THE CANADIAN FISH CULTURIST

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

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NOTES ON DEVELOPMENT OF FISH CULTURE IN CANADA

By J. A. Rodd[1]

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

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

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

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

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

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

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

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

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

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

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

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

In the experiments with whitefish eggs, glass grills and trays were used, but when the first large whitefish hatchery was built at Sandwich on the Detroit River it was equipped with troughs 12 feet long by 12 inches wide, and 10 inches in depth, and divided into a series of compartments 15 inches long. Eight, ten or more hatching trays, one upon the other, were placed in each compartment. Between each compartment in the trough there was a space of three inches, by which means the water could be made to flow either upwards or downwards through the eggs at pleasure, by reversing the troughs end for end upon the staging which supported them. This narrow space of three inches, having a hole and plug at the bottom, was also used to draw off the water and sediment from each compartment without interfering with the one adjoining. The troughs were placed one after the other lengthwise of the room, and connected by short pieces of rubber hose let into the ends of each.

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

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

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

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

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

Live fish and egg carriers—Bronze Medal and Diploma.

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

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

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

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

Equipment:

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

Nutrition:

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

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

Improvement of Stock:

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

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

Acclimatization:

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

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

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

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

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

BY A. L. PRITCHARD[1]

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

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

(Diagram on the following page)

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

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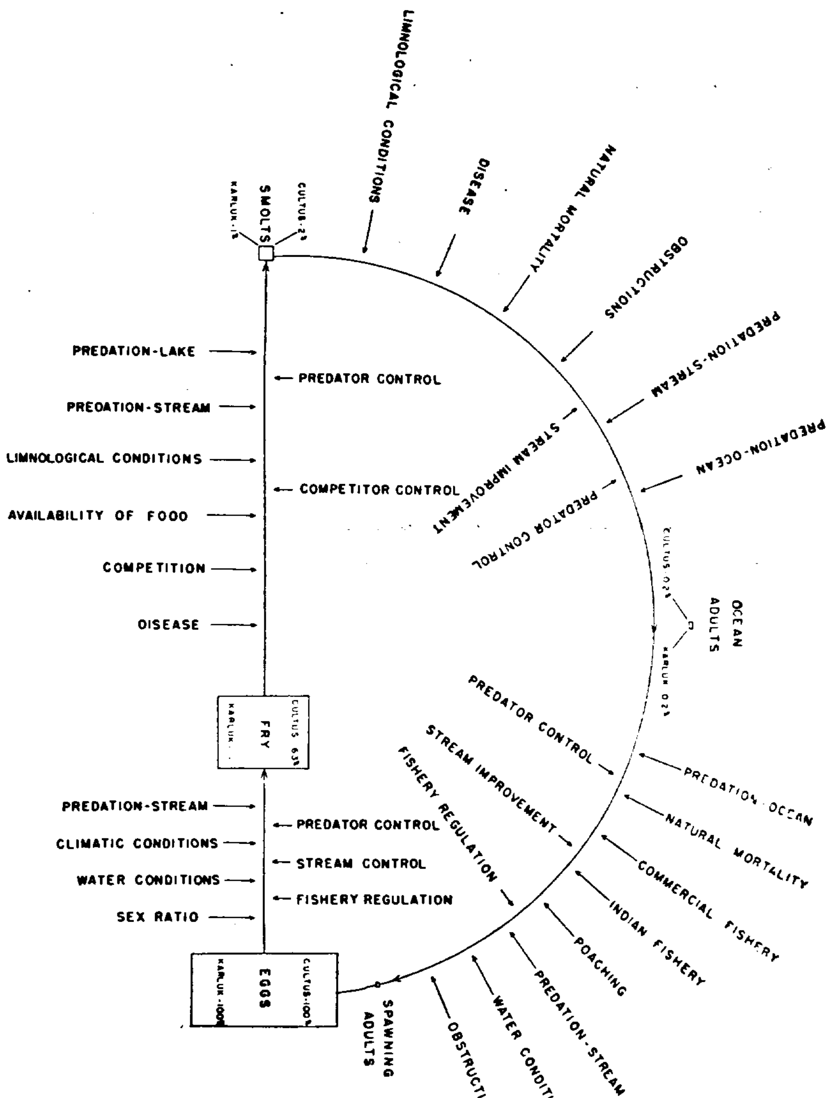

Diagram showing relative losses occurring in various stages of the life history of the sockeye salmon, the factors causing them and possible remedies.

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

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

1. The losses occurring during the life cycle and their extent in the various stages of the life history.

2. The factors which may affect production in four stages, viz., (a) from egg deposition until fry migration from the stream (ca. 6 months); (b) during the lake residence (usually 1 year); (c) from the time of leaving the lake until the fish reach the ocean, have matured, and are about to return to spawn (ca. 1-3 years); and (d) during the time of return from the ocean to the spawning beds (2 to 4 months).

3. Remedies which might be applied in these arbitrary stages to counteract adverse factors.

4. **The complexity of the natural relationships in the life cycle of the sockeye which make conservation not simply a matter of adjusting one factor but of establishing a sound balance between many.**

LOSSES, THE PERIOD OF THEIR OCCURRENCE AND EXTENT

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

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

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

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

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

FACTORS AFFECTING PRODUCTION AND POSSIBLE REMEDIES

Stage 1 — Eggs to Fry

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

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

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

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

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

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

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

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

Stage 2 — Lake Residence

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

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

Stage 3 — Migrant to Ocean Adult

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

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

Stage 4 — Ocean to Spawning Grounds

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

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

THE COMPLEXITY OF THE PROBLEM

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

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

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

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

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

BY W. A. KENNEDY[1]

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

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

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

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

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

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

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

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

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

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

BLACK SPOT DISEASE OF BASS

PART 1. DISTRIBUTION OF THE DISEASE[1]

BY FRANÇOIS DE S. LAČHANCE[2]

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

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

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

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

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

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

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

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

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

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

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

Distribution of Black Spot of Bass

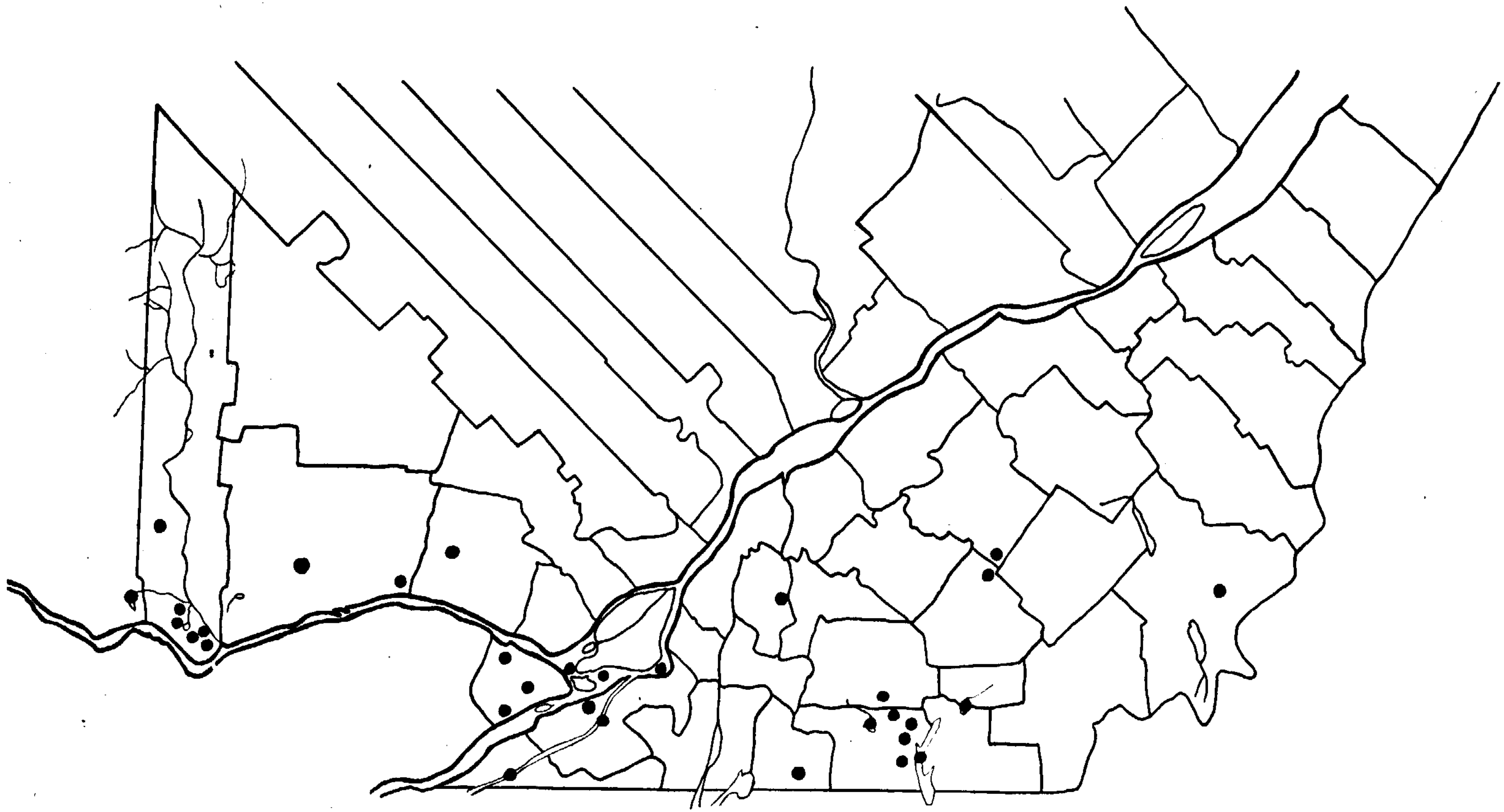
The small-mouth black bass is found in large areas of Quebec, although it is more widely distributed throughout Ontario. From the Georgian Bay across the Kawartha system, through the Rideau chain to the St. Lawrence, is the principal distribution belt, though it is found in great abundance, also, in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

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

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

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

*In Mount Bruno area



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

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

SUMMARY

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

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

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

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

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

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EFFICIENCY OF NATURAL PROPAGATION OF PACIFIC SALMON

BY A. L. PRITCHARD[1]

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

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

RESULTS

Sockeye Salmon

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

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

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

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

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

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[3] Senior Biologist, Pacific Biological Station.

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

Coho Salmon

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

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

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

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

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

Pink Salmon

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

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

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

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

Chum Salmon

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

DISCUSSION

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

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

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

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

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

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

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

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

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

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

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

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STREAM CONTROL AND NEW FISH CULTURAL PROCEDURES ON A SWEDISH RIVER

BOOK REVIEW BY W. PERCY WICKETT[1]

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

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

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

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

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

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

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

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

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

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

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

Wrack Organism. Water fleas cannot be supplied in sufficient quantities to feed larger three-month-old fry. A source of live food, mainly *Orchestia platensis,* has been found in the huge beds of wrack (seaweed) along the coastal beaches. The seaweed is tossed onto a frame 10 x 7 feet covered with ½-inch wire netting. The animals fall into a linen bag below. Two men working an eight-hour day collected on the average 300 quarts in July, 250 in August and 125 in September. The animals and seaweed remains were scattered in small quantities in the centre of the fry ponds. The ponds should be at least 50 yards in radius, so that the wrack fleas may be caught before they swim ashore. The seaweed remains, if not too plentiful, have the added effect of fertilizing the ponds. Throughout July, August and September 418 gallons of wrack animals and remains were put into a pond 2,500 square yards in area. Of the 35,000 sea trout fry planted in the spring, 17,181 fish averaging 2.7 inches in length were taken out in December. This is a production of 268 pounds per acre.

"Wolf" Trap. In order to collect all living matter, including fish, that may drift down the streams, the author has designed a self-cleaning trap with 0.3 millimeter mesh able to handle up to 80 cubic feet per second of water and which could be enlarged to handle up to 2,000 cubic feet. Sixteen inches below a 5½-foot dam, a fine screen 10 feet wide is placed at a slight angle away from the pond. Attached to the lower edge of the screen is a large box made of screening. The box has a cleaning door at the side. The force of the falling water keeps the screen clear even when the stream is full of leaves. All solid material and organisms large enough for fish food collect in the box. If the box is made sufficiently large, the device will function without supervision for periods up to two weeks. Fish and fish food are not injured at all. Anyone interested in using this device may obtain additional information by applying to the association.

POLLUTION STUDIES IN BRITAIN

BY J. R. DYMOND[1]

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

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

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

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

Department of Scientific and Industrial Research.
Water Pollution Research Technical papers.
Survey of the River Tees
  No. 2 Part I Hydrographical
  No. 5 Part II Estuary — chemical and biological.
  No. 6 Part III Non-tidal reaches — chemical and biological.

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

[1]Professor of Systematic Zoology, University of Toronto; Director, Royal Ontario Museum of Zoology; Member, Fisheries Research Board of Canada.

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

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

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

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

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

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

CORRECTION

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

OTTAWA
EDMOND CLOUTIER, C.M.G., B.A., L.PH.,
IMPRIMEUR DE SA TRÈS EXCELLENTE MAJESTÉ LE ROI
CONTRÔLEUR DE LA PAPETERIE
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ON COUNTING THE TROUT IN A LAKE

By F. R. Hayes[1]

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

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

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

[1] *Zoological Laboratory, Dalhousie, and Department of Industry, Province of Nova Scotia.*

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

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

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

There are several sources of error in the method; for instance, some of the marked fish may die as a result of handling, after they have been returned to the water. Again, the census taker is likely to miss an occasional marked fish. Both these errors will result in too high an estimate of the total population. Further, the method assumes that the marked fish will take the hook a second time as readily as the population as a whole; if they fail to do so the estimate will be high. Much more serious, however, is the inherent error if the ratio of marked to unmarked fish is too small. In the example above, fluctuations in the marked fish count will be multiplied fifty fold in the estimate of total population. If the marked fish had represented 10 per cent of the population instead of 2 per cent, the error would have been ten fold; had they represented 50 per cent the error would have been only two fold, which is the best result possible. It follows that it is desirable to bring the marked group as closely as possible up to 50 per cent of the population of the lake. In practice this is not likely to be attained by angling, although something in the direction of traps might be developed.

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

A few general observations on angling conditions were made.

1. No relation could be observed between weather and angling success, wind, sunlight, and rainfall being equivalent.

2. More fish were caught within 100 feet of shore than farther out in the lake.

3. No difference in fish response could be observed between flies and worms, nor could any one fly be shown to be better than any other.

4. Noise did not appear to interfere with results, as evidenced by the operation of an outboard motor, in the tailrace of which, fish could be caught.

5. Local help was disappointing; it was found suprisingly difficult to engage people who would fish actively, and those who did not do so caught very few fish.

6. The fish appeared to bite in cycles; thus after a disappointing interval nearly everybody scattered over the lake would begin to get bites at once. Whether this phenomenon is associated with a change in some physical condition such as light, was not clear.

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

Date (May)	Total Catch	Marked Fish	Per cent Marked
12	182	3	1·6
13	129	9	7·0
14	201	11	5·5
15	124	2	1·6
16	123	0	0·0
17	108	0	0·0
18 (Sunday)	347	9	2·6
19	38	0	0·0
20	32	0	0·0
21	43	0	0·0
TOTAL	1327	34	

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

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

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

1. *The proportions of marked fish taken from day to day, differ more than would be expected in random samples of homogenous material.* In applying the Chi square test to show this, the days were grouped as follows, in order to reduce the risk of fallacious results due to the small size of the samples; May 12 and 13, 14, 15 and 16, 17 and 18, 19-21. Chi square = 15·54; degrees of freedom = 4; P is less than 0·01.

2. *Although the successive percentages of marked fish fluctuate, there is a general downward trend, that is to say, the proportion of marked fish was really diminishing.* Linear regression is a test for this trend, in so far as it can be represented by a straight line. Fisher's angular transformation of percentages was applied, and the regression equation for these values was estimated. The downward slope of the regression was found to be significant; P is less than 0·05.

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

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

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

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

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

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

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

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

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

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

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

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

BY WM. M. SPRULES[1]

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

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

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

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The results of the investigation showed that such conditions actually existed. Seining operations carried out behind the dams during the summers of 1945 and 1946 showed that large numbers of goldeye averaging 2½ inches in length began to accumulate at the dams early in August. By the middle of August a short sweep of the seine produced as many as two hundred goldeye in addition to other species. This condition was repeated behind eight of the ten dams visited.

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

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

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

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

March, 1947

DO SMALL SALMON TEND TO PRODUCE SMALL SALMON?

BY F. NEAVE AND A. L. PRITCHARD[1]

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

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

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

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

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

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

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

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

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

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

By D. S. Rawson[1]

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

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

Maligne Lake

Maligne Lake is the largest in the Jasper region, having an area of 8·5 square miles and a maximum depth of 315 feet. Its altitude is 5,460 feet and being fed by adjacent glaciers, it is heavily silted and extremely cold. The general physical and biological characters of this lake have been described by the writer (Rawson, 1942). Stocking was carried on in the years 1928, 1929, and 1931 with large numbers (an average of about 175,000 per year) of eastern brook trout *(Salvelinus fontinalis)* fry. It was formerly barren of fish and the trout developed rapidly providing excellent fishing from 1932 to 1935. The large fish then deteriorated quickly to a low point in 1937 at which time they were severely emaciated. After that time a gradual recovery occurred but the fish were smaller than those of 1933. An account of the experiment up to 1940 has been published by the writer (1940). It was suggested that the difficulty was not the presence of too many fish but of too many large fish, a population of almost uniform size which could not find suitable food and was unable to adjust itself by cannibalism.

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

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Amethyst Lake

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

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

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

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

Marvel Lake

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

The first evidence of deterioration was reported in 1932, five years after the initial planting. In 1933 many fish were caught and about one-quarter were emaciated and had soft flesh. The number of fish in poor condition increased in 1934 and 1935. In 1936 a large number of fish were examined by the writer. All the larger fish were thin, most of them were 25 per cent below the normal weight of cutthroats of similar length in the Banff area and some of them were less than half the normal weight. One fish 18 inches long weighed only 19 ounces as compared with the average expected weight of 49 ounces. All this time the smaller fish—less than 13 inches and 1 pound weight, were in good condition. In 1937 some improvement was made and in 1938 a sample of large trout, obtained through the kindness of Erling Strom, Mount Assiniboine Lodge, was mostly in fair condition. A few were thin and one very thin. In 1941 and 1942 two-thirds of the large fish were in good condition. The remainder were thin but most of them edible. A report in 1944 suggests that all fish are in good condition.

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

Egypt Lake

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

Rainbow Lake

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

TABLE 1

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

Lake	Maligne	Amethyst	Marvel	Egypt	Rainbow	Kananaskis
Area, acres	5,000	1,160	450	40	15	1,600
Max. depth feet	315	79	220	100	60	280
Shoreline miles	35	8·3	6	1·3	0·6	9
Altitude feet	5,460	6,450	5,900	6,600	7,400	5,550
Initial Stocking—						
Year	1928	1932	1927	1930	1937	1935
Species	E. Brook	Rainbow	Cutthroat	Cutthroat	Rainbow	Rainbow
Number	175,000	46,000	8,000	24,000	10,000	75,000
Number per acre	35	40	18	600	660	47
Number per mile of shoreline	5,000	5,500	1,300	18,500	16,500	8,300
Years from planting[1] to first record of deterioration	7	5	5	6	–	–
Years from first[1] deterioration to first record of improvement	5	3	5	4	–	–
Years from first[1] improvement to recovery or adjustment	5	4	6	3	–	–

[1] *These figures are only approximations, derived in many cases from reports of wardens and anglers.*

Upper Kananaskis Lake

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

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

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

Comparison of the Lakes

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

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

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

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

THE CAUSE OF DETERIORATION

An explanation of the deterioration in these lakes was proposed earlier in a study of Maligne Lake (Rawson 1940). It was suggested that there were too many large fish present to find suitable food, and since they were of nearly uniform size the population failed to adjust itself by cannibalism which occurs in most trout populations. The delayed spawning and failure to spawn in several of the lakes may also be considered as a contributing factor in the poor condition of some of the fish. Difficulty in spawning, however, would have the same effect on the population from year to year and would not account for the deterioration and later recovery. In this connection also it should be noted that in Maligne Lake, where severe degeneration occurred, the eastern brook trout is a fall spawning species capable of living and spawning in low temperatures. Also in Marvel Lake where the most severe deterioration took place, there was no evidence of failure to spawn. It is of interest that deterioration occurred in three populations of cutthroat, two of rainbow and one of eastern brook trout.

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

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

SUGGESTIONS FOR MANAGEMENT

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

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

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

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

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

The scarcity of published data as to the age composition of natural trout populations in lakes formerly barren of fish, suggests that this would be a profitable study. In the absence of such data and of information as to the degree of cannibalism in such lakes we can only suggest a "rule of thumb" gradation based roughly on the known age composition of other fish populations. It is suggested that in barren lakes the ratio of initial to subsequent plantings might be about 1 to 10 to 30. Thus a lake for which a "normal" annual planting might be 30,000 fry, would receive 1,000 in the first year, 10,000 in the second and 30,000 in the third. It is also pointed out that the past plantings in these lakes have tended to be too heavy and that it would be better to plant more sparingly even though the achievement of maximum production might be delayed.

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

SUMMARY

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

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

BY B. DERBACK [1]

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

Heming lake is situated at approximately 54° 53′ N. Lat., and 101° 7′ W. Long., about 18 miles south of the town of Sherridon. It is 3 miles in length from north to south, from ¼ to ½ mile in width, and is 588 acres in area. It lies at the headwaters of Grass river which flows into Nelson river at Split lake.

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

There are two main tributary streams. Heming creek flows in from the south, is marshy, deep, meandering, and arises in a muskeg lake from which fish are blocked by a beaver dam. It is used mostly by spawning jackfish or pike, *Esox lucius*. Northwest creek flows into the northwest corner of Heming lake, and drains a small, shallow lake about ¼ mile distant. A 5-foot beaver dam offers a barrier to the passage of fish where the creek leaves the upper lake. The bottom of Northwest creek is hard, with many stones, and a rapids occurs midway its course. The maximum depth of water in the spring of 1947 was 3 feet, and the rate of flow varied from 0·9 to 4·5 miles per hour. This stream is used mostly by spawning pickerel and suckers, *Catostomus commersonnii*. There are a few other creeks entering Heming lake but they arise in muskeg, and are too small for the passage of fish.

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

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

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

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

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

The pickerel eggs were round and had a diameter of 1·5 to 1·7 mm., as compared with the much larger sucker eggs. When first fertilized they were translucent and slightly pinkish, but when not fertilized they became opaque and grey. They were found imbedded in loose organic material and in the submerged dead grass along the stream, below the rapids, and beneath the sucker eggs that were deposited in the same stream.

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

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

BOOK REVIEWS

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

REVIEW BY R. E. FOERSTER[1]

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

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

"The most obvious characteristic of the yields is the rapid decline in production per acre as the lakes increase in size. The optimistic production estimates of most fishery experts are not borne out; but it is believed that this is owing largely to the fact that such opinions have been based on the production of very small ponds. For instance, the total population falls from 268·5 pounds in ponds of one acre to only 32·3 pounds in lakes of 200 acres. . . .

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

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

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

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

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

REVIEW BY A. L. PRITCHARD[1]

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

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

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

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

Under the conditions of the Swedish experiments, it appears that the nature and relative abundance of the food and the hydrogen ion concentration of the water may be disregarded as factors causing the change in growth. The ponds used had abundant food perhaps better than in the lakes, yet the best growth took place in the lakes. There was, however, no lack of nutriment in any of the three environments investigated, namely, brook, pond and lake. The pH value of the water was 7·3 in the river, about 7·0 in the ponds, and less in the lakes. No connection of importance could be demonstrated between this variation and changes in growth.

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

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

The length of the growing period and the availability of space exert some control. The most favorable temperature for growth of these trout is 16°C. or 17° C. This is rarely encountered in brooks for any extended period of time. The space factor is important. In Norrbäcken, the river under examination, based on catch estimates, there ought to be in the neighbourhood of 16,600 river trout or 1·3 per sq. m. In the ponds, there were from 0·3 to 3 fish per sq. m. (in the latter case only fry), and in spite of abundant food, growth was invariably better when they were less heavily stocked. In the lakes, where the area per fish was undoubtedly much greater, the fish were considerably larger.

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

Review By D. J. Milne[1]

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

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

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

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

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

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

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

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

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