ISSUE TWENTY-TWO
MAY - - 1958

THE CANADIAN FISH CULTURIST

Published at Ottawa by
The Department of Fisheries of Canada

EDMOND CLOUTIER, C.M.G., O.A., D.S.P.
QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1958

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The papers in this issue were presented at a meeting of the Committee on Biological Investigations of the Fisheries Research Board of Canada held at Ottawa in January, 1957, under the chairmanship of Dr. J. R. Dymond, of Toronto.

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Minister of Fisheries

Some Principles Involved in Regulation of Fisheries by Quota

by
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All kinds of fishery regulations are designed to stop people from catching fish, even when they promise larger catches later on as a reward. Regulations may operate in one of a number of ways: 1. They may reduce the catch of a species at all sizes, or only at some particular range of sizes; 2. They may prohibit fishing in certain places; 3. They may prohibit fishing at certain times of year, or certain times of the day; 4. They may prohibit the use of certain kinds of gear; 5. They may prohibit taking fish in excess of a certain number (or weight) by any one individual, or boat; 6. They may prohibit taking fish in excess of a given total number or weight, each year, from the stock in question.

The motives which lead to these regulations are all, I believe, economic in the broad sense. However they are classifiable in two groups: those which aim at direct economic ends, and those which aim at increasing the general level of potential catch. Among the more direct economic aims may be, for example: 1. a desire to share the catch among as large a number of fishermen as possible (e.g., bag limits in sport fisheries); 2. a desire to restrict the number of individual fishermen or boats so that each can have a desirable net return from his activities (for example, leasing of oyster beds, and restricted licencing of nets or traps); 3. a desire to favour certain types of fishing, or certain groups of fishermen (prohibition of trawling by *large* trawlers within 12 miles of the coast, in the Maritime Provinces); 4. a desire to spread out landings over the year to promote orderly marketing of fresh fish (separate "summer" and "winter" quotas for prairie lakes); 5. a desire to restrict the duration of fishing so as to avoid stormy weather (prohibition of winter halibut fishing in the north Pacific) or so as to work only when the fish are concentrated and easy to catch; 6. a desire to obtain a more valuable product by increasing the average size of fish caught (special size restrictions on lobsters in certain areas), or by catching fish only when they are of prime quality (for example, salmon or herring before their fat is converted to sexual products).

The second type of regulation, often called *biological*, has to do with obtaining maximum sustained yield from the stock, or some similar objective. Regulations of this type are distinguished by the fact that they try to promote the economic objective of increased yield, or a larger catch per fisherman, by way of a manipulation of the size of the stock or its age composition. In their economic aspects, these so-called "biological" measures tend to benefit all fishermen indiscriminately, rather than the interests of particular groups. They are often described by names that have a certain emotional content, like "protection" or "conservation"[1] or "prevention of depletion".

[1] *I am not, of course, deprecating conservation. Using the word in its strictest sense, there is a place and a need for conservation of various fishes and of other animals and plants from the forays of man, almost everywhere on the globe.*

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The actual kinds of biological regulation vary somewhat. With salmon, which in Canada are mostly caught only toward the end of their growth, effort is devoted mainly to getting the best number of spawners on the redds—not too few and not too many—and getting them there at the proper time. With species like cod or flatfishes, where the individual fish can be available over several years of its life, the problem of maximizing yield has two aspects. For any given number of fish entering a fishery, and given amount of fishing gear, a best minimum size of fish caught can be computed from existing rates of growth and natural mortality, which will permit maximum catch from that group of fish. Existing restrictions on net size in the North Sea and parts of the northwest Atlantic are based mainly on computations of this type. However, the amount of recruitment, also, can vary with stock size or average fish size, as can rate of growth and possibly natural mortality rate; and these effects may modify or might even reverse the expected catch trend computed from existing conditions. We need to consider not only best use of available recruits, but also maintaining and increasing the production of recruits; and compromise may be necessary among conditions which favour each goal.

Before leaving these generalities, we might notice that a given regulation may sometimes serve both direct economic purposes and also the less direct economic goals which have a biological background. This is fair enough, as long as there is agreement that both ends are desirable. What is not so desirable, but quite common nonetheless, is for the biological aspects of a regulation—the "general good"—to be made a front for promoting the interests of particular groups of fishermen. I recall how the salmon traps of Puget Sound were abolished in 1935 by a public referendum or "Initiative" in the State of Washington, which had the combined support of the salmon seiners and the sport fishermen. Among the arguments put forth was the contention that the traps were a particularly destructive and pernicious type of gear, that they "didn't give the fish a chance", though actually they were taking far less salmon than the seines did. In the same vein, sea fishermen will maintain that it is shameful for salmon to be caught after they get into a river, and river anglers consider it positively sinful to take salmon from spawning beds—though the salmon are just as dead when caught in one place as in another. It would be foolish to conclude from this that all kinds of fishing are equally desirable, from the point of view of economics and public policy: however, each method should be rated on its own relative contribution to income and to satisfaction, rather than on the alleged destructiveness of competing methods.

Characteristics of Catch Quotas

So much for regulation in general. One method of regulation is to establish a catch quota, and at this meeting we are interested in quotas particularly. On the non-biological side, *daily* quotas for individual sport fishermen are a very popular device for sharing the wealth, though quite often they are ineffective because they are made so large that few fishermen ever reach them. Individual boat quotas are also sometimes applied in commercial fisheries, usually by mutual agreement rather than by law, in order to share markets or processing facilities in times of temporary glut.

However, the term quota usually refers to a limit set on the total catch taken from a stock during a season. What are the peculiar advantages and disadvantages of such quotas? Now it happens that one of the most spirited eulogies of quota regulation has been made by Professor F. I. Baranov (1947). He refers to quotas as the "American" system of fishery management, in contrast to the "European" system of closed seasons, closed areas, gear restrictions, etc. Furthermore, his knowledge of and affection for quotas is based on accounts of their operation in two Canadian fisheries—the whitefish fisheries of some of our prairie lakes, and the eastern Pacific halibut fishery which is shared by Canada and the United States. I can do no better for quotas than to quote some of his remarks.

"All restrictions on fishing," says Baranov, "are useful only insofar as they lead, by one means or another, to a decrease in the catch. In that event it is simpler, more logical and more honest to limit the size of the catch directly, without stooping to petty interference with fishing techniques." Further, "once a quota is established, all other restrictions on the fishery merely increase costs for the operators, without doing the fish stocks any good." "The work of regulatory authorities is simplified [by quotas] . . . and it is possible to reduce the enforcement apparatus. The work of the fishermen is also simplified. They can use the greatest fishing power of their nets, and they can devote their means and energy not to multiplying fishing apparatus in pursuit of an impractical level of catch, but in a restriction and rationalization of this apparatus for attaining the highest economic return from the established quota."

Contrasting quotas with other methods, Baranov notes that "properly speaking, the majority of traditional restrictions on fishing are also directed toward decreasing the intensity of fishing." "But," he says, "they do not achieve that goal. Prohibition of one kind of fishing results in the fishermen turning to a different, still-legal, one, so that the amount of fishing is not reduced. Establishing a limit for size of nets . . . is followed by an increase in their number. Closure of one region to fishing is compensated by increased activity in another. Introduction of a closed season on fishing means that fishing becomes greater during the remainder of the year."

There is obviously much truth in these various points, and it would be easy to document them by illustrations from many fisheries. Yet anyone who is close to fishery administration knows that regulation by quota is not always and everywhere as simple and as beneficial as Baranov's words make it sound.

An important technical problem is the need for a highly developed statistical system which provides day-by-day information on catch taken, especially as the quota limit is approached. Such a system can be developed, and it has in fact been developed for the British Columbia herring fishery and salmon fisheries, for example; but it is expensive. If fishing success is more predictable, and if the number of boats that will fish can be estimated fairly accurately, then up-to-the-minute statistics are not essential; an estimate of the probable catch per day can be made in advance with sufficient accuracy, and the fishing season can be made of a length to conform to the desired quota.

In some fisheries neither of the above methods of approximating a quota may be available, or there may be other conditions which make an overall quota dangerous or impractical. For example, a quota covering a broad area may lead to overexploitation of nearby grounds and underexploitation of distant ones: since the fishermen, each competing for a share of the quota, will make their cruising time as short as possible. This can be alleviated by setting individual quotas for individual subareas; but when this is done there immediately arise those problems of supervision and enforcement which quotas are supposed to obviate. Still other special conditions may make the use of overall quotas unrealistic, particularly where successive populations of a migratory fish proceed through a fishing area.

Furthermore, when you get down to cases, the difference between a quota system and other methods of regulation is by no means clear-cut. Even in Baranov's example of the Pacific halibut, we find that the actual regulations specify a certain fishing season or seasons, not a certain total catch for the year. The length of the season is of course estimated to conform to the desired catch; but, ideally at least, *any* regulation of season or time of fishing is made with a view to adjusting the catch to the most desirable level. Thus the difference between the "traditional" methods of regulation, and the so-called "American" method of regulating by quotas, becomes tenuous and indistinct.

However I do not suggest that the distinction disappears altogether. One thing which a quota brings into sharp focus is the question of the productivity of the stock. If a quota is set at 50 million pounds, for example, the first question a fisherman asks is, why is it 50? Why not 60? or 40? For that matter, how do you know that there will actually be 50 million pounds of fish on hand? Such questions are pertinent with *any* kind of regulation. But when a numerical quota has to be announced, they have a special urgency; there is no avoiding them by vague reference to a "need for conservation" or "protection of spawners". I think we can fairly claim as an advantage for quotas, over other types of regulation, that they more urgently demand information on stock size and *productive potential*, and that they stimulate efforts to determine these[2].

British Columbia herring quotas

I have been asked to indicate the status of the quotas on herring catches in British Columbia, in relation to the general question of regulation by quota. A good general summary of this matter is given by Taylor (1955). Catch quotas were introduced to a part of the British Columbia herring fishery first during the 1936-37 season. Prior to this time important fishing areas east and west of Vancouver Island had been closed to fishing for herring to be used for reduction purposes—the feeling being that there was greater economic return in using the herring for human food. However the demand for food herring had decreased, and the Province consented to wholesale reduction provided a quota was set to avoid possible excessive exploitation. The quotas set were below the known maximum catches but greater than the minimum catches for the areas concerned.

The supply of British Columbia herring varies from year to year, but usually only moderately: in this respect they are intermediate between halibut and salmon. Nowadays only two or three age-groups occur in the catches to any important degree. Success

[2]*Note especially that knowing the size of the stock is not enough. Too much preoccupation with size of stock can lead to the conscious or unconscious assumption that a large stock is an end in itself. Both theoretically and from experience we know that this is not so. It is possible for a stock to be too great to provide maximum yield, as well as too small.*

of reproduction varies considerably from year to year—more in some stocks than in others, but nowhere nearly as much as in, for example, the Norwegian herring stocks. If there are two poor year-classes in succession it means poor fishing two to three years later, while successive good reproductions set the stage for an abundant catch. In addition, in certain areas the stock is more vulnerable to capture in some years than in others. Mainly because of this last, predictions of each year's supply are not yet reliable enough to be used to set a special quota in each area for each year in advance; instead there is nominally the same quota for all years.

In practice, when herring are relatively scarce the quota is not taken. When they are abundant, nearly always a quota extension is granted. The result is that the quota sets a limit to the catch only about once in three years, and even when it does, usually only a few days remain in the season and not much more herring could be taken anyway.

However the herring stocks and fishery are far from being unregulated. There exists a closed season during spawning time, which protects the fish at a time when they are massed into very dense schools. Appropriate gear could make very large catches at such times, and could increase the total seasonal rate of exploitation of the stock from the present 45-55 per cent up to possibly 80 per cent, 90 per cent, or even higher.

In summary, the British Columbia herring fishery is producing an excellent annual yield and gives every appearance of being in a healthy state. But it is *not* a good example of the effects of regulation by quota, since the quotas to-day do not often or very greatly restrict fishing: restriction is accomplished by the closed season. However, the quotas may have potential value as a standby, in case pre-spawning fishing were ever to become substantially more effective than it is to-day.

Effects on fishermen and the industry

I do not intend to consider the economic and sociological effects of quota regulation in any detail. However it seems necessary to comment on one of the statements quoted earlier: that the use of quotas makes it possible for the fishermen to restrict and rationalize their fishing, by eliminating gear in excess of what is needed to take the quota. This of course is possible if quotas are set for individual fishermen or boats, and this system has been used in the whitefish fishery of, for example, Lake Winnipeg. A disadvantage, possibly, of this practice is that it may tend to discourage individual initiative among the fishermen (since the more skilful or enterprising ones can take no more than others) and it relaxes normal incentives to improve fishing equipment and to exploit fully the whole area from which a catch can be taken.

On the other hand, if only an over-all quota is assigned and there is no limit on total gear in use, each fisherman is exposed to the full rigours of competition—something he may not altogether care for. The general economic situation is then the same as for other common-resource operations, whose advantages and disadvantages will be evident from the remarks of the speakers who follow.

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Regulation of the Atlantic Salmon Fisheries

by
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Since 1949 the research and management programme for Atlantic salmon in eastern Canada has been under review by a Federal-Provincial Co-ordinating Committee. The main objective is to make more salmon available for use by both the commercial and sport fishermen. The various projects and recent results of the joint programme have been described in articles published in the April, 1955, and April, 1956, issues of the Department of Fisheries' monthly publication "Trade News".

Economic Value of the Salmon Fisheries

Wide fluctuations in total annual commercial landings of Atlantic salmon in eastern Canada have occurred since 1870 when the first statistics were published. Peak levels of production usually followed periods of below-average yields at intervals of about ten years. The most recent peak in commercial production occurred in 1930, however, when over 13 million pounds were landed, with a value of over $4 million. This was followed by a steady decline to a level of 4 million pounds in 1945, no indication of significant improvement by 1949, and a still lower level of 3 million pounds with a landed value of about $1 million by 1955. From one-half to two-thirds of these total landings have come from Newfoundland, including Labrador. The landings in all parts of the Canadian Atlantic coast have shown a similar trend, and it is interesting that there is a close correspondence between fluctuations in commercial landings here and in the eastern part of the North Atlantic around the British Isles.

There has been widespread concern over this last prolonged depression in commercial landings with its widespread effect on the netsmen, and anxiety about the future of the valuable sport fishery in the rivers. Actually there is no evidence of a general decline in angling catches since 1930, and even more salmon have likely been caught through an increased total rod effort in recent years. Since 1949 improved statistics have been obtained on angling catches, and it is known that at least 75,000 salmon are now taken annually in all the rivers combined. Of these about 45,000 are angled in the rivers of the Gulf of St. Lawrence, 5,000 in rivers around the outer coast of Nova Scotia, 5,000 in Bay of Fundy rivers, 5,000 in Quebec rivers on the north shore of the St. Lawrence, and 15,000 in Newfoundland rivers. Unfortunately it is very difficult to assign a reliable economic value to the sport fishery, where the value of recreation alone accounts for such a large proportion of the total. Judging by the value of comparable sport fisheries in the United States recently estimated by a careful census, our salmon angling is probably worth several million dollars. There is no doubt that the availability of Atlantic salmon for angling in Canadian rivers is a very valuable national asset. This, combined with the commercial fishery, which can be

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expected to be worth about $3 million in normal years, justifies considerable effort to see that the best possible management techniques are employed for this species.

Salmon Life History in Relation to the Fisheries in a Typical River Area

The accompanying figure shows the life history of Atlantic salmon and its relationship to the commercial and sport fisheries in a typical large New Brunswick river system. Over the whole Atlantic coast of Canada, the duration of the fresh water stage varies more than is indicated for this one area.

Spawning

A convenient starting point is the spawning of adults in October and November. Experiments on the Pollett River, N.B., are now indicating that a rather modest number of parents is needed for optimum smolt production If predatory birds, chiefly mergansers, are controlled it is estimated that about 45 pounds of adult females are needed per average mile of stream 10 yards wide, to give the optimum number of about 200 eggs per 100 square yards of bottom. This applies only to streams which commonly have two-year smolts. For rivers like the Miramichi with typically three-year smolts, about 250 eggs per 100 square yards seem to be needed. This allows for normal fishing effort after the adults have entered fresh water, so the numbers of eggs are higher than are actually required to be deposited in the spawning redds. Studies over the past five years indicate that the Miramichi River has been receiving about this level of spawners.

An important point is that a much lower egg deposition can be allowed if mergansers are not controlled, because these predatory birds will drastically reduce the number of parr to give much lower smolt production than would otherwise occur. To allow for the above levels of spawning without predatory bird control would be expected to lead to a waste of adult salmon.

From eggs to smolts

In the Pollett River experiments now in progress, the survival rate from eggs to fry with three "light" spawnings has averaged 6 per cent, while the survival rate from fry to large, pre-smolt, parr has been 80 per cent. Comparable data for "medium" and "heavy" spawnings are not yet available. It is hoped that the results of these studies combined with similar observations on other rivers will shortly give a relationship between smolt production, egg deposition, and numbers of spawning adults.

