yards and is tough, pliable and much lighter than rubber-covered wire. The positive electrode is attached to the free end of this wire.

The positive or fishing electrode is a straight piece of aluminum tubing, five feet long, to which is attached, by flared-type couplings, an oblong grid (8 x 12 inches). One end of the straight piece is insulated with a short length of rubber garden hose, which in turn is covered with electrical tape to provide a handle. A Hubbell twist lock connector is clamped on the end of the handle; this provides a connection to the fishing reel. The electrode is so constructed as to allow quick repairs in the field.

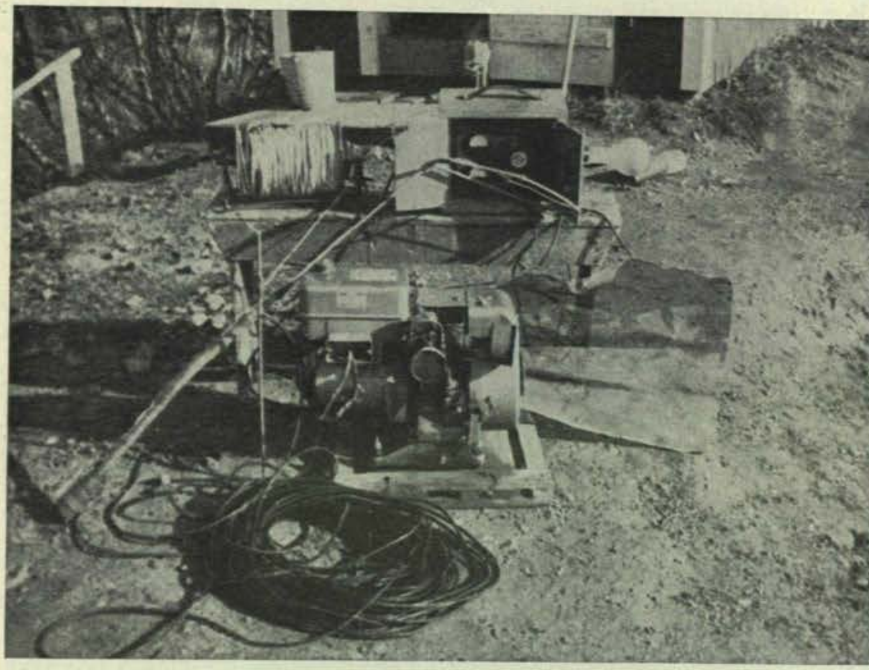

Figure 1. Electrofishing apparatus employed in Ellerslie Brook. Coil of two-conductor wire in foreground; behind this, generator with positive fishing electrode and negative ground screen; in background, wire-reel and control box, the latter with volt and ammeter exposed to view.

The negative electrode consists of a piece of copper-wire screen (2 x 5 feet) which is laid on the stream bed and held down by stones.

A one-wheeled trailer pulled by a passenger car is used to transport the equipment. The generator is usually left in the trailer while a section of stream is being fished (Fig. 2), but two men can readily carry it if necessary.

Method of Operation

At Ellerslie Brook the trailer can usually be taken to within 75 yards of the section to be fished. The apparatus is connected as described above, with the control box and reel on the bank of the stream. The positive electrode has been fished 300 yards away from the grounded negative electrode with no apparent loss in efficiency.

Each sample area (usually 50 yards long) was blocked by nets to prevent inward and outward movement of fish while an estimate was being made.

The fishing reel was placed near the downstream block net and the operator started fishing at the net, moving the fishing electrode back and forth across the stream while moving upstream to the upper net, pulling wire off the reel as required. Two men carried dip nets and collected fish which had been affected by the energized field. In fast waters fish were led into hand seines. The fish collected in these manners were held in a live car pulled along by one of the party. When the upper block net was reached the operator turned and worked downstream, picking up the wire and carrying it in coils in one hand or on two "S"-shaped hooks on his belt. This procedure

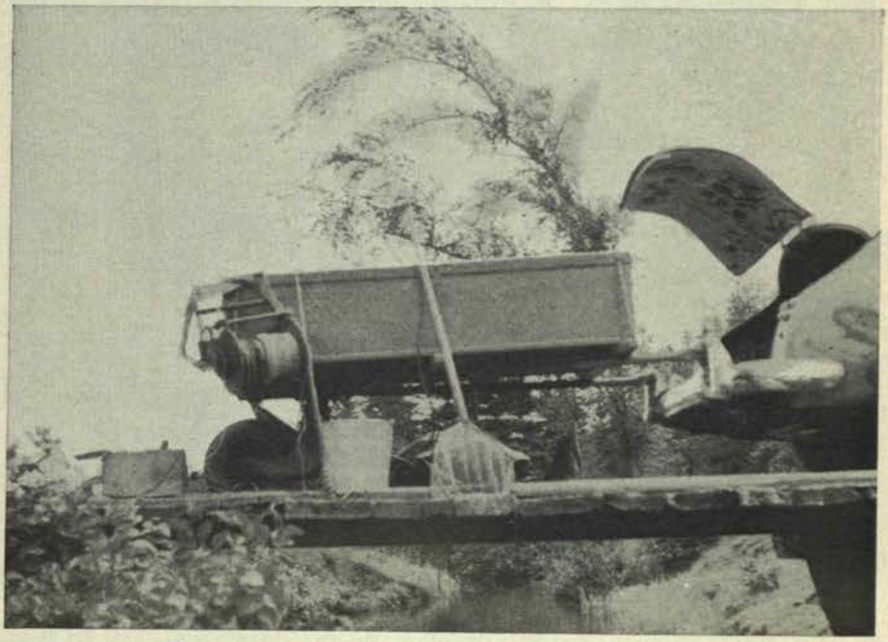

Figure 2. Trailer used in transport of generator and equipment. In position for operation.

was repeated (usually three times) until the section appeared to be cleared of fish. On the average a section was fished in about an hour. For small fish, such as fingerlings, it is necessary to keep the fishing electrode close to the bottom. For larger fish it was found more effective to fish near the surface.

Power Requirements for Stream Studies

The aim in this work has been to collect the maximum number of fish without injury.

No instruments were available for the measurement of the energized field in the water and all measurements of voltage and currents presented in this paper are direct readings from the generator voltmeter and ammeter. The purpose throughout has been to use and develop further a technique found to have definite advantages for population studies in Ellerslie Brook rather than to investigate the electrical characteristics of energized fields in water.

Most papers on electrofishing stress two features of D.C. fish shockers: (1) electrical dislodgment of fish and (2) their immobilization. A third and more important feature from a practical viewpoint is that, through proper voltage adjustment of the generator, fish can be held at the fishing electrode in a condition of partial paralysis without stunning.

When fish are immobilized in pools they tend to drop to the stream bottom and in fast water are carried downstream; in either situation it is difficult to recover the fish. On the other hand, when the stimulus is sufficient to attract and hold them at the electrode without stunning, more complete collection of fish is possible with the least injury. Care must be taken, however, to remove fish from the energized field before they are fatigued because once this occurs they fail to respond to the stimulus until time is allowed for their recovery. In practice, when fish come toward the fishing electrode, it is slowly moved through the water away from the fish. They will then follow it until they are fatigued or are removed from the field.

Experience showed that in Ellerslie Brook a more effective field is obtained when additional load beyond that drawn by the fishing apparatus is placed on the generator. This has been accomplished by inserting electric light bulbs in the control box circuit so that they are connected to the generator output in parallel and on the proximal side of the electrodes. This results in a total drain on the generator of $3\frac{1}{2}$ to 4 amperes at 150 to 160 volts output.

Procedure for Testing Efficiency of the Shocker

In order to test the efficiency of the electrofishing apparatus now in use, marking and recapture procedures were carried out in 1952 and 1953 in all of the sections of the brook in which population estimates were made. Fish were captured by seining and electrofishing; trout fingerlings (2 to 3 inches) and salmon parr (4 to 6 inches) were marked by fin clipping; older trout (3 to a maximum of about 12 inches) were jaw-tagged. All were then released in the area from which they had been captured.

Recapture of Marked Fingerling Trout

The difference between the proportions of marked fingerlings recapture in 1952 (60 per cent) and 1953 (82 per cent) resulted from failure to provide for proper circulation in the live car in which the fingerlings were held during the 1952 experiment, with the result that the fingerlings, when released after marking, were in a state of fatigue and would not respond well to the electrical stimulus (Table I).

It was noted that when fatigued fingerlings were subjected to an electric field, instead of being attracted to the positive electrode they were stunned and remained under rocks and debris on the bottom and accordingly were more difficult to recover. Similar difficulties were encountered with salmon parr but not with older trout. Recaptures immediately improved when the trouble was found and a new live car was constructed, but not, unfortunately, until the next to the last section was being studied in 1952.

It is apparent that it is more difficult to approximate total capture of fingerling trout than of older trout or of salmon parr (cf. Tables I, II and III). Three reasons may be advanced:

1. Voltages are insufficient for the efficient capture of fingerlings.
2. Nature of fingerling habitats.
3. Escapement through block nets.

It was found that when higher voltages were used there was more stunning of fingerlings but the proportion of recaptures was no higher. Furthermore in sections where physical conditions did not make collection difficult, the voltage regularly employed resulted in 100 per cent recapture (Table I). This would seem to indicate that insufficient voltage does not explain the less efficient capture of small fish.

Fingerlings are commonly, though not always, found in shallow, rocky, fast-water sections of the stream. Under such conditions it is difficult to collect those individuals which are stunned on the stream bottom and remain under rocks and debris.

Table I

Recapture of Marked Fingerling Trout

1952

Length of section (yd.)	No. marked	% recapture	Total marked and unmarked
50	4	25	31
50	38	63	108
50	30	66	61
50	17	53	76
50	22	64	93
50	11	73	185
50	25	80	29
1953			
50	4	100	8
50	31	90	41
50	6	100	15
75	37	73*	87
50	41	98	124
50	57	86	91
50	20	100	32
50	6	100	15
50	7	43*	10
24	4	no recap.	10
50	12	92	56
50	24	100	82

*Escapement observed.

The third reason is largely an extension of the second since fingerlings immobilized in fast water may drift into the downstream block net where they are held by the pressure of water on the net until they are forced through or, as sometimes happens, become lost in the trash which accumulates on the block net, in which case they are killed. To some extent the difficulties encountered in fast, shallow water can be overcome by fishing first at the downstream block net and working upstream using a hand seine to collect the fish.

Recapture of Marked Older Trout

Most of the older trout (3 inches and over) in any of the areas of the brook can be captured without difficulty (Table II). In the few cases where recaptures fell below 90 per cent the cause was found to be escapement from the area.

Table II

Recapture of Marked Older Trout

1952

Length of sections (yd.)	No. marked	% recapture	Total marked and unmarked
30	60	90	151
50	24	100	28
50	35	94	52
50	28	93	33
50	19	90	49
50	12	83	22
50	12	100	56
50	5	100	5

1953

Length of sections (yd.)	No. marked	% recapture	Total marked and unmarked
50	25	80	26
50	21	95	22
50	12	92	21
450*	54	98	347
50	59	81	85
50	18	100	18
50	15	100	18
50	25	92	29
55	47	94	132
50	22	100	39
50	50	94	62
24	24	92	36
75	72	94	149
50	55	100	93

*Hayes Brook.

Recapture of Marked Salmon Parr

The results of electrofishing young salmon are given in Table III. Some of the salmon parr which were held in the live car in 1952 were obviously fatigued when released. When the section was fished again on the same day relatively few of these fish were recaptured.

At the voltage employed, 150 to 160 volts, salmon parr were observed to be more sensitive to the electric stimulation than were trout of the same size (4 to 6 inches). Salmon parr are quickly immobilized once they are in the stronger portions of the field and, if injury is to be avoided, they must be removed from the field at once. By exercising caution, however, it has been possible to assess salmon populations in Ellerslie Brook, using the same voltages as those employed for fishing trout, without any undue injury to the salmon parr. Less voltage might have been sufficient to capture salmon parr.

Table III

Recapture of Marked Salmon

1952

Length of section (yd.)	No. marked	% recapture	Total marked and unmarked
50	10	90	14
50	26	85	35
50	40	87	59
50	4	75	12
50	1	100	3
50	2	100	12

1953

Length of section (yd.)	No. marked	% recapture	Total marked and unmarked
50	6	67*	7
50	7	86	7
50	3	100	4
50	2	100	4
24	2	100	2
75	2	100	4
50	4	100	6

*Escapement observed.

Influence of Depth, Width and Temperature of Water

Depth and Width

The maximum depth encountered in our sampling areas is 3 feet but in most areas depths were not more than 2 feet, and stream width ranged from 3 to 20 feet. No significant variation in the efficiency of the electrofishing apparatus was observed. However, it has been observed in other Prince Edward Island streams that at widths exceeding 20 feet trout can swim around the field and escape. This occurs to some extent at widths from 15 to 20 feet but if care is taken no difficulties are encountered. Although there are limits to the depth and width within which the shocker can be used for total capture of fish this does not preclude the usefulness of this equipment as a sampling tool in situations where total capture is impossible. In a larger Prince Edward Island stream we have removed trout from depths of 10 feet and at widths of 30 feet.

Temperature

Over the summer temperature range of Ellerslie water (10 to 20° C.) there has been no significant change in the efficiency of capture.

Injury to Fish

No evidence was had in Ellerslie Brook that any mortality occurred as a direct result of fish being brought into an energized field. Extensive fatigue and even death will result if fish are held for a prolonged length of time at the positive electrode, but this can easily be avoided.

Error from Escapement Through Block Nets

Care must be taken in the installation of block nets. Little escapement occurred when the nets were properly set.

Summary

1. Electrofishing was carried out in Ellerslie Brook whose waters have a conductivity of 168 reciprocal mega-ohms at 25° C.

2. The apparatus employed was a D.C. generator rated at 115 volts and 1200 watts. It was operated at 150 to 160 volts, with a load applied to give a total drain of 3½ to 4 amperes.

3. A high and consistent recovery of marked trout and young salmon was obtained.

4. The value of electrofishing in making estimates of total populations in a small stream was demonstrated.

Assistance in the field by Messrs. C. R. Hayes, C. Williams and H. Ross is gratefully acknowledged. A portion of the terminal gear was designed by Mr. H. Y. Brownrigg. This paper is published with permission of The Fisheries Research Board of Canada.

Literature Cited

LEVERIN, H. A. 1947. *Industrial waters of Canada. Report on investigations, 1934 to 1943.* (Revised edition of Report 807.) Canada, Department of Mines and Resources, Mines and Geology Branch, Bureau of Mines, Report No. 819, 109 pp.

WHITESIDE, G. B. 1950. *Soil Survey of Prince Edward Island.* Experimental Farms Service, Canada Department of Agriculture in co-operation with the Prince Edward Island Department of Agriculture, Charlottetown, 83 pp.

EDMOND CLOUTIER, C.M.G., O.A., D.S.P.
QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1954