From smolts to adults

There are inadequate data yet on the rate of survival from descending smolts to the adult stage when the salmon are taken by various fisheries or contribute to the spawning escapement. Some evidence that the survival rate lies between five and ten per cent has come from our smolt marking experiments and from other investigations. For the Miramichi River the estimated total annual smolt production in recent years has averaged about $1\frac{1}{2}$ million. With such a high mortality in the sea, only 75,000 to 100,000 of this output would survive for use by the fisheries or for spawning.

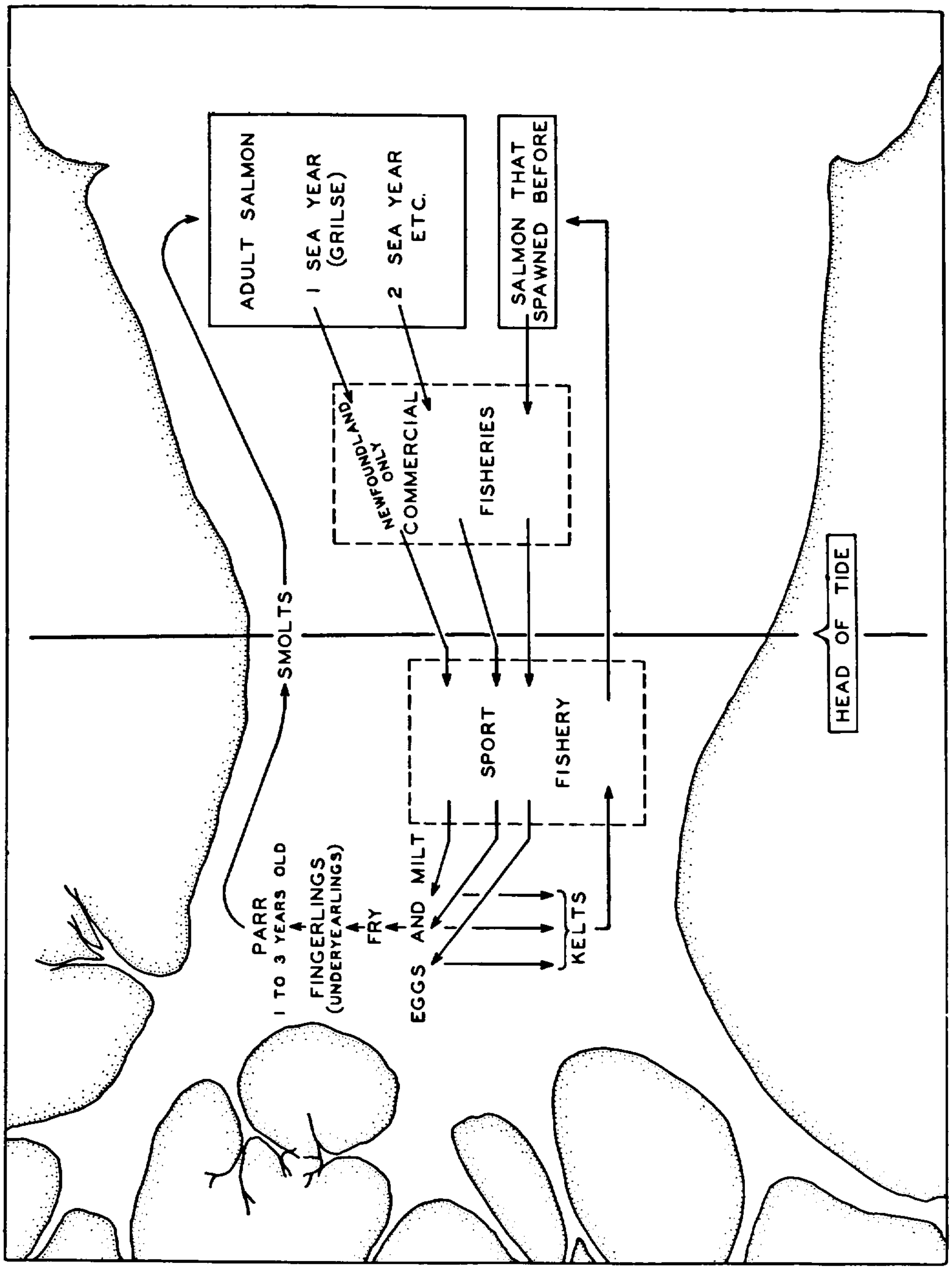

Figure 1.—Life cycle and utilization of Atlantic salmon in New Brunswick, Canada.

Capture by commercial gear

For the whole Canadian coast the gear comprises surface drift-nets operated offshore, inshore fixed trap nets and a few floating gill-nets, while some salmon are taken incidentally in gear set for other species. Traditionally the nets have been set to take adult fish as they apparently move from the feeding areas which are often far away in the sea, towards the native streams to spawn. Reliable information on the capture of adult salmon of known river origin by such gear over a wide area of the coast is now coming from a marking programme involving smolts produced in the Miramichi and Pollett Rivers, N.B., the Port Daniel River, Que., and the Little Codroy River, Nfld. It has been found, for example, that many salmon produced in Maritime streams are taken far away in commercial nets, particularly around the east coast of Newfoundland. Also they may wander into the estuaries of other maritime rivers and be caught there by commercial gear. Of course, many are taken also by the gear set in the estuary of their native river.

There are fishery regulations covering the opening and closing dates of the seasons which are different for different areas of the coast, mesh regulations aimed at protecting small salmon (grilse), weekly close periods to allow fish to escape the nets completely for a couple of days each week, but no quota systems. Most of the catch consists of two-sea-year fish, except around Newfoundland where grilse can still be caught for market in commercial nets. Each year the run of fish into many estuaries is marked by two peaks, one early in the summer and one in the autumn. In some rivers like the Miramichi the late run has by far the most fish, which come in after the commercial season is over. Only early run fish are desired by most commercial fishermen, and at present there is no demand for a fall fishery. As the spawning season approaches, salmon are not considered to be in good condition for the market.

The sport fishery

Upon reaching fresh water areas of the rivers the salmon become available to anglers, who can legally keep both grilse and large salmon. In some rivers, like the Miramichi, grilse comprise about one-half the total angling catch. Other rivers, like those of the east coast of Newfoundland, may provide only grilse angling, while in others large salmon provide the bulk of the angling catch as in some Quebec streams. In New Brunswick alone there is a legal fishery for kelts in the spring. There seems to be no objection to this on biological grounds because very few kelts (5 to 10 per cent) ever turn up again after the first spawning. About 5,000 kelts are taken each spring in the Miramichi River which is now the most popular place for such fishing.

The fishery regulations for angling include opening and closing dates for the season which differ from one area to another depending on the usual time of arrival of the fish, daily and weekly bag limits, and restriction of method to the use of artificial flies when angling for salmon.

Discussion

The primary aim of fishery regulations for Atlantic salmon is to assure an adequate spawning escapement. Obviously most of the existing regulations were put into effect many years ago when requirements for spawning were unknown. Reliable information on this point is now being obtained for the experimental rivers where concentrated work is in progress. It is hoped that the requirements for many streams can be developed from data obtained on a few typical ones. A useful supplement to these studies is the counting of ascending fish through traps installed in many fishways, and annual surveys of spawning activities on a number of rivers now being carried out by the Conservation and Development Service of the Department of Fisheries.

It seems reasonable to aim at providing, through regulation, for the amount of spawn that will give the optimum number of young under average conditions for hatching and survival. An idea of the amount of variation to be expected from year to year in the smolt production of the same river area is provided by data of recent experiments on the Pollett River. On a ten-mile experimental stretch, ample stocking was provided by planting 250,000 fingerlings in five successive years, with predatory birds controlled. The average smolt production from these five plantings was 20,000; the minimum was 14,000, the maximum was 25,000. This variation amounts to about plus or minus 25 per cent of the basic "capacity" of the stretch to produce smolts.

A very important point concerning regulations to insure adequate spawning escapement, is the possibility of early-run or late-run adults tending to produce young salmon that will inherit the tendency to return to fresh water early or late, as adults. If this were the case and if attention were given only to the numbers of young salmon being produced per unit area of stream, the future supply of early-run adult salmon could be inadequate. There is some evidence that such a tendency to return early or late is not generally inherited in Atlantic salmon. Nevertheless, in 1954 the fishery regulations for both commercial and sport fishing were amended to allow more early-run salmon to reach the spawning grounds. It was reasoned that this could do no harm and that it was desirable to be on the safe side until more information could be obtained. This information will start to accumulate in 1957 as the first returns of adult salmon come from an experiment started in 1953. The experiment involves the planting of marked fingerlings of known parentage, in streams which have runs predominantly of the other type as regards time of entry of adults. The time of return of the marked salmon will be compared with the time of return of the native stock.

Most of the fishery regulations for Atlantic salmon have likely been too restrictive in the past, owing to inadequate knowledge. An example of a situation where liberalization of regulations might be desirable is the closing date of the commercial fishing season in the Miramichi River area. Closing the trap-net season on August 31 prevents utilization of most of the total run of salmon here each year, because at least 85 per cent of all the large salmon enter the estuary after September 1. Since 1954, however, abnormal conditions affecting smolt production have been created in the whole Miramichi watershed through extensive spraying of the woodland with DDT against the spruce budworm. The spraying has had such serious effects on parr survival that it is not safe to reduce spawning stocks at this time.

Several years ago when the present research and management programme was being planned it was necessary to assign priorities to a list of projects considered to be worthy of attention in the near future. Almost all the projects have been undertaken except physiological and behaviour studies which would require special facilities and staff. Quite recently it has become apparent that particular attention should be given to the effects of hydro-electric developments, pollution as from mining operations or DDT spraying, deforestation, and other factors associated with industrialization, on the general behaviour and survival of various stages of salmon. New studies along these lines are now being planned. It is quite possible that the information so obtained will be of great importance in any attempts to manage the Atlantic salmon fisheries by regulation or other means a few years hence.

Regulation of the Lobster Fishery

by

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Introduction

Canada's lobster fishery is our most valuable inshore fishery on the Atlantic Coast. In recent years the catch has approximated 50 million pounds with a marketed value of 20 million dollars. Almost 20 thousand fishermen fish about two million traps valued at over five million dollars. In the major producing areas inshore fishermen derive a high proportion of their fisheries income from this one species.

Everyone is agreed that conservation of this valuable resource is of primary importance but just what is conservation and what are its objectives? Conservation has been defined as "Wise Use" and a commonly stated objective is to obtain the maximum sustained yield. In marine fisheries the yield is usually thought of in pounds. With staple foods, sufficient production to maintain national nutritional standards is, of course, of primary importance. The lobster, however, is a luxury item that contributes relatively little to our nutritional welfare. Even if our total production were consumed in Canada the per capita consumption of edible meat would be less than one pound per year. The per capita consumption in North America is less than two ounces a year. With such a product it can be questioned whether the maximum sustained yield is as important an objective as the welfare of the 20,000 primary producers.

Regulations

Over the 100 year history of the lobster fishery numerous regulations have been adopted. These have become so complex in detail as to require a special office consolidation for ready reference. Of these regulations the three most important appear to be those that (a) prohibit the sale of egg-bearing lobsters, (b) establish closed fishing seasons and (c) provide for a minimum legal size. To what extent have these regulations affected the yield from the fishery or the welfare of the fishermen?

Protection of egg-bearing lobsters

Lobsters mature when 7 to 12 inches long and the females spawn every other year. The eggs remain fastened to the abdominal swimmerets until they hatch a year later. Regulations prohibiting the sale of egg-bearing lobsters are in general supported by fishermen, particularly in areas where such lobsters are scarce.

Observations in the southern Gulf of St. Lawrence over the past nine years on the newly-hatched, free-swimming larvae show that the hatch varies as much as 2:1. Survival during the one to two month free-swimming period is, however, much more variable—the numbers surviving to the last free-swimming stage varying as much as

40:1. To date it has not been possible in this area to demonstrate any clear relationship between the number hatched and the number that survive the free-swimming period. In this area lobsters mature early with the result that egg-bearing females and larvae are abundant—apparently many times as abundant as in southern Nova Scotia, an area of late maturity where very few lobsters escape the fishery to become mature. In spite of this great disparity in the abundance of mature lobsters and larvae, the commercial production in the two regions is very similar—about 10,000 pounds per square nautical mile. These observations have failed to provide any factual basis for protecting egg-bearing females. Although the regulation may be of little value in improving the yield or the welfare of the fishermen it seems unlikely that it is actually harmful. The regulation is popular with most fishermen, it affects a relatively small proportion of the catch, and the lobsters released become legal when the eggs hatch.

Closed seasons

Closed seasons were originally introduced in an effort to reduce the fishing intensity and so arrest a steady decline in landings during the early 1900's. Later, adjustments in the seasons were made to aid marketing and to permit fishermen to engage in other fisheries or other seasonal occupations. At present in the Bay of Fundy and southern Nova Scotia the season is open for six to $7\frac{1}{2}$ months but along the remainder of the coast for only two to three months. Studies of tag returns, size compositions, seasonal declines in catch per unit effort, days fished, gear set and hauled show that the rate of exploitation is often higher in the short seasons. The fishery has simply adjusted to the shorter season by employing more men, boats and gear. It seems obvious that closed seasons have failed in their primary objective of improving the sustained yield. They have, however, had numerous secondary effects—some good, some bad.

With short seasons fishermen can turn to other fisheries, farming, lumbering etc., and in some areas it is only by so doing that they are able to subsist. Closed seasons have improved the quality of the lobsters in that less than 20 per cent are caught from July to September when they are soft-shelled and slack meated, difficult to hold and ship and give a poor meat yield. Closed seasons are difficult and costly to enforce and supplementary regulations restricting fishermen, boats and gear to one fishing season a year have been adopted. These supplementary regulations have been seriously questioned on sociological and economic grounds. With short seasons persons who have been gainfully employed elsewhere find it advantageous to engage in the fishery when lobsters are unusually abundant. This effectively reduces the catch of the steady fishermen who find it difficult to see the value of restrictive conservation measures when the accruing benefits are divided among individuals who have not contributed.

With year round fishing over half our lobsters would be landed from July to September and would depress an already low summer market resulting from heavy United States production. One possible solution is a universal closed season from July to September to avoid the period of heavy United States production and to limit the sale of newly-moulted lobsters. With such a season weather and ice conditions would permit from four to nine months' fishing in the various districts. Landings would be concentrated in the early fall.

Size limits

Minimum legal sizes are established with the objective of increasing the sustained yield, either by allowing more animals to mature and so increasing reproduction or by taking advantage of the period where growth is rapid enough to more than offset losses through natural mortality. There is so little evidence of a relationship between the abundance of mature lobsters and commercial production that the prospects of size limits improving the yield through their effect on reproduction do not appear good. There is, however, considerable evidence that sub-legal lobsters grow enough to more than compensate for natural losses. Extensive marking experiments have shown that lobsters near present size limits survive well and as a general rule moult once a year and grow about 50 per cent in weight. In certain warm water areas growth of the smaller catchable lobsters exceeds 100 per cent a year. Size distribution studies show exceptionally high total mortality rates. Extremely high tag returns (general average of 60 per cent) and the rapid seasonal drop in catch per unit effort show that most of the mortality can be ascribed to the very intensive fishery. These observations provide strong support for minimum size limits. There is also the fact that wherever size limits have been observed the commercial catch has improved. On the basis of the available evidence it is concluded that size limits are the most effective means of increasing the yield from the fishery. If this conclusion is substantiated by controlled experiments, work should be extended to determine the best minimum size limits for the major stocks of lobsters.

Economic and sociological effects

There are two market categories for lobsters, the smaller "canners" which are hermetically sealed or processed as chilled meat and the larger "markets" which are sold alive. There is usually a marked price differential with the markets worth considerably more per pound to the fishermen. From the fishermen's point of view the maximum sustained yield should be measured in value rather than weight. There is, of course, the contribution that the actual processing of canner lobsters makes to the communities. Is this contribution great enough to compensate for the lower price to the primary producer?

In the final analysis conservation is action by individuals. It is the individual fisherman who releases undersized or berried lobsters. To be effective, of course, conservation must be practised by all or a large majority of those using the resource. The individual or group of individuals is led to believe and perhaps has a right to believe that he will benefit. In the lobster fishery this is not always the case. In 1947 a group of fishermen at Fourchu, Nova Scotia, agreed to a regulation which required them to release their smaller lobsters to the extent of approximately half their catch. In 1948 they further agreed to limit their traps in the firm belief that they were wasting money in excess effort. The value of the catch increased rapidly to the point where new fishermen were attracted. By 1956 the fleet had increased

80 per cent and the number of traps doubled. The catch per boat has started to decline. At Tignish, Prince Edward Island, fishermen were forced in 1954 to observe an unpopular size limit. Catches have improved and in 1956 the catch per boat was the highest in recent history. Judging from 13 years' records at this port it seems certain that the fleet will increase to the point where the average catch per boat is about the same as previously.

The rather unique features of the lobster fishery—a readily available but limited supply, a heavy demand and high price, and a relatively low capital investment lead to a degree of exploitation and competition that is perhaps unequalled in marine fisheries. Long-term, enthusiastic co-operation in restrictive conservation measures seems unlikely unless fishermen receive more assurance that as individuals they will benefit. Limited licensing is a possible but unpopular solution. Less drastic measures such as increased licence fees, licence cancellation for infraction of regulations, residence requirements and restriction of government loans for lobster boats and gear might ease the situation considerably. Any reduction in boats or gear should increase the net value of the catch.

Possibly our primary objectives in the management of the lobster fishery are (1) discover and apply the minimum size limits that will yield the greatest gross value and (2) reduce the fishing intensity to increase the net value of the catch and give the fishermen who practise conservation greater assurance that they will benefit. The problem involves a complicated interplay of biological, economic and sociological factors and is of sufficient importance to warrant detailed study.

Some Sociological Effects of Quota Control of Fisheries

by

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Recently striking changes have occurred in many of our fisheries. Some of them seem to centre around the management of the fisheries by quota. Most of these changes, when not forced upon us by circumstances, have been economically advantageous. They have, however, strongly affected in one way or another the lives of the people engaged in the fishery. Superficially some of the results do not appear to be improvements. If the well-being of the people is in fact impaired by quota control, it may be appropriate to examine the sociological implications of this tool of management. The following comments point out some of the problems. Some of these may seem to justify investigation by sociologists.

Quota management of fisheries is resorted to in cases where we presumably know how much fish can be removed from a stock without diminishing the contribution of the stock to our economy. It is applied by allowing fishing from an opening date until the amount of the pre-determined quota is caught up. Apparently where we have the required biological information, quotas provide a seemingly logical method of management for maintaining fish stocks at levels where their yield is maximum or otherwise optimum.

Any type of management will have economic and sociological ramifications. Catch quotas are no exceptions. And as in the cases of other means of management economic and sociological effects are inextricably mixed.

My interest in the sociological results of quota regulation was first roused at a public hearing on halibut regulations for the International Fisheries Commission. As background, I might mention that quota regulation of halibut had been followed by a great increase in availability of fish which led to very fast fishing. The good fishing attracted additional fishing efforts. As a result of the high reward for fishing effort, and of the increased effort, the quotas were (and are still) caught up very quickly. The incident involved the protest of a veteran Norwegian skipper. I wish I could accurately reproduce in full his dignified but perturbed statement. Instead I shall have to provide a poor paraphrase—something like this: "They say that the halibut is being conserved and perhaps it is. I don't know. I do know that before the halibut was conserved and I worked on the schooners I used to fish halibut nine months of the year and make a decent living. Now the season is so short a boat can't catch enough fish to provide a year's income. So I have to turn to working on salmon packers and other things that don't suit me."

So much for our Norwegian friend. He said enough to make it clear that he had suffered severe vocational dislocation as a result of management policies imposed to increase the growth of the halibut biomass. For him it was an important matter.

It seems that sociological stresses result from quota regulation because the regulation accentuates competition among fishermen on the grounds. In some cases there are co-operative aspects to operations within fishing fleets so that for any situation of fish density and distribution there may be an optimum amount of fishing effort. However, fishermen are always in competition with each other. The fish caught and boated by one fisherman are no longer available to his fellows. However, under quota regulation competitive effects are reinforced. The fish landed by one fisherman reduce the chances of his competitors (and of himself, too, for that matter) of catching the fish which remain in the water. The situation could be approximated under some circumstances where fishermen were in competition for markets, but such occurrences are not common in stabilized fisheries.

The competition leads to an hectic scramble for fish, inordinately long hard working days, perhaps taking unwise chances, near financial disaster to the individual from breakdowns in gear and equipment or from temporary illness. To me these things do not seem good from the point of view of the fishermen involved.

It is more difficult to assess the effects of concentrated production on the economics of fishing. While it seems likely that much uneconomic expense is incurred for competition, there must be real advantage in the mechanization that is encouraged.

The situation for packers and secondary handlers of fish and their shore crews is also difficult to assess. To do so one must weigh the advantages of concentrated predictable operating seasons and their evident economies and rewards against the disadvantages of general rush, crowded facilities, and overworked crews. The effects of congestion and delay on the quality of the fish placed before the consumer might also be considered as a sociological result.

The main sociological effect of quotas would appear to be the discouragement of specialized full time fishermen or of fishermen who specialize in one particular fishery. The fisherman is forced into other fisheries or other occupations in order to maintain his position in society. To some very worthy people this is a most unwelcome development. Whether it is actually bad or not would appear to be a problem for the sociologists. If bad, it must be decided whether to endure the shortcomings so as to enjoy the advantages of a tidy method of management, or to modify the management method to adapt it to human needs.

Another and related effect arises from the very productive fishing each year at the beginning of the quota period. This encourages many fishermen to take part in harvesting the resource. Some of them are part time fishermen or men who are only moderately well qualified for the work. Their participation adds money and variety to their own lives. The fish they catch, however, are taken away from the potential landings of professional fishermen.

Some of the foregoing remarks may suggest basic antagonism to quotas as a method of management. There is no such antagonism. Management of a fishery is complicated and none of the applicable tools is perfect. I recognize that quotas also have shortcomings.

We must realize also that quota control shows strongly features which are present in some other devices of management. For example, seasons, whether imposed by regulation or by the availability of the fish, when the size of the exploitable stock is limited, may have similar effects.

In closing I might add that trial has shown that the headlong exploitation stimulated by quotas even has some disadvantages from the point of view of maintaining the fish stock. The halibut fishery—opening intensively at the beginning of the growing season for the fish—derives little advantage from the growth of the current year. In addition intensive fishing for halibut takes the quota before all parts of the stock are fully available and thus failed to make complete use of the resource until special adjustments were invoked. To me it seems that these biological defects in the quota system resemble what I regard as the sociological shortcomings. Each defect arises from ignoring the complexities of its subject matter.

Some Economic Aspects of Control by Quota

by

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The optimal allocation of resources in the fishing industry has been discussed in several recent papers[1] and an international gathering[2] to discuss the subject has also taken place. In the following notes, an attempt is made to present the gist of these discussions with particular reference to catch quotas as an instrument of fishery management policy.

In view of the interests of the present meeting, this question is approached here in its relationship to fishery conservation. Conservation may be defined, in economic terms, as postponement of the use of a resource. Its rationale is similar to that of the investment of capital generally: postponement of utilization is expected to result in a larger supply being available at a future time.

As applied to the fisheries, it follows that the optimum degree of utilization must be conceived of as a time-function of some kind, i.e. a catch per unit of time. Achievement of this optimum involves a synthesis or reconciliation of the dynamics of fish populations, the rate of withdrawal from the stock (by fishing) and the time-preference schedule of the community concerned (or the rate of interest on invested capital). How may such a complex objective be realized?

Let us consider first of all the nature of the principal instrument for its realization, viz. the primary fishing enterprise. That is, the unit of ownership and management—the two functions are normally combined in the same person or group—operating fishing craft with the accompanying gear and making the first sale of the fish taken. These units range in size from single own-account fishermen to relatively large firms (or divisions of firms) operating fleets of several vessels.

Generalization, concerning such things as the shape of supply curves and the variability of labour and capital factors for primary fishing enterprises, is seldom possible—even within a single country, and especially on an international basis. At least one characteristic is exceedingly persistent and widespread, however. That is the sharing, or "lay", system of remuneration. Returns to both capital and labour factors are based on prearranged shares in proceeds from the sale of the catch. There is no return to the resource factor, i.e. rent. We'll return to this in a moment.

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[1]*Crutchfield, James, A., "Common Property Resources and Factor Allocation", The Canadian Journal of Economics and Political Science, vol. 22, no. 3.*

Gordon, H. Scott, "An Economic Approach to the Optimum Utilization of Fishery Resources", The Journal of the Fisheries Research Board of Canada, vol. 10, no. 7; "The Economic Theory of a Common-Property Resource: the Fishery", The Journal of Political Economy, vol. LXII, no. 2.

Scott, Anthony, "The Fishery: the Objectives of Sole Ownership", ibid., vol. LXIII, no. 2.

[2]*The Round Table on Fisheries, under the sponsorship of the International Economic Association, convened at Rome, Italy, Sept. 13-18, 1956.*

The ubiquity of the share system is related, apparently, to the fact that it permits the peculiar risks incurred in fishing operations being shifted or spread to some extent. For that reason, the system is thought in some quarters to encourage investment—in expansion or innovation, for example. On the other hand, because of its comparative rigidity, it is sometimes held to have the opposite effect. On the whole, its significance in this respect does not seem to be great—at least in the Canadian milieu, where renegotiation of shares (to facilitate adaptation to technological change) may be accomplished usually without difficulty.

Of very great significance, however, is the point we touched upon a moment ago: the absence of a rental return in the fishing industry. This arises out of the fact that fisheries, in contrast with most other sectors of the economy, are exploited generally under conditions of tenure which make the resource common property. Being unowned—indeed impossible of ownership, probably, in most cases—the resource cannot yield a rent. This may be explained as follows.

Let us suppose that, in the case of a particular fishery, supplies have been drawn from the more accessible and/or richer grounds at relatively constant costs. At some point, as the demand for the products of the fishery grows, operations will be intensified beyond the constant-cost level, or extended to more distant and/or less rich grounds, or both—resulting in higher costs at either the intensive or extensive margins. Under these conditions, if, as in the case of land resources, for example, the grounds were possible of ownership, an income increment (known as rent) would accrue to the owners of the more accessible and richer ones.

Now, since total cost tends to equal total revenue (by definition, as it were), the absence of rent (explicit or implicit) results in a gap that may be filled by an increase in capital costs. In short, the industry probably has a "built in" tendency toward over-capitalization.[3] Over-capitalization represents a misallocation or mal-allocation of production factors. The effect is to dissipate, in excess capacity[4] (numbers of fishing craft with their complement, etc.), any increase in aggregate returns to the industry.

What are the implications of all this for control policy? The above outline probably simplifies drastically—not to say vulgarizes—events in the real world. Nevertheless, insofar as it does approximate reality, it has very important implications for our problem.

Assuming, as we may in normal circumstances, a continuous secular growth in demand, the imposition of restrictions on the catch, i.e. a quota or the like, designed to maintain the fish stocks at or restore them to a predetermined level, will be followed by a rise in price and consequently in aggregate returns. The gap mentioned earlier will be widened and the tendency toward development of excess capacity will be strengthened. In other words, the quota will be filled with successively larger numbers of vessels, each taking fewer fish in a shorter period of time.

The effect is not only to waste resources in over-capacity in the case of the fishery under quota. The development of a fleet capable of participation in other fisheries

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[3]*This applies to the industry as a whole and, as shown later, such a tendency is compatible with under-capitalization in the units of the industry, i.e. in individual fishing enterprises.*

[4]*The stand-by capacity required to provide for variation in raw-material supply and the flow of distribution is, of course, a different matter altogether.*

during the "off-season" will be fostered. This tends to generalize over-capacity by forcing enterprises in the latter fisheries to diversify operations and equipment also.[5]

The impairment of efficiency, from the economic and social point of view, extends beyond the primary fishing industry and into the secondary and tertiary (or trade) phases of the industry. The shortening of the operating season increases overhead costs (per unit of output) in handling and processing. In addition to higher direct costs, the prolonged storage of fish products—required to adjust concentration in the supply period to the comparatively regular flow of distribution—results often in serious loss of quality.

The extent to which these tendencies are realized in practice may be illustrated from the recent history of the Pacific halibut fishery—perhaps the outstanding example of a fishery under quota control. During the past 25 years or so, while the catch of Pacific halibut increased by about 20-25 per cent, the number of vessels engaged in the fishery increased by some 120-125 per cent. The figures understate the increase in fishing intensity, since no allowance is made for the growth in productivity resulting from improvements in design, construction, power and equipment with electronic fish-finding and communication devices.

At the same time, the fishing season has been reduced to less than ten per cent of its original length on one of the principal grounds and to about twenty per cent on another. As a concomitant of this, over eighty per cent of the catch is now frozen as compared with about forty-five per cent at the beginning of the period mentioned.[6]

It may be said too that, according to estimate, about one-third of the Pacific halibut fleet is idle between seasons. Some proportion of the vessels that do obtain employment, doubtless, would be under-utilized in operations for which they are imperfectly fitted.

A quota or similar limitation on the catch, below the level that would be forthcoming on a free market, must also have an important influence on price formation at waterfront or dockside markets—through its effect on the supply function of the primary producers. In the short run at least, supply will be inelastic as to price. A reduction in price will tend to result in a longer season, rather than a shorter supply—assuming our earlier analysis to have some validity. In fact, the supply function would become elastic only if prices fell to the point where the attraction of occupational alternatives reduced fleet capacity below the level at which the quota could be filled by the remaining vessels fishing on a full-time basis.

The further implications of this kind of supply situation would depend on the organization or structure of the dockside markets. In perfectly competitive markets, buyers' margins would be minimized and the fullest development of over-capacity in primary production would be encouraged. Completely monopsonistic markets[7] would lead to opposite results: excessive costs (due to the existence of over-capacity) would be minimized, but at the expense of equitable distribution of income. The actual position, of course, lies somewhere between these extremes.

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[5]*Under certain conditions, of course, overall efficiency may best be served by the development of flexibility in fleet operations—as, for example, when seasonality or relative price changes make some mobility among different fisheries desirable—but that does not affect the principle here.*

[6]*Technological progress in fish processing and marketing has contributed to this development, of course.*

[7]*That is, markets dominated by a single buyer.*

Enough has been said to indicate that quota control may involve substantial diseconomies, both internal and external, for the fishing industry. Can anything be done about it? It is probable that a program restricting the catch to a level consistent with, say, maximum sustainable physical yield would not deviate seriously from the social optimum if inputs could also be controlled. Such control would mean restriction on entry to the fishery or fisheries involved.

To accomplish this, since, in most cases, private ownership of fishery resources is out of the question, it has been suggested that the state assume a property right in these resources and collect a rental for the privilege of access to their use. The most efficient fishing enterprises would be able to offer the most rent (in the form of a share of the catch or of an absolute sum of money) and the least efficient enterprises would be eliminated from the industry.

With perfect competition, all the rent would accrue to the state and efficiency would be maximized. Under less perfect conditions, the number of privileges would have to be limited more arbitrarily on the basis of some calculation of the (fully-utilized) capacity needed to fill the quota within the period in which fishing operations normally are possible.

In any event, competitive bidding for fishing privileges would be necessary at intervals to facilitate the movement of capital and labour into and out of the industry. A market in such privileges might arise, under certain conditions, as enterprises changed hands or engaged in different combinations of activity. If there were no need periodically to change the number of privileges, this market could be permitted to allocate them.

As to what should be done with the rents collected, these might accrue to the state as landlord, or, at the outset, they might be used to resettle or compensate displaced fishermen, or, later on, they might be used for purposes like research and protection for the controlled fishery or fisheries. Redistribution to the privileged fishermen, another possibility, would probably result in their being discounted in the application for privileges.

Despite the advantages of this scheme, there are formidable obstacles in the way of its implementation. We need not be too greatly concerned, perhaps, with the strengthening of the fishermen's bargaining power vis-a-vis the fish buyers. Nor need consumers be adversely affected, if, as seems likely, the ability of a producers' monopoly to raise fish prices is limited by cross-elasticities of demand or substitutability among the group of animal protein food products. Producers excluded from the fishery or fisheries, and thus forced to liquidate investments in unfavourable circumstances, could be compensated as already suggested.

Insuperable difficulties, however, might arise in the case of international fisheries. Since total production costs include the "opportunity" incomes of fishermen, countries with a low level of living would tend to pursue a more intensive fishery than others to achieve an optimum degree of exploitation of a given resource (fish stock)—the optimum being defined as the maximum net economic yield or, in simplified terms, as the maximum difference between total production costs and total value of catch. There would be no one unique optimum level of fishing intensity, therefore, for a resource that is subject to international exploitation—there might be several. If so, agreement among the countries concerned to a system of control like the one described here would probably be precluded.

CORRECTION

In Issue 21 of "The Canadian Fish Culturist," published December, 1957, the following corrections should be noted:

Under "Literature Cited"—page 17, line 2, *for* "000-000" *read* "19-23", line 4, *for* "000-000" *read* "1-6"; page 23, line 2, *for* "Issue VI, pp. 00-00" *read* "Issue 21, pp. 7-17", line 4, *for* "Issue VI, pp. 00-00" *read* "Issue 21, pp. 1-6", line 6, *for* "No. 62, pp. 17-2" *read* "No. 62, pp. 17-23"; page 31, line 7, *for* "No. VI, pp. 00-00" *read* "No. 21, pp. 7-17", lines 8-9, *for* "No. VI, pp. 000-000" *read* "No. 21, pp. 19-23".

On page 20, Table I, headings for the last two columns should read:

Survival from	
Under yearlings	Eggs
100%	6%
54%	4%
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ISSUE TWENTY-THREE
DECEMBER - 1958

THE CANADIAN FISH CULTURIST

Published at Ottawa by
The Department of Fisheries of Canada

ISSUE TWENTY-THREE
DECEMBER - 1958

The Canadian Fish Culturist

Published at Ottawa by
The Department of Fisheries of Canada

THE QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1958

59417-6—1

CONTENTS

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

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

Published under Authority

of

HON. J. ANGUS MACLEAN, M.P.,

Minister of Fisheries

Observations on the Spawning of Lake Trout, *Salvelinus Namaycush*, and the Post-spawning Movement of Adult Trout in Lake Simcoe

by

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Introduction

The material presented in this paper comprises a summary of observations made on spawning populations of lake trout in Lake Simcoe between 1951 and 1957. The majority of the data was collected at the extensive Glenrest Beach shoals at the north end of the lake where submarine trap-nets were set each autumn by the Fish and Wildlife Division of the Ontario Department of Lands and Forests for the collection of lake trout eggs as a part of Ontario's fish culture programme. Records of the post-spawning movements of parent fish from the Glenrest Beach shoals were obtained by the recovery of tagged fish by anglers.

Description of Lake Simcoe

Lake Simcoe, the fourth largest inland lake of Ontario, has an area of 280 square miles but a relatively short and generally exposed shoreline of only 144 miles, including that of the few islands. The average depth has been calculated at 56 feet with some six per cent of the lake over 90 feet deep (Rawson, 1930). The main body of the lake is oval in shape with a long deep bay, Kempfenfeldt Bay, on the west and a shallow bay, Cook's Bay, on the south. The shoreline of the lake is about 55 per cent stony, 35 per cent sandy, and the remaining 10 per cent capable of supporting vegetation in rich muddy bays. On account of the wide variety of habitat conditions present, Lake Simcoe is ideally suited for the production of both warm water and cold water fishes which enables an active sport fishery at all seasons of the year (McCrimmon, 1956). Habitat conditions are very favourable for the reproduction, growth, and harvest of lake trout.

Spawning Grounds

Lake Simcoe provides extensive shoal areas for the spawning of lake trout. The trout spawn on shoals located along the shores of the mainland and few islands, also on several submerged mid-lake shoals. These shoals are covered characteristically by wave-washed gravel, rubble, and stones, and are quite free of silt. Some 50 per cent of the shoreline of the lake is suitable for trout spawning and at some locations the stony beaches extend off-shore in excess of 500 feet before reaching water depths of 20 feet. Several submerged shoals are over a mile in length. Spawning generally takes place in less than 20 feet of water, occurring frequently at depths of two to ten feet.

Pre-Spawning Movement of Adult Trout

The lake trout appeared at the spawning shoals of Lake Simcoe early in October, the actual dates varying between October 4 and October 9 in the years from 1951 to 1956. The autumn migration of the trout from the depths of the lake was, of course, coincident with dropping surface water temperatures and the fall turnover. During the years of study, surface water temperatures were between 50° and 57°F. at the time of arrival of the lake trout. The arrival of the trout on the spawning shoals each year followed one or more days of strong winds, averaging over 10 m.p.h. in velocity for a 24-hour period and with gusts in excess of 15 m.p.h. These statistics support the observations of local fishermen that strong winds are necessary before the trout come to the shoals.

A summary of weather conditions on the day previous to the evening when trout were first observed on the shoals is given in Table I.

Table I

Summary of Weather Conditions on First Date of Appearance of Lake Trout on the Shoals

Year	Surface Water Temp. Deg. F.	Air Temp. Deg. F.		Wind Conditions	M.P.H.		Hours of Sun-light	Synopsis
		Min.	Max.		Av.	Max. (1 hr.)		
1951	52	44	50	Strong	20	27SW	0.0	Overcast, drizzle rain-showers
1952	50	45	55	Mod.	11	20SW	2.5	Overcast, with clear intervals
1953	54	54	75	Mod.	15	19N	2.9	Generally overcast, rain-showers
1954	54	32	50	Mod.	11	23NW	3.2	Overcast by 10 a.m. rain
1955	57	57	61	Strong	19	25E	0.0	Overcast and rain
1956	57	41	55	Mod.	12	26NW	8.5	Cloudy, clearing by 9 a.m.

Activity of Trout on Spawning Shoals

The time during which the adult lake trout are concentrated on the spawning shoals can be divided conveniently into two periods: *the pre-spawning interval* when the trout frequent the shoals but are not yet ready to spawn, and the *spawning period* when the eggs are laid and fertilized.

Chronological data on the movements of trout to the shoals and the subsequent spawning periods are given in Table II.

Table II

Observations on the Autumn Movement and Spawning of the Lake Trout

Year	Night of Arrival of Trout at Shoals	Night of First Known Spawning	Peak Spawning Period	Night of Last Known Spawning	Duration of Spawning Period
1951	Oct. 8	Oct. 17	Oct. 21-25	Oct. 29	12 days
1952	Oct. 5	Oct. 15	Oct. 17-19	Oct. 24	9 days
1953	Oct. 6	Oct. 16	Oct. 19-21	Oct. 25	9 days
1954	Oct. 6	Oct. 21	Oct. 25-28	Nov. 1	9 days
1955	Oct. 5	Oct. 24	Oct. 27-30	Nov. 2	10 days
1956	Oct. 4	Oct. 14	Oct. 22-27	Oct. 29	16 days

(1) *Pre-Spawning Interval*

The adult lake trout frequented the spawning shoals of the lake for a variable length of time each year before actual spawning began. This period between the advent to the spawning shoals and the initiation of spawning each year varied from a minimum of nine days in 1951 to a maximum of 19 days in 1955. A summary of weather conditions which occurred during the pre-spawning interval is tabulated in Table III.

Table III

Summary of Weather Conditions between the Arrival of Trout on Shoals and Initiation of Spawning

Part (*a*)

Year	Duration of Interval	Av. Water Temp. Deg. F. at Surface	Water Temp. Total Degrees Below 60°F.	Average Mean Air Temperature Deg. F.
1951	9 days	53 (50-60)	61	51 (38-72) normal
1952	10 days	52 (48-56)	85	48 (32-66) below normal
1953	10 days	55 (52-61)	50	50 (30-69) below normal
1954	15 days	56 (51-58)	75	54 (28-74) above normal
1955	19 days	55 (50-66)	85	62 (30-75) above normal
1954	10 days	54 (54-57)	43	50 (31-72) below normal

Part (*b*) Table III.—*Continued*

Year	Total Hours of Sunlight	Wind Conditions		Synopsis
		Av. Daily (m.p.h.)	% of Days with Max. Vel. Greater Than 10 m.p.h.	
1951	60.6	7.4	13	Generally clear, no rain
1952	61.5	8.1	0	Generally clear, rain only last 2 days
1953	64.8	8.6	10	Generally clear, rain only on Oct. 11th
1954	64.8	12.7	50	50% clear, 50% overcast, rain on 6 days in mid-period
1955	60.8	9.9	62	40% clear, balance rain
1956	61.6	10.7	60	Generally clear, rain only on Oct. 7th and 9th

A comparison of a number of measurable weather conditions (*see* Tables III and IV) occurring during the pre-spawning interval which may have influenced the length of the interval suggested a correlation only with the total hours of sunlight accumulated after the arrival of the trout on the shoals. In each year approximately 60-65 hours of sunlight had occurred at the time of first spawning. While it is recognized that spawning began each year with water temperatures between 52° and 57°F., temperatures in this range did not precipitate spawning. In five of the six years between 1951 and 1956, water temperatures had dropped to 55°F. or less by October 9 but spawning did not begin until some days later when some 60 hours of sunlight had been accumulated. No correlation was apparent between the duration of the pre-spawning interval and other limnological, meteorological, or astronomical factors studied. The significance of the apparent correlation between accumulated sunlight following the arrival of the trout on the shoals and the initiation of spawning, which may be only a coincidence, would seem worthy of further investigation.

(2) *The Spawning Period*

A considerable variation has been observed in the date of first spawning during the years of study, a maximum difference of 10 days being noted between the start of spawning in 1955 and 1956.

Table IV

Summary of Weather Conditions on the First Day of Spawning.

Year	Night of First Known Spawning October	Surface Water Temperature	Wind Conditions During Day	Duration of Sunlight Hours	Phase of Moon
1951	17th	53°F	light (6.3NE)	6.4	past full
1952	15th	52°F	light (8.2SW)	1.0	none
1953	16th	56°F	light (5.4NW)	9.0	past I Q.
1954	21st	52°F	light (7.5NW)	9.7	third Q.
1955	24th	52°F	strong (19SW)	0.5	past I Q.
1956	14th	54°F	light (5.9SW)	7.4	past I Q.

Reference to Table IV reveals no uniformity in weather conditions at the initiation of the spawning period other than a water temperature of 52° to 56°F. Winds were generally light in contrast to the strong winds that marked the arrival of the trout on the spawning beds although heavy winds occurred during the first day of spawning in 1955. Sunlight varied from a maximum in excess of nine hours to overcast skies. Rain occurred on two occasions. As noted above in the text, it is possible that the extent of accumulated sunlight during the pre-spawning interval may directly or indirectly influence the time of spawning.

The spawning period extended over a period varying from nine to 16 days between 1951 and 1956. A summary of average weather conditions which prevailed during each of the spawning periods is given in Table V.

Table V

Summary of Weather Conditions During the Lake Trout Spawning Period

Year	Duration in Days	Water Temperature		Air Temp. Deg. F.	Hours of Sunlight
		Average Deg. F.	Day Degrees Below 60°F.		
1951	12	59	70	54	28
1952	9	49	58	44	64
1953	9	55	30	57	47
1954	9	52	56	48	57
1955	10	49	97	48	29
1956	16	52	119	55	84

Observations on the spawning activity of the lake trout revealed that maximum activity was usually reached within four days after spawning began and continued at a high level for the next three to five days, by which time the majority of trout were spawned out. The spawning activity then decreased abruptly and there was an exodus of trout from the spawning areas within the next three or four days.

An analysis of environmental factors which might be expected to affect spawning activity has shown no definite correlation of any factor other than wind. Local fishermen state that heavy onshore winds and rough water generally result in a short spawning season whereas calm weather allows spawning over a more prolonged period. Observations made on the spawning runs at Glenrest beach indicated that strong onshore winds hastened the peak in spawning activity once the fish had begun to spawn and this shortened the overall spawning period. A comparison of the more-or-less normal spawning periods of the years between 1951 and 1955 with the extended spawning period of 1956 shows a relationship between onshore winds and spawning activity.

In the years from 1951 to 1955, onshore winds followed closely after the initiation of spawning and peak spawning activity occurred within two to four days. In contrast, during the extended spawning season of 1956 there were no onshore winds until over a week after spawning was first noted and spawning activity remained at a low level. Spawning activity increased rapidly in 1956, eight days after spawning had begun with the arrival of moderate southerly onshore winds which developed into strong winds for the remainder of the peak spawning period.

Species of Fish Frequenting Lake Trout Spawning Shoals

The captures of fish made by two 15-foot submarine trap-nets on the Glenrest beach spawning shoals during October for the collection of lake trout eggs are recorded in Table VI. The kinds and numbers of fish frequenting the shoals are apparent in this Table. Between 1951 and 1956, some 3,547,000 fertilized lake trout eggs were collected for culture.

Table VI

October Capture of Fish by Two Submarine Trap-nets Set at the Glenrest Beach Spawning Shoal between 1951 and 1956.

Duration of Netting		Number of Fish Captured												
Year	Operation	Lake Trout	Whitefish	Pickerel	Maskinonge	Catfish Family	Rainbow	Pike	Smallm. and largem. Bass	Carp	Suckers	Burbot	Cisco	Perch
1951	Oct. 3 to Oct. 30	1341	2004	435	0	232	2	23	63	8	193	20	0	1
1952	Oct. 7 to Oct. 25	1218	2987	126	0	952	0	40	10	11	522	86	0	0
1953	Oct. 5 to Oct. 23	835	425	1368	0	735	0	33	50	11	228	3	4	0
1954	Oct. 5 to Oct. 30	1089	4130	352	1	1551	1	16	23	11	710	16	2	0
1955	Oct. 3 to Nov. 2	1135	7694	238	0	674	0	26	206	2	465	68	0	0
1956	Oct. 5 to Oct. 30	445	10588	2535	0	269	0	22	65	4	531	48	0	17
Total......		6063	27828	5054	1	4413	3	160	417	47	2649	241	6	18

Post-Spawning Movement of Adult Lake Trout

A total of 500 lake trout were tagged from captures of 3,059 trout made by submarine trap nets set on the Glenrest Beach spawning shoals at the north end of the lake during the early part of October in the years 1953, 1954, and 1955.

The trout were tagged with coloured plastic tags attached at the base of the dorsal fin by nylon thread. Most records of the recovery of tagged fish were provided voluntarily by anglers.

The purpose of the study was to follow the movements and distribution of adult lake trout after leaving the spawning beds in order to determine firstly, if the spawning population was a local one restricted to a segment of the lake and, secondly, if there was any evidence of a homing behaviour among the trout. A summary of the recovery of tagged trout is given in Table VII. The locations of recoveries are shown in Figure 1.

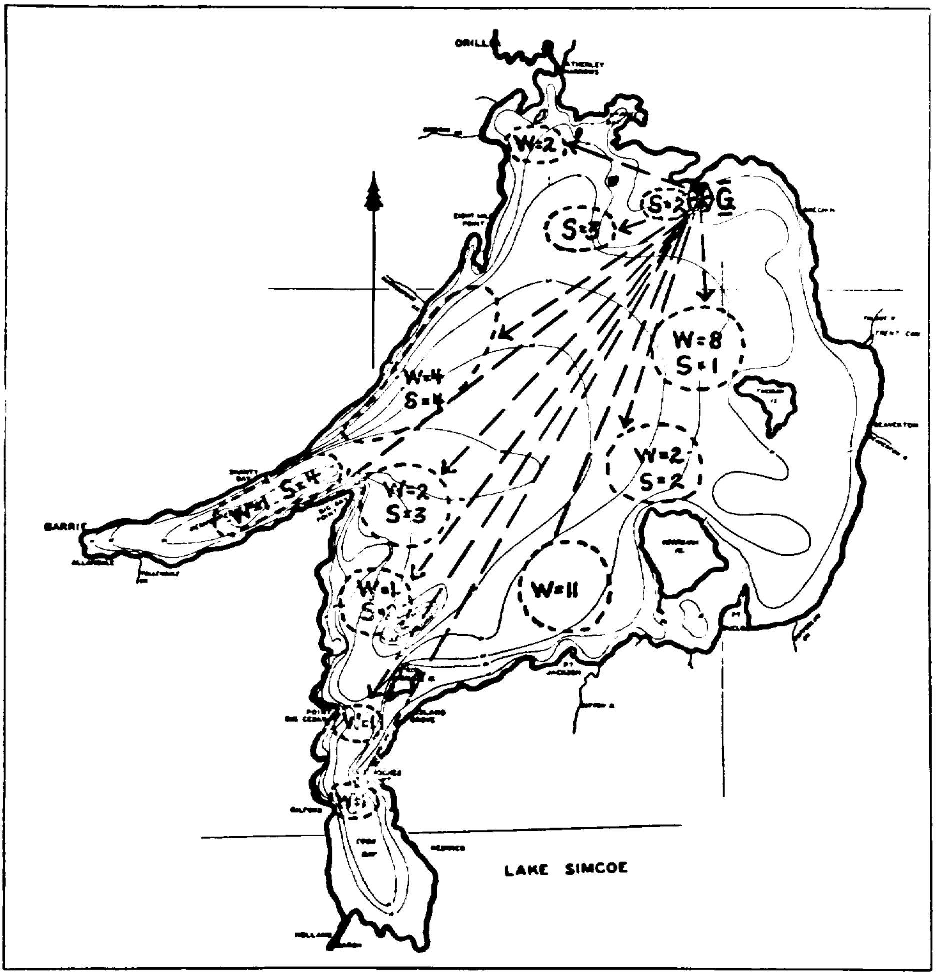

Figure 1.—Recoveries of tagged lake trout in Lake Simcoe, G = Location of tagging, S = Summer recoveries, W = Winter recoveries.

Table VII

Summary of Recovery Records for Adult Lake Trout Tagged on Glenrest Beach Spawning Grounds.

Year of Tagging	Time of Recovery	Number of Trout Recovered	Maximum Lineal Distance Travelled	Percentage Recovery
1953	Winter 1953-54	8	8.3 mi.	
	Summer 1954	7	10.1	
(150 fish tagged)	Winter 1954-55	2	12.8	
	Summer 1955	3	9.0	
	Winter 1955-56	7	11.2	
	Summer 1956	2	8.5	
	Winter 1956-57	1	5.3	
	Total	30		20.0
1954	Winter 1954-55	2	8.2	
	Summer 1955	4	10.5	
(200 fish tagged)	Winter 1955-56	1	8.2	
	Summer 1956	0	—	
	Winter 1956-57	5	9.8	
	Total	12		6.0
1955	Winter 1955-56	6	8.0	
	Summer 1956	3	11.3	
(150 fish tagged)	Winter 1956-57	2	3.8	
	Total	11		7.3
	Grand Total	53	12.8	10.6

A study of the recapture records shows (1) that 10.6 per cent of the 500 lake trout tagged between 1953 and 1955 had been recovered by March 1, 1957. Additional recoveries are anticipated. A comparatively high return of 20.0 per cent resulted from the 1953 tagging, a low figure of 6.0 per cent from the 1954 tagging, and a return to date of 7.3 per cent for the 1955 tagging project. Over 63 per cent of the recoveries were made by winter anglers, 37 per cent by summer anglers, and the remainder by trap nets set at Glenrest Beach.

(2) That those trout which spawned at the Glenrest Beach shoals became widely distributed in Lake Simcoe at other seasons of the year and occupied all those deep basins of the lake where trout normally congregate. The greatest distance recorded between the point of release and that of recapture was nearly 13 lineal miles. As the lake trout are limited to several deep-water areas during the heat of summer and recaptures of tagged trout occurred at each of these locations, one may conclude that there was a mixing of trout from all spawning areas of the lake during the summer stagnation period at least.

(3) That there was no evidence of a homing behaviour to the spawning beds among the lake trout, only two of the tagged fish having re-appeared in the trap nets set on the Glenrest Beach shoals although nearly 2,700 lake trout were handled during the 1954, 1955 and 1956 spawning seasons. The homing behaviour recorded by several authors (Martin 1957) may be influenced in Lake Simcoe by the unusually great expanse of suitable spawning beds and the similar character of the various shoals.

Summary

Observations were made on the spawning and movement of adult lake trout between 1951 and 1957 in Lake Simcoe, a lake ideally suited for the production of this species and its harvest by anglers.

The adult lake trout approached the spawning shoals during early October in each of the study years when surface water temperatures had dropped to between 52°F. and 57°F. Strong onshore winds occurred immediately before the arrival of the trout and would appear necessary to bring the trout to the shoals.

The lake trout frequented the shoals for a pre-spawning interval between nine and 19 days before actual spawning began. A relationship observed between the duration of this period and the extent of accumulated sunlight would seem worthy of further study.

The spawning period varied from nine to 16 days. Maximum spawning activity was reached within four days (except in 1956), continued at a high level for from three to five days, then decreased rapidly with an exodus of trout from the shoals within the next three or four days. Strong onshore winds appeared to hasten the peak in spawning activity and thus shorten the overall spawning period.

Tagged lake trout from a specific spawning shoal became widely distributed in the lake at other seasons of the year, the recovery of over 10 per cent of these trout representing a mixing of trout from all spawning areas of the lake at least during the summer stagnation period. There was no evidence of a homing behaviour among the adult lake trout in Lake Simcoe.

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The Survival of Yearling Lake Trout Planted in South Bay, Lake Huron*

by

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Introduction

Shortly after the Fisheries Laboratory had been established on South Bay, an inlet into Manitoulin Island which lies in northern Lake Huron, it became evident that there had been no substantial lake trout spawning there after 1944 or 1945. The reason for this lack of adult lake trout was not immediately apparent but subsequently it has appeared certain that at least the final reduction and the continued absence of adult trout have been due to predation by the sea lamprey, *Petromyzon marinus*. Because of the lack of native spawning stock, a programme of experimental planting of marked yearling lake trout was begun in 1949 and plantings were made each year thereafter, except for 1950, ending in 1955. In addition, a spring planting of unmarked fry was made in 1955. The details of these plantings are given in Table I.

The main purpose of these plantings was simply to determine as accurately as possible the degree to which such fish would survive to catchable size and to compare their growth rate and behaviour with data already available from native South Bay lake trout. However, with the continued predations of the sea lamprey, the plantings have also enabled us to extend our study of the effect of the lamprey on the lake trout beyond the period when the natural population of this species had disappeared. It is hoped now, in particular, to gather data which may be of value in predicting the success of any future efforts to rehabilitate the lake trout in the upper lakes when the current sea lamprey control programme shows promise of success.

Planting Procedure

The stocks planted were from Lake Superior except for one year when some Lake Simcoe fish were included. They were reared to the end of the second summer in various Provincial Hatcheries. (*See* Table I.) A few days before planting the fish were moved to the Sandfield rearing station about ten miles from the South Bay laboratory.

*Presented at the 10th meeting of the Canadian Committee for Freshwater Fisheries Research, Ottawa, January 4, 1957.

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It is felt that the recovery period thus allowed, after a long trip either by truck or by air, is a valuable precaution against planting them in an overfatigued state with lessened chance for survival (Black 1956). They were then moved in small loads to the laboratory and placed in three-foot square hatchery tanks aboard the boat from which they were to be planted. The fish were planted over broken rock along the shore of the upper basin of the bay in 10 to 20 feet of water. The areas chosen for planting were the same areas where native lake trout were known to have spawned. The fish were distributed evenly along the shoreline by tossing them overboard from the slowly moving boat by means of a scap net. Only from three to five fish per netful were handled, thus allowing the planter to keep an accurate count. Distribution was at the rate of approximately 2,000 fish per mile of shoreline. The plantings were delayed until surface temperatures were 55°F. (12.8°C.) or lower. The plant of unmarked advanced fry made in May of 1955 was air-dropped in the manner commonly used in stocking inaccessible lakes.

Some weeks prior to planting, all yearlings were marked by removing the adipose fin with a razor blade. The same mark was used on every plant, reliance being placed on scale reading to separate the groups when captured.

Approximately 1,400 planted fish, so recognized by the absence of their adipose fins, have been recovered to date. Along with these, 185 other lake trout have been taken for which the lack of an adipose has not been recorded or for which its presence has been specifically noted. The fish thus recognized as unmarked have been consistently about 10 per cent of the total sample from each year class for which plantings were made, except for the hatch of 1951. Samples from that year class have contained 14 per cent. The fall of 1950 was the only one during the period when adult trout were noted on the spawning beds. It has been estimated (Fry 1953) that egg deposition in that fall was of the order of 50,000 to 120,000 eggs. The increased incidence of unmarked fish from the 1951 hatch, although not statistically significant, is possibly, therefore, to be ascribed to this small spawning. It would appear then that it can safely be presumed that the majority of the unmarked lake trout that have been taken in South Bay in late years are planted fish that were improperly clipped or for which the clips were not recognized when they were handled after recapture. A summary of the numbers of lake trout taken in South Bay classified by marking and year class is given in Table II.

Growth of Planted Fish

The age length relation of the various samples of the planted fish are shown in Figure I in comparison with the curve obtained for the native fish taken from Fry (1953). The ages were estimated from impressions on cellulose acetate read on various projectors or in some cases with a binocular microscope. The first year's growth showed the complex pattern recently described by Cable (1956). Scales from samples of the fish planted and of certain fish which had been tagged before planting and later recaptured, were available to enable the position of the first annulus to be placed. Little difficulty was experienced in reading the scales and internal evidence indicates that the readings are in general reliable. For instance no fish of the 1949 year class were planted and only four marked fish of the adjacent year classes were incorrectly assigned to that group. In addition, as Figure I shows, the growth curve of a given year class tended to remain consistent in its course in comparison with other year

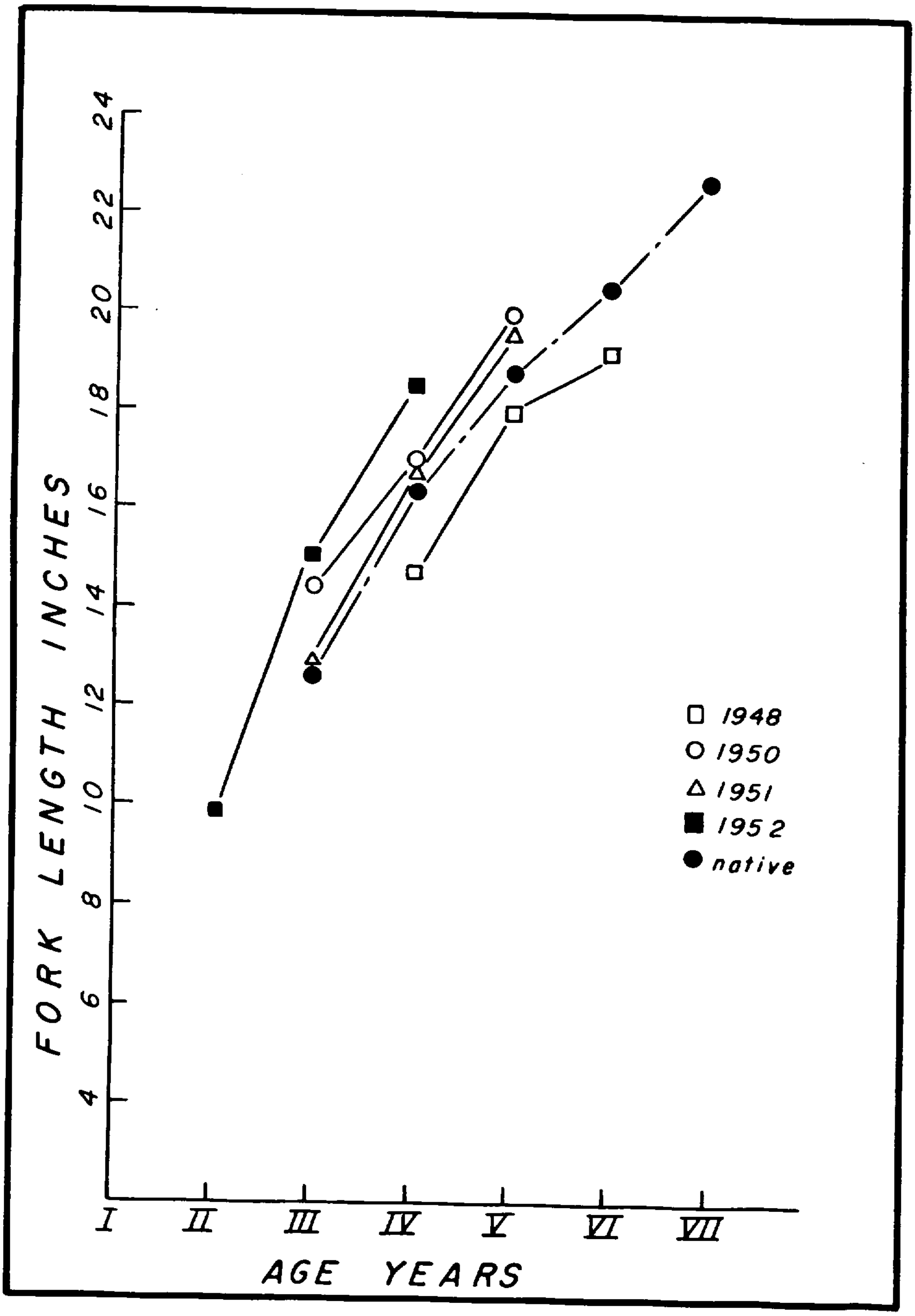

Figure I.—Growth of South Bay lake trout showing a comparison between the various year classes of hatchery stocked fish and the native stock.

classes. Note for example the curve for the 1948 year class. It can be seen that the growth of the planted fish has been in general the same as that which was displayed by the native stock. The 1948 year class (planted in 1949), which consisted of fish known to have been small when planted, although the sample taken for measurement was lost, showed the smallest size at a given age throughout its history.

In addition to the growth curves in Figure I, which are assessments based on scale reading, a direct comparison, based on marking and recovery data of the growth of planted fish for the year 1956, can be made with native fish for 1949. Twenty-seven of the fish released with tags in June of 1956 were recaptured in September and October. These fish had a mean length of 18.6 inches when released at a mean date of June 16. They were recaptured at a mean date of September 13 and had gained a mean increment in length of 1.3 inches. From Fry's (1953) Figure 2 it may be estimated that over the same period in 1949, native lake trout of similar size gained 1.1 inches.

The samples of 1956 also gave an estimate of the intraseasonal growth of the age II individuals. Two samples of approximately 20 fish each were taken, one in June and the other in September. The mean length of the June sample was 9.5 inches, that of the September sample 11.5 inches.

Survival

In 1956 it was possible to make direct estimates of the sizes of the population of two of the year classes of planted lake trout, those of 1951 and 1952. These estimates were of the Petersen type and were made by releasing tagged trout taken in pound nets in the spring and recapturing a fraction in gill nets in late summer. The number of tagged fish released was 98 estimated to be age IV and 52 of age V. Of these, 15 age IV fish were recaptured with 276 untagged fish of the same age. The number of tagged fish of age V retaken was 10 together with 93 untagged ones. These data give Petersen estimates, in round numbers, of 2,000 age IV lake trout and 500 age V present at the time of tagging. These two estimates yield widely different percentage survivals from the two plants. Only two per cent of the 23,100 yearlings of the 1951 year class are thus estimated to have survived to age V, whereas 45 per cent of the 1952 year class of 4,500 planted are estimated to have survived to age IV. It has not been possible to make any further direct estimates of the number of survivors from other plants by the mark recapture method. However, some estimates are given below based on catch per unit effort.

Pound net catches

Five pound nets have been fished in essentially the same locations in South Bay since fishing started in 1947. In certain of the earlier years additional pound nets were set, but for comparative catch-effort studies only the five basic nets have been considered. The catches of the five nets in question for the month of June are listed in Table III. June has been taken as the best month for comparison since the nets almost invariably can be expected to take trout throughout that month. In some years it was not possible to get all nets set and fishing much before the first of June so comparisons of May fishing would include very irregular sections of that month. Also in some years the trout retreat to deep water early in July, therefore weather might be expected to greatly influence comparisons made for that month. In general, pound net fishing for lake trout extends from mid-May to mid-July with June being the most productive period. Even in June it is possible that water temperature in some years has an influence on the pound net catch of trout; therefore the catch per unit effort of these nets cannot be considered a precise estimate of the relative size of the lake trout population from year to year.

The possibility of using the catch per unit effort to give rough estimates of the survival of the planted lake trout in South Bay rests on the series of population estimates made for the native lake trout population which still existed there until 1951. Population estimates of both the Schnabel and the Petersen types were made for the lake trout in the years 1948 through 1952 (Fry 1953). Petersen estimates were made again in 1956 as is discussed above. These various estimates, together with the catch per unit effort calculated for the same years, form the basis of the estimates of population size made for the other three years in which pound net catches were of any significance. Thus from the first five rows of Table III it may be estimated that, over the ages represented, a catch of one lake trout per lift represents a population of 775 lake trout present in South Bay. The data shown show no trend in the catch per unit effort with age so that it is not worth while to calculate the means for the individual ages. The population estimates given in the lower four rows of Table III are derived from the mean relation of C.U.E. and catch given above.

In Table IV the population estimates for the planted fish given in Table III are related to the year classes. There is undoubtedly a great deal of uncertainty to be attached to these estimates. For example the estimate for the size of the 1951 year class at age IV is obviously wrong since approximately 200 individuals of this year class were taken in the sampling at ages IV and V after this estimate was made (*see* Table II). The season of 1955 in which the low population estimate was obtained was distinguished by being the warmest on record during the course of our observations. For that reason the pound net fishing for trout was terminated early, as the fish withdrew to deeper water, and the estimates based on the whole of the June fishery, would be expected to be low. In any event, while the percentage error may be gross, the values appear to indicate the order of magnitude of the various year classes in the fishery.

Percentage survivals to age V based on the estimates are shown in the last column of Table IV. A notable feature of the estimates is that the numbers surviving have borne no direct relationship to the numbers planted. Indeed, as far as the data go, the relation has been inverse which seems to indicate that at present the conditions in South Bay are such that no more than 1,500 or so lake trout can survive to age V regardless of the size of the plant. It will be of interest to see whether such continues to be the case as the histories of the plants are followed further. This appears to be a rather surprising circumstance since earlier conditions permitted age V populations several times this number. The only obvious change in the environment which might be expected to affect the lake trout at sizes beyond those at which they were planted is the sea lamprey.

Another notable feature of Table IV is that fish of the 1948 year class did not survive to age VII, the age at which most females reach maturity, nor did the 1950 year class survive to age VI. These losses can both certainly be attributed to the depredations of the sea lamprey. This points out rather clearly why it is possible for the lamprey to completely eliminate a lake trout population by effectively halting all reproduction.

Lamprey Scarring

The scarring data are summarized in Table V which continues the type of summary given for the years 1947 through 1951 in Fry (1953) except that the size classes above 19 inches have been further condensed. The table is based on records of all fish handled during the period either killed or released. Fresh and healed scars have been combined.

Lamprey scarring on fish 19 inches and over has continued at the level attained in 1950 and was much increased in four of the later years. The apparent drop from the 1950 value in scarring on fish under 19inches is due largely to the capture of many more fish under 16 inches in the net sampling during the years reported here. The 1950 sample was taken by angling and very few fish were captured that were under 18 inches. Thus many more fish of the lengths that are immune to scarring are included in the samples since 1950. In general the evidence from the scarring data indicates that the first year of substantial lamprey attack on the lake trout in South Bay was 1949 and that severe attacks began in 1950. The data for 1951 and 1952 are weak. Scarring probably continued at the 1950 level until the end of 1954. The severity of lamprey attack has further increased in the two last years of the records, 1955 and 1956.

The argument that the lack of healed scars on small lake trout is perhaps only an indication that virtually every attack at this size is fatal and that the mortality from this cause may be actually greater among small fish than among large ones, is not supported by the evidence gathered in South Bay. The South Bay data suggest rather that a wave of mortality (not due to lamprey) may come among the small fish early after planting and that the lake trout are then relatively immune to further losses until they approach twenty inches in length. In 1955, 89 fish from six to nine inches in length were tagged at the time of planting. During the 1956 fishing operations, nine of these tagged fish were recovered, ranging in size from 11 to 14 inches. The recovery of these tagged fish does not indicate any substantial mortality from lamprey attack among lake trout up to 14 inches long. It is rare that a lamprey scar is observed on fish of these lengths.

If the size composition of a year class of lake trout is followed through, year by year, in detail in South Bay, it seems that the loss by lamprey attack sharply increases as the fish approach a length of 20 inches, regardless of age. It is this circumstance apparently that has prevented the lake trout from living to be much older than age V in late years in South Bay. The single year class that reached age VI in substantial numbers, the 1948 year class, had apparently been retarded in the first and second year and did not attain the critical size as early as did the other year classes.

Conclusions

1. To date the plantings have shown that it promises to be quite feasible to rehabilitate a lake trout population in the Great Lakes by the planting of yearling stock. In the absence of lampreys two to 50 per cent of such planted fish could have been expected to have reached maturity in South Bay. It is possible, but not yet proven, that the maximum efficiency could be obtained with relatively small introductions, for the data suggest that about the same absolute number of lake trout have survived regardless of the number planted.

2. The stocks introduced into South Bay have behaved in growth and distribution in essentially the same manner as did the native stock.

3. When sea lamprey are present in substantial numbers, planted lake trout can still survive in numbers for several years and apparently become highly susceptible to lamprey attack only after reaching a certain critical size which in South Bay is approximately 20 inches fork length.

4. It is improbable that any planted lake trout will survive to spawning in South Bay while the sea lamprey maintains its present population desntity there.

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Table I

Summary of Lake Trout Planting in South Bay, Lake Huron.

Year Class	Number Planted	Date Planted	Average Length[1]	Origin of Eggs	Rearing Station
1948	(100's) 71	Oct. 1949	no record (small)	Lake Superior	North Bay
1949	0	....	....	....	....
1950	101	Oct. 1951	5.3 (68)	Lake Superior	Chatsworth
1951	231	Nov. 1952	3.7 (176)	Lake Superior	Sault Ste. Marie
1952	45	Oct. 1953	4.1 (41)	Lake Simcoe and Lake Superior	Chatsworth
1953	184	May 1954	3.6 (92)	Lake Superior	Chatsworth
1954	157	Nov. 1955	6.2 (185)	Lake Superior	Chatsworth
1955	510 (est.) advanced fry, air dropped	May 1955	1.5 (no actual measurements)	Lake Superior	Sault Ste. Marie

[1] Based on sample measured, number of fish in sample shown in parentheses.

Table II

Numbers of Lake Trout Taken in South Bay in the Years 1952 to 1956.
(The numbers in brackets are unmarked fish.)

Year Class	Number Planted	II	III	IV	V	VI	VII	Total	Per cent Unmarked
	(100's)								
1947	0	....	....	....	0(4)	1(0)	1(1)	7	....
1948	71	....	....	73(16)	90(14)	79(2)	....	274	11
1949	0	....	2(0)	0(4)	2(2)	....	....	10	....
1950	101	2(0)	12(3)	85(8)	20(2)	9(1)	....	142	10
1951	231	0(1)	24(6)	25(4)	149(22)	....	....	231	14
1952	45	17(5)	63(14)	386(40)	....	....	....	525	11
1953	184	30(5)	193(18)	....	....	....	....	246	9
1954	157	140(13)	....	....	....	....	....	153	9
Total...	....	....	....	....	....	....	....	1588	....

Table III

June Catches of Lake Trout in South Bay Pound Nets.

Year	June Lifts	Catch	Catch/life or C.U.E.	C.U.E. by Age Gronps				[1]Population Estimates			
				IV	V	VI	VII	IV	V	VI	VII
1948	44	1383	31.4	27.3	4.0	0.1	......	16,700	2,500	300	....
1949	132	1559	11.8	2.7	9.1	......	......	3,200	10,800	....	....
1950	69	477	6.9	......	1.7	5.0	0.2	....	1,000	3,000	160
1951	84	50	0.6	......	......	0.1	0.5	....	....	125	475
1956	50	160	3.2	2.1	1.1	......	......	2,000	500	....	....
								Based on C.U.E. and above estimates			
1952	Insufficient data										
1953	39	56	1.4	......	1.4	......	......	....	1,400	....	....
1954	30	40	1.3	0.4	......	0.9	......	310	....	700	....
1955	51	17	0.3	0.1	0.2	......	......	80	160	....	....

[1] Estimates based on mark recapture data prior to 1956 from (Fry 1953).

Table IV

Population Estimates in Relation to Age for Various Year Classes of Planted Fish.

Year Class	Age IV	Age V	Age VI	Age VII	Per Cent Survival to Age V
1948		1 100	700	0	15
1950	310	160	0	....	2
1951	80	500	....	....	2
1952	2,000	....	....	....	"40"

Table V

Percentages of Lake Trout from South Bay Examined Bearing Lamprey Marks, a dash indicates a negative finding on a sample of less than 10 fish.

Year	Fork Length, Inches: Under 19	19-21	22 and Over
1949	1	4	11
1950	14	20	25
1951	—	54	37
1952	4	50	19
1953	9	18	—
1954	6	17	—
1955	14	56	71 (7 fish)
1956	12	47	85 (13 fish)

Notes on the Food of the Young of Three Species of Pacific Salmon in the Sea

by

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During July, 1950, very considerable numbers of young pink, chum and spring Pacific salmon were taken in beach seining operations in the San Juan Island area, carried out as part of the work in a course in Fish Biology given at the Oceanographic Laboratories of the University of Washington at Friday Harbor, Wash. Cursory examination of some stomach contents of these fish revealed the presence of dipterous larvae and pupae in addition to crustaceans, and so from July 10 to 31, 206 specimens were preserved for more detailed examination.

In the final analyses of the data, no differences were found in the nature of the foods among the three species of salmon or in relation to the size of the fish. The data were therefore not segregated.

The species were represented as follows: pink salmon, *Oncorhynchus gorbuscha* 103; chum salmon, *O. keta* 54; and spring salmon, *O. tshawytscha* 49; total 206. The total lengths of the fish ranged from 4.0 to 9.5 cm., with a mean length of 6.5 cm.

The food materials of the total number of fish were estimated to be: Copepoda 50 per cent; Diptera (larvae and pupae) 26 per cent; miscellaneous items including small crustacea (copepods, isopods, amphipods) and unidentifiable material 24 per cent.

Since the presence of Diptera was surprising, special attention was given to the identification and occurrence of this food item.

Reference to publications by Saunders (1928) and Johannsen (1936) readily led to the identification of the insect as *Camptocladius pacificus* Saunders in the family Chironomidae. However, systematists at the present time appear to prefer to consider *Camptocladius* as a sub-genus of the genus *Spanistoma* (from correspondence with the U.S. National Museum). On this basis the name is *Spanistoma pacifica* (Saunders).

Examination of larvae and pupae was made after clearing specimens in xylol and mounting in paramount. Drawings are presented in Figure 1.

The data on occurrence are given in Tables I and II. When the Diptera were more abundant than other food items, they were recorded as predominant. Fewer Diptera were eaten as the season progressed. Either they became fewer or other food forms became more plentiful.

The writer is indebted to Dr. W. A. Clemens for suggesting the study.

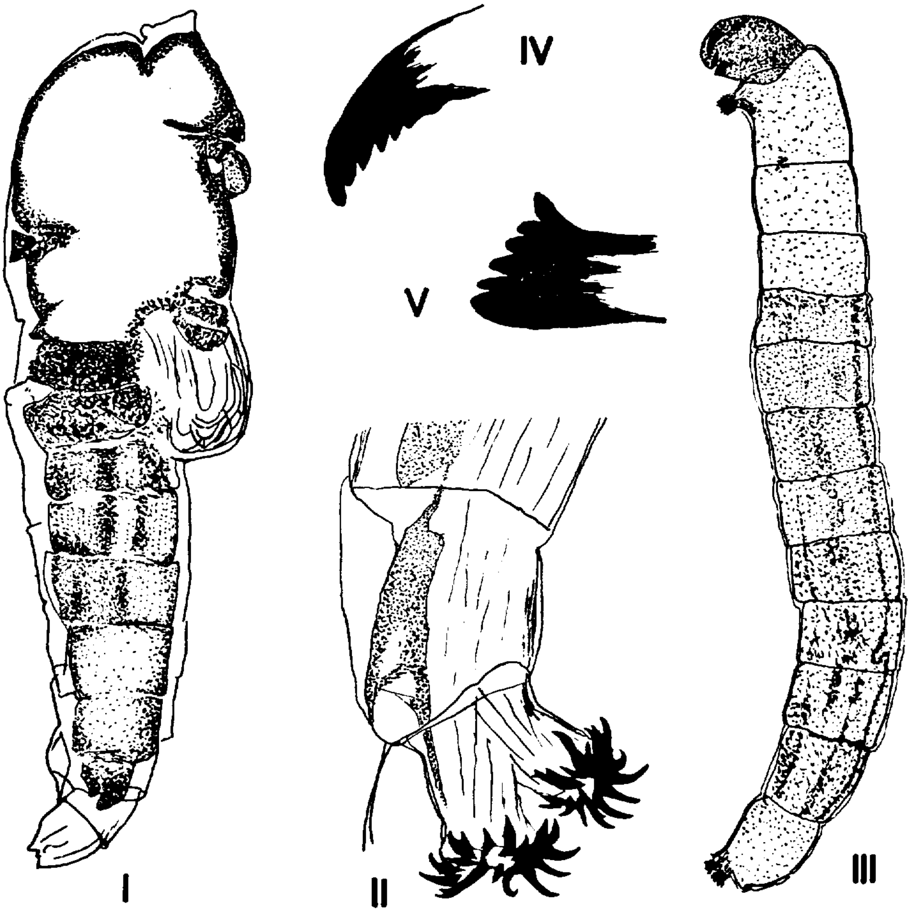

Figure 1.—*Spanistoma pacificus (Saunders). I Pupa. II Anal pseudopod showing hooks. III Larva. IV Mandible. V Labium. Drawings made with the aid of a camera lucida.*

Table I

Diptera, *Spanistoma pacifica*, in the Stomachs of Young Salmon.

Date	Number of Salmon	Number Having Diptera Predominant	Per Cent	Number Having No Diptera	Per Cent
10 July	7	4	57	0	0
10 July	32	18	56	3	9
10 July	20	14	70	2	10
10 July	17	4	24	3	18
10 July	8	2	25	1	13
17 July	18	0	0	10	56
17 July	35	11	31	6	17
17 July	8	1	13	4	50
24 July	6	0	0	4	67
24 July	11	0	0	7	64
24 July	1	0	0	1	100
31 July	28	0	0	24	86
31 July	15	0	0	15	100
	206	54	26	80	39

Table II

Occurrence of Diptera, *Spanistoma pacifica*, in the Stomachs of Young Salmon by Weeks.

Week of	Number of Salmon	Number Having Diptera Predominant	Per Cent	Number Having No Diptera	Per Cent
10 July	84	42	50	9	11
17 July	61	12	20	20	33
24 July	18	0	0	12	67
31 July	43	0	0	39	91
	206	54	26	80	39

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A Direct-Current Electrofishing Apparatus Using Separate Excitation

by

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In order to determine the standing crops of Atlantic salmon, brook trout, and eels in the Little Codroy River, Newfoundland, a direct-current electrofishing apparatus using separate excitation has recently been devised. Separate excitation is a simple and practical method for getting excellent output voltage control. It is also a safer and more economical means of producing power for electrofishing. The purpose of this paper is primarily to describe the unit and report briefly on some results of its use.

The electrofishing apparatus consisting of engine, generators, control panel, cable and reel, positive fishing electrode, and negative ground electrode, is shown in Figure 1A. The source of power is a 6.5 h.p. Briggs and Stratton air-cooled, gasoline engine. An engine of this size was selected in order to take advantage of its relatively low r.p.m. characteristics (2,400 r.p.m.). The generators are belt driven (Figure 1B), with the exciter generator turning at 1,440 r.p.m., and the main generator at 1,250 r.p.m.

The wiring diagram for the electrofishing apparatus is shown in Figure 2. The main generator (Figure 1C) is a rebuilt, separately excited, direct-current unit mounted in an "Imperial Electric" frame. The armature is capable of producing a maximum unloaded potential of 675 volts at 3 amperes continuous service, or 4 amperes intermittent service. The resistance of the armature is 4 ohms. The field is wound for separate 12-volt excitation with an external field rheostat mounted in the control panel for output control. The resistance of the field is 36 ohms. Interpole windings are used to improve voltage regulation under varying load conditions.

The exciter generator (Figure 1D) is a Lucas 12-volt, shunt-wound, direct-current generator. There are three reasons for using separate excitation. First, excellent voltage control can be obtained using separate excitation (along with interpole windings) because field troubles from variable voltage and load are minimized. Separate excitation means that the main generator has a low voltage separately excited field (i.e., 12 volts, as compared with 675 volts if the generator were self-excited). This minimizes the danger of insulation breakdown and flashover in the damp conditions existing beside rivers. Second, safety is a feature of separate excitation because 12 volts are used to control 675 volts. There are actually two safety factors involved: (*a*) the 12 volts separate excitation, and (*b*) the relay which is mounted in the control panel. The 12-volt generator is the source of power for the relay. The switch in the handle of the positive electrode (Figure 2) controls the relay, and the relay, in turn, controls the field of the main generator. Thus there is just enough low voltage current flowing through the electrode switch to operate the relay. Third, because the resistors, relay, and switches are in the 12-volt circuit they are low priced and easily obtainable.

The control panel (Figure 1E) consisting of field rheostat, voltmeter, ammeter, 12-volt relay, and main switch, is mounted in a standard steel junction box. The

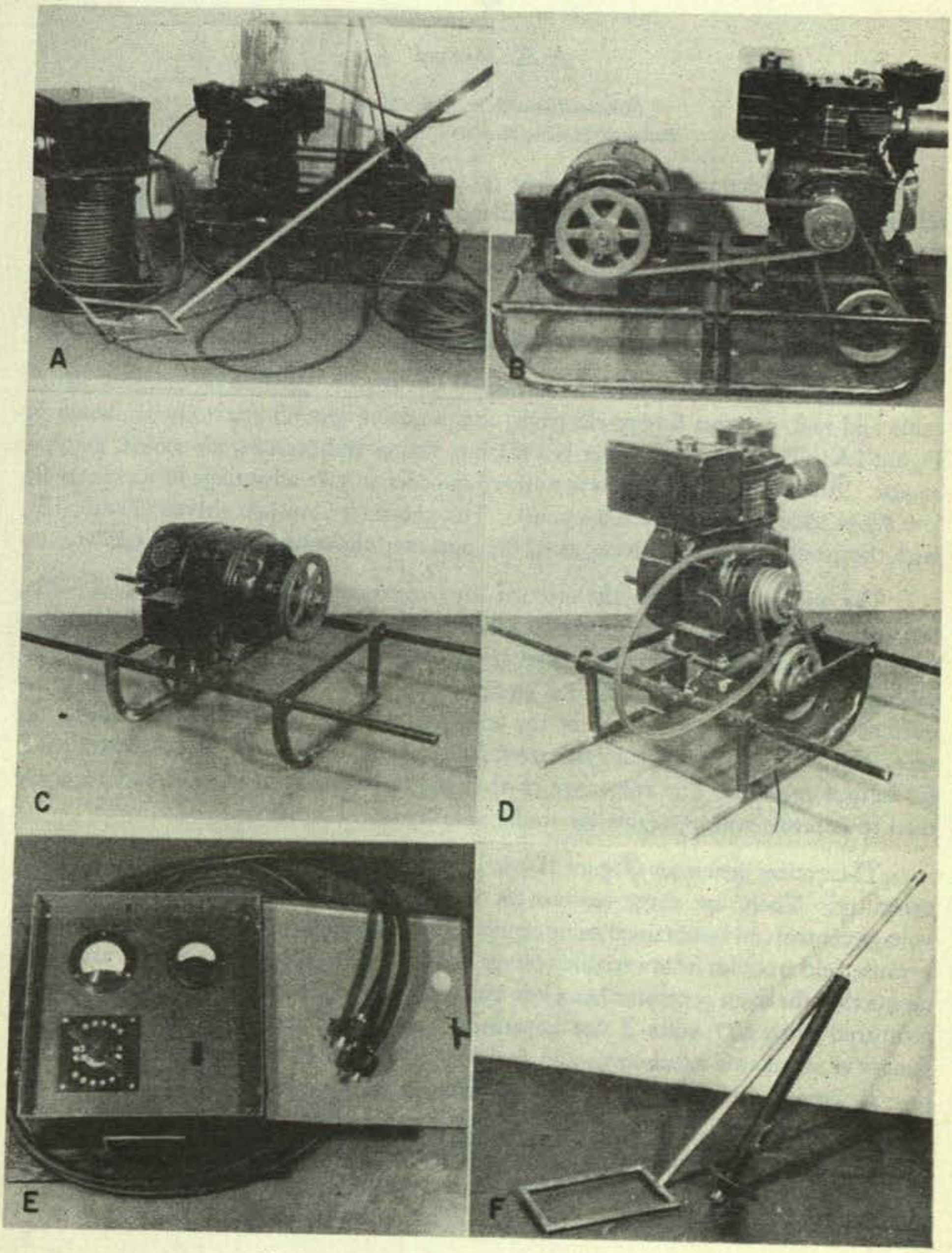

Figure 1.—Direct-current electrofishing apparatus.

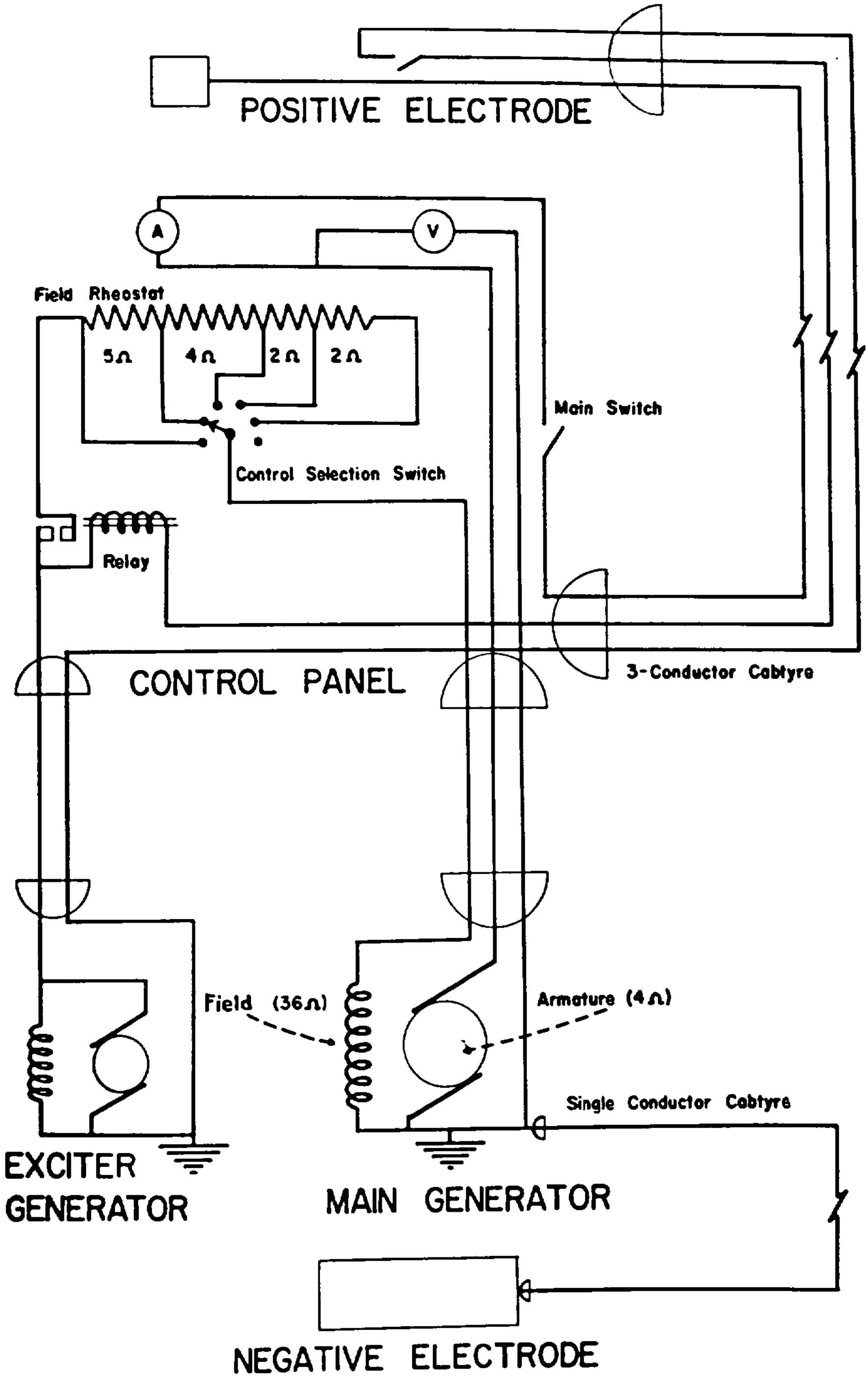

Figure 2.—Schematic wiring diagram of direct-current electrofishing apparatus.

control switch on the 13-ohm field rheostat allows the selection of any one of 5 output voltages (unloaded values): 200, 300, 400, 520, and 675. The variable output voltage is a useful feature for it allows the selection of the voltage best suited to the conductivity of the water, as well as the size and species of fish being collected. The control panel is separate from the engine and generators, the circuits being completed by means of two short cables from the control panel plugged into polarized receptacles on each generator.

The engine and generators are bolted to a light weight tubular steel (bicycle-type) frame made in two sections, one carrying the engine and exciter generator, and the other the main generator. The weight of the engine and exciter section is 168 pounds, and the weight of the main generator section is 144 pounds. The two sections are carried separately (Figures 1C and 1D), but are bolted together when the unit is in operation (Figures 1A and 1B). The main generator can be moved back and forth on its frame to allow for belt adjustment. As suggested by Smith and Elson (1950), the engine and generators are mounted on two frames for convenience in handling because of their weight. However, an overall improvement in portability has not resulted because of their bulk and also because of the weight of some of the accessory gear (such as the barrier nets). Hence it is possible to use this equipment only in the areas of the river which are accessible by vehicle.

The cable reel (Figure 1A) is a metal flanged drum which carries 300 feet of 3-conductor, number 14, cabtyre cable. One end of the cable is plugged into a polarized receptacle on the control panel, and the other end into a polarized receptacle on the handle of the positive fishing electrode. In practice, the reel is mounted on a horizontal axle, which is supported by a stand made of steel pipe, and the approximate amount of cable required is pulled from the reel and stretched along the stream bank. The man operating the fishing electrode drags the cable behind him. The negative pole of the main generator is grounded by connecting it through 100 feet of single-conductor, number 14, cabtyre to a 3- by 10-foot piece of copper hardware cloth which is set on the stream bottom and covered with rock or gravel. The single-conductor cable is also carried on the reel. The total weight of the reel and both cables is 114 pounds.

The positive fishing electrode (Figure 1F) consists of a straight piece of $\frac{5}{8}$ inch copper tubing, on the distal end of which is a rectangular piece of $\frac{1}{2}$ inch copper tubing, size 8 by 11 inches. The proximal end of the electrode is attached to a tubular insulated handle by means of a brass coupling. There is a sliding contact switch on the handle which indirectly controls the main generator through the relay, hence the high potential will not be produced unless both the electrode switch and relay are closed. All members of the electrofishing crew wear electrician's rubber gloves and rubber chest waders.

A Jeep and 2 wheel, $\frac{1}{2}$-ton trailer are used to transport the crew, apparatus, and accessory equipment.

The unit has been used under a wide variety of conditions on the Little Codroy River, and has proven highly satisfactory. It has, for example, been used in both winter and summer in water ranging from 2.8°C. to 19.2°C. It has been used in various parts of the drainage basin in water the resistivity of which has varied from 19,800 to 42,200 ohms per centimeter cube ($\Omega/cm.^3$). The positive fishing electrode has been fished up to 400 feet from the negative ground electrode with no apparent decrease in efficiency.

The total numbers of fish captured at the various sampling stations are shown in Table I. Because this work is in its preliminary stages, a more complete analysis is not given. The data are included only to indicate that the apparatus has been successfully used to catch Atlantic salmon parr, brook trout, and eels under a variety of conditions. The method of blocking off the sample areas with barrier nets, and the fishing procedure used at each station were much the same as that described by Godfrey (1956).

Observations on the behaviour of Atlantic salmon parr, brook trout, and eels in the direct-current field parallel those of Godfrey. As reported by Saunders and Smith (1954), it was found that collection of fish was easiest when the generator voltage was adjusted so that the fish could be held at the positive fishing electrode in a condition of partial paralysis. The potential was around 300-375 volts. In general, voltages around 300 were found to be more satisfactory in warm water, whereas voltages around 375 were more satisfactory in cold water. This complements the findings of Smith and Elson.

Table I

Numbers of fish taken at each of the sampling areas, Little Codroy River, 1956.

Station Number	Atlantic Salmon Parr		Brook Trout	Eels
	Under-yearlings	Yearlings and Older		
2	38	35	0	31
3	26	57	1	46
5	31	47	1	27
6	63	30	23	53
8	237	22	10	5
9	1	3	0	28
16	92	78	19	59
16a	110	74	13	5
17	0	39	4	32
18	56	47	15	18
19	29	89	2	66

In connection with voltage adjustment, it was observed that the lower the resistivity of the water, the lower the voltage produced, and the greater the current drawn, at any one setting of the control selection switch on the field rheostat. For example, when the control selection switch was set so that the main generator was producing 650-675 volts (no load), under load in water of 19,800 Ω/cm.[3] resistivity it was producing 330 volts at 1.7 amperes, and in water of 42,200 Ω/cm.[3] resistivity it was producing 600 volts at 0.9 amperes. The effect of water temperature and water resistivity on voltage adjustment were also observed in a general way. At any given resistivity, the higher the water temperature, the lower the voltage produced, and the higher the current drawn. For example, with the control selection switch set as above, the main generator produced 500 volts at 1.2 amperes in water of 40,200 Ω/cm.[3] and 15.3°C., whereas it produced 600 volts at 0.9 amperes in water of 42,200 Ω/cm.[3] and 4.4.°C.

Some immediate mortality was observed in two instances when fishing in rapid water over rubble bottom when dislodged and shocked parr drifted downstream into the lower barrier net and were held by the pressure of the water and by the accumulation of debris on the net. This occurred early in the season when the apparatus and its attendant techniques were new to the crew. As the season progressed and the crew became more proficient, there was no further immediate mortality.

Shortly after the unit was completed in January 1956, it was tested in the Salmonier River, St. Mary's Bay, Newfoundland. Approximately 160 Atlantic salmon and brown trout parr were collected. These fish were brought back to the Biological Station and held for observation in wooden troughs and glass aquaria for a period of one month. There were no mortalities during this period. Accordingly, delayed mortality has been assumed to be not significant, and it has further been assumed that fish which recovered immediately from the effects of the electroshock were uninjured. Similar conclusions have been drawn by Smith and Elson.

Acknowledgements

Assistance in the design of the apparatus by Mr. W. Brown, of the Department of Transport, St. Andrews, Newfoundland, Mr. R. C. Hawksford, of the Vocational Institute, St. John's, and Mr. M. A. Foley, of the Fisheries Research Board of Canada, Technological Unit, St. John's, is gratefully acknowledged. The apparatus was built by Canadian Machinery and Industry Construction Limited, St. John's. This paper is published with the permission of the Fisheries Research Board of Canada.

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Back-pack Fish Shocker

by

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The value of small, portable, electrical fish shockers is fast becoming apparent to fishery workers. The immediate need for such a unit in Newfoundland was for collecting live salmon parr for laboratory experiments on tagging. The intention was to assemble a unit similar to one described by Haskell *et al.* (1954). Difficulty was experienced in obtaining the specified parts locally, but this was overcome by obtaining a packaged D.C. unit, the Vibrapack, with a similar circuit from P. R. Mallory & Co. Inc., Indianapolis, Indiana.

Description

The complete shocker is shown in Figure 1. It consists of a 6-volt motorcycle battery, the Vibrapack, and a voltmeter housed in a fairly water-tight box and two paddle-type electrodes. The outside dimensions of the box are 15 inches wide, 15 inches high, and 8½ inches deep. A pack-sack frame is attached to the box so that the outfit can be carried comfortably on the back. The electrodes, which are made of ½ inch copper tubing, are 4½ feet long, the round end being 7 inches in diameter. The grid in the round end is formed of heavy copper wire. A switch in the low voltage D.C. circuit for starting and stopping the unit is conveniently located on the handle of the right or positive electrode. A switch for use as a main switch or in emergencies is situated on top of the case. It has a pull cord which is readily accessible to the operator or the second man of the team. The unit SHOULD NEVER be used by one man alone.

The total weight of the outfit is 44 pounds, so it can be carried fairly easily by one man. The cost in St. John's, Newfoundland, was $120.00. (It should be less in most other cities in Canada.) The following is a list of parts and materials used:—

Parts

Battery .... 6-volt motorcycle battery, Lucas PUZ 7E-9

Vibrapack .... Mallory VP-555H

Voltmeter .... 0-500 V.D.C., 1,000 ohms per volt, Triplett

Main fuse .... 30 amp.

Vibrapack fuses .... 10 amp. 3 AG

Switch No. 1 .... Open knife, SPDT, mounted on outside of case

Switch No. 2	Slide switch, SPST, mounted on positive electrode handle
Relay	Automobile horn relay, Sorensen HR-2
Discharge resistor R-4	400 K safety resistor

Materials

Electrodes	$\frac{1}{2}$ inch copper tubing
Electrode handle insulation	$\frac{5}{8}$ inch automobile heater hose
Electrode connections	For positive electrode, three conductor No. 12 cab tyre
	For negative electrode, single conductor No. 12 cab tyre
Battery connections	No. 6 insulated flexible cable

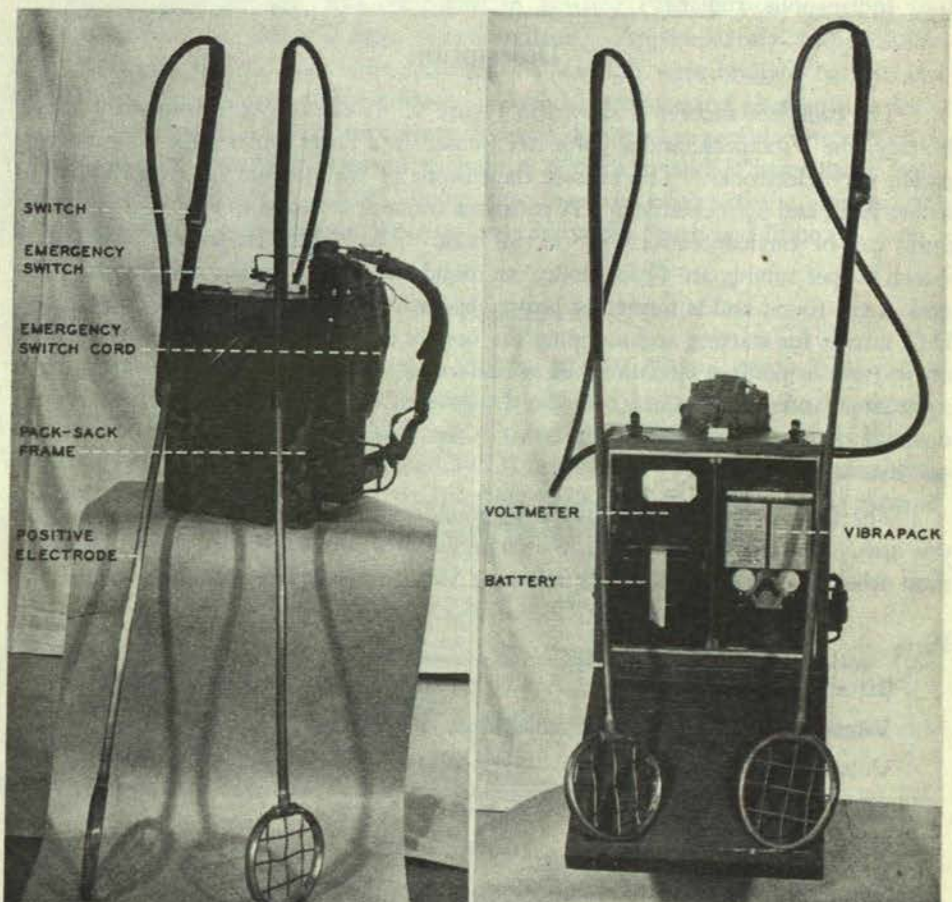

Figure 1.—On the left a view of the shocker ready for use, and on the right a view of the interior.

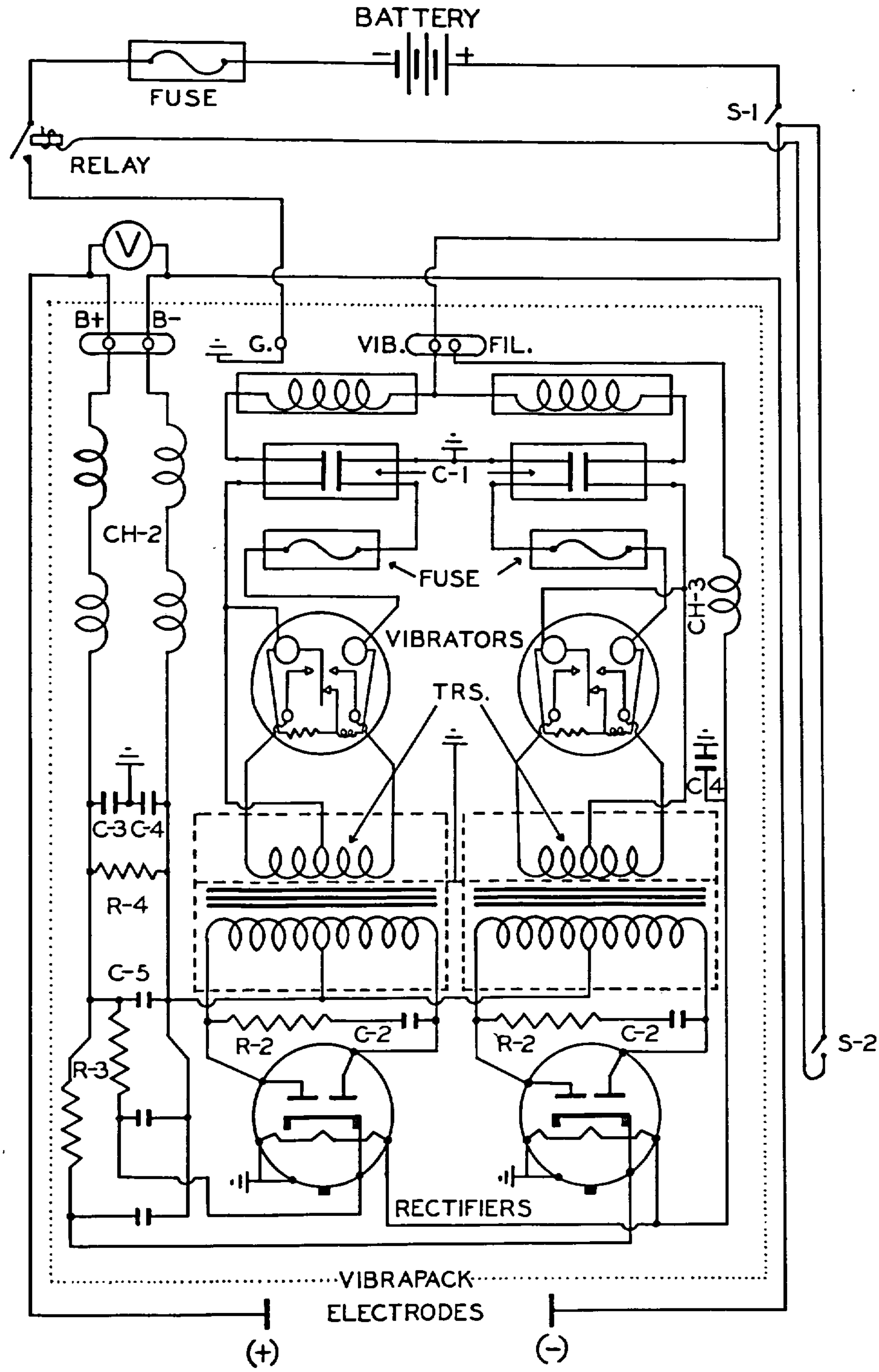

Figure 2.—Schematic wiring diagram. Symbols: B—, battery negative; B+, battery positive; C-1, C-2, C-3, C-4, condensers; CH-2, CH-3, chokes; FIL., filament; G, ground; R-2, R-3, R-4, resistors; S-1, S-2, switches; TRS., transformers; VIB., Vibrapack; and Ⓥ, *voltmeter.*

The Vibrapack or main power unit is factory built. Types are available for nominal input of 6, 12, and 32 volts, nominal output ranging from 125 to 400 volts, and maximum output of 60, 100, 150, and 200 milliamperes. The one selected for operation in Newfoundland streams has a nominal input of 6 volts, a nominal output of 300 volts, and a maximum output of 200 milliamperes. The wiring diagram of the Vibrapack unit is shown within dotted lines in the schematic wiring diagram of the shocker (Fig. 2). For ease in assembly and to give good connections all wires have soldered terminals. The Vibrapack is supplied with OZ4A rectifier tubes which according to the manufacturer's description require a minimum current load of 140 milliamperes to start the unit. However, in this particular installation it was found that the unit would start with a load as low as 90 milliamperes.

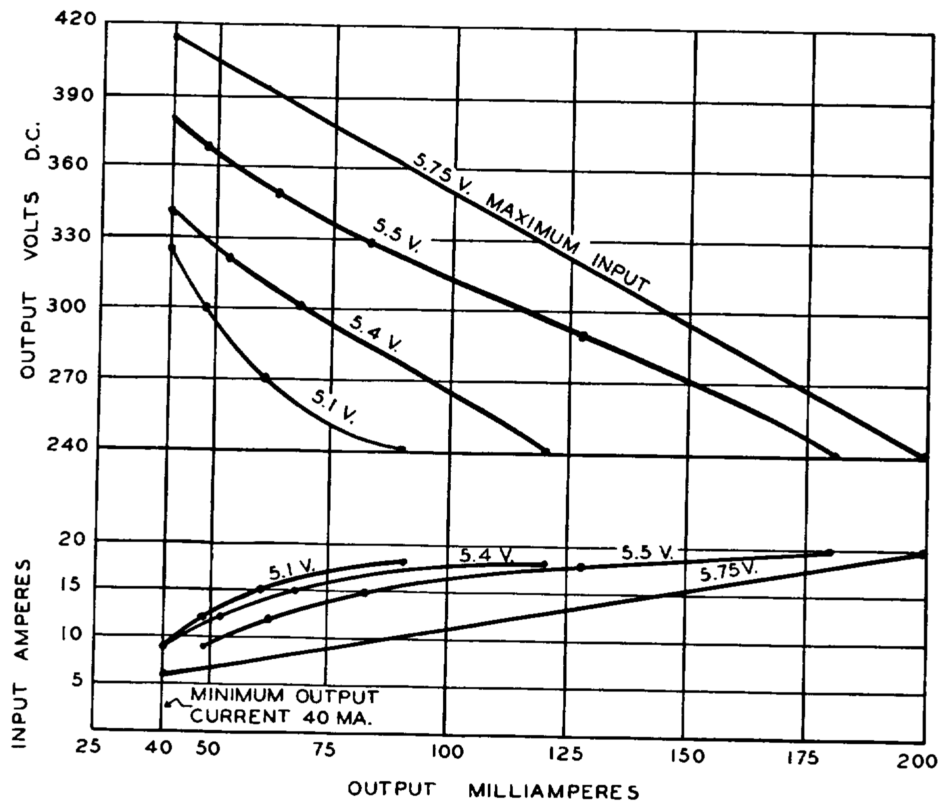

Figure 3.—Operating characteristics of the shocker in 6 inches of water with distances of 6 inches to 4 feet between electrodes.

Operation

The power to operate the shocker is supplied by a 6-volt motorcycle battery. This direct current is changed successively as follows: to low voltage alternating current by a vibrator, to high voltage alternating current by a transformer, and to high voltage direct current by a rectifier. This high voltage direct current is conducted to the electrodes for shocking the fish. The operating characteristics of the shocker

(Fig. 3) were determined in 6 inches of water in a wooden trough, 4 feet long and 14 inches wide, with distances of 6 inches to 4 feet between electrodes. All readings depend on electrode separation and immersion. The drain on the battery ranged from 5.1 to 5.75 volts and from 6 to 20 amperes. The output of the unit ranged from 240 to 415 volts and from 40 to 200 milliamperes. When the battery cannot produce 18 amperes at 5.1 volts, the unit will not start. If the output drops below 40 milliamperes at 240 volts, the unit will cease to operate. If the electrodes should accidentally come closer together than 6 inches at any time, a blown fuse will result, safeguarding the unit from overloading and damage to the component parts.

The shocker has worked quite well in the streams fished so far where depths ranged from 6 inches to 3 feet. Fishing downstream was found to be more effective than fishing upstream. A team of two men is required, one man to operate the shocker and the second man to do the collecting. In clear water with little current, the collector used a dip net and moved along with the operator. In turbid or swift water, the collector used a one-man seine and took up a stationary position while the operator started about 20 feet above and worked down to the seine. Fish were narcotized within 1 foot of the positive electrode. Beyond that, some were attracted to the positive electrode but most appeared to receive a slight shock and moved in all directions. Occasionally fish were led into the seine. All fish recovered quickly.

Since the unit has been quite effective in occasional collections, it shows that a current of 40 to 200 milliamperes is ample for small stream sampling in soft waters. The unit has not been used in hard waters, which would require a higher output current (Haskell *et al.*, 1954). Two fully charged batteries have supplied enough power for a full day's fishing. One battery will operate the unit continuously for 1 hour. Under actual fishing conditions where the unit is not in continuous operation, it is estimated that the battery will operate the unit effectively for a maximum of 2 hours. Fishing time is thus limited by the number of batteries available or distance travelled from a charger. A word of caution is necessary in connection with shutting off the unit. This should be done while the electrodes are immersed in the water so as to drain off any current left in the condensers. Otherwise the resultant shock upon contact with any of the uninsulated parts is quite uncomfortable and may cause other accidents. This danger could be eliminated by inserting a discharge resistor of 400 K across the output leads. It is shown as R-4 in the schematic wiring diagram (Fig. 2).

Acknowledgements

The fish shocker described in this paper was assembled by Mr. A. P. Cowan who is a technician on the staff of the Fisheries Research Board of Canada Biological Station at St. John's, Newfoundland. He also prepared the figures. Mr. W. M. Gaskell, Electrical Equipment Technician with the Newfoundland Light and Power Company, Limited, very kindly checked the technical parts of the paper.

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Experiments with Toxaphene As Fish Poison

by

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Introduction

Elimination of undesirable fish species and subsequent re-introduction of preferred species is an effective means of improving sport fishing. Since this form of management is expensive, the volume and number of lakes which can be treated is limited. If a cheaper chemical treatment could be proven, lake rehabilitation through poisoning would become more popular. In this report, the commercial insecticide, Toxaphene (a chlorinated camphene) has shown some promise when tried in a series of alkaline lakes in British Columbia.

Although some information is available concerning the chemistry of Toxaphene and its effects on warm-blooded animals, little critical work has been done on its use as a fish toxicant. Since British Columbia contains many lakes in which the sport fishery would benefit by removal of predator and competitor fish, it seemed desirable to determine the effectiveness and limitations of Toxaphene both with respect to fish as well as to plankton and bottom fauna. To obtain this information, eight small alkaline lakes typical of those found in the interior of the province were chosen. They contained a variety of coarse fish, all were readily accessible, and with one exception, had no permanent inlet or outlet streams.

Methods

In 1954, several British Columbia lakes were treated with "Fish Tox" (a rotenone based chemical containing 10 per cent Toxaphene). These lakes remained toxic for over two years. The prolonged period of toxicity was attributed to the presence of Toxaphene. As a result of this observation, a series of four Toxaphene concentrations was chosen in this experiment ranging downward from 0.10 p.p.m. (concentration represents actual concentration of 100 per cent Toxaphene). The concentrations, 0.01 p.p.m., 0.03 p.p.m., 0.07 p.p.m. and 0.10 p.p.m. were duplicated. Some of the more important physical and chemical features of the experimental lakes are listed in Table I.

Table I

Physical and Chemical Features of Toxaphene Treated Lakes

Name of Lake	Toxaphene Concentration (p.p.m.)	Area (acres)	Mean Depth (feet)	Volume (acre feet)	pH	T.D.S. (p.p.m.)
Alleyne	0.01	135	55	7,425	8.3	308
Taylor	0.01	14	32	463	7.9	249
Gladstone	0.03	22	25	533	7.9	277
Round	0.03	91	58	5,278	8.2	295
Gallagher	0.07	17	34	571	8.2	172
Spectacle	0.07	9	11	96	8.4	285
Summit	0.10	12	30	360	7.9	249
Lady King [1]	0.10	15	18	270	8.2	170

[1] Lady King has an outlet stream discharging about two cubic feet per second.

In addition to the physical and chemical surveys of the lakes, bottom fauna and plankton samples were taken prior to treatment. Poisoning of the lakes took place during the first week of August, 1956. Gill nettings, live cage sets (rainbow trout), plankton hauls, and bottom samplings were carried out after the poisonings at an interval of one month and again at nine months. Periodic checks will continue until the lakes become non-toxic to fish.

Initially, when mixing and handling containers of liquid Toxaphene, workers were completely enclosed in rubber clothing including goggles and respirators. Toxaphene splashed on the skin produced no harmful effects provided that it was immediately washed off with a detergent. Respirators reduced the possibility of inhaling fumes while transferring liquid from one sealed contained to another. When applying the concentrate, only goggles, rubber boots and gloves were found necessary as additional protective clothing. Although all experimental lakes lie within cattle raising country and are used constantly as water holes, no adverse effect on cattle has been noted. Reasonable caution makes the handling and distribution of Toxaphene no more hazardous than other similar chemicals in daily use.

Liquid Toxaphene was easily and quickly distributed by the use of an outboard motorboat, fire pump, a 10 or 20 gallon drum and fittings. The required amount of Toxaphene for each lake was measured into 10 or 20 gallon drums and sealed before being transported to the lake. Each drum was provided with two outlets, one to a shut-off valve and the other to a capped breather pipe. Neoprene connections led from the shut-off valve, first to a needle valve which provided a fine flow adjustment, and then to a domestic water meter. This meter recorded volume delivered but not rate. The latter was calculated from timed runs using water and allowing the pump to operate at capacity. The metered line from the drum was then bled directly into the suction line of the firepump, which drew water from the lake continuously and at capacity (50 to 75 gallons per minute). Discharge of the mixed dilute Toxaphene was effected by two lines from the pump which released the mixture underwater on either side of the boat.

Toxaphene Effects

Fish

In order to subject as many fish species as possible to the various Toxaphene concentrations, cages containing fish not occurring in the lake were used to augment indigenous species. These were:—

1. Largescale sucker (*Catostomus macrocheilus*)
2. Squawfish (*Ptychocheilus oregonense*)
3. Carp (*Cyprinus carpio*)
4. Redside shiner (*Richardsonius balteatus*)
5. Perch (*Perca flavescens*)
6. Peamouth chub (*Mylocheilus caurinum*)
7. Lake chub (*Couesius plumbeus*)
8. Mountain Whitefish (*Coregonus williamsoni*)
9. Kokanee (*Oncorhynhus nerka*)
10. Rainbow Trout (*Salmo gairdneri*)
11. Prickly sculpin (*Cottus asper*)

At time of treatment, all lakes were thermally stratified with surface temperatures ranging between 64°F. and 67°F. In general fish displayed distress symptoms (erratic swimming, surfacing, and little alarm reaction) within four hours of treatment. Within 48 hours, the majority of fish were dead at all concentrations of Toxaphene; higher concentrations killed more quickly. At 0.10 p.p.m. all caged fish (suckers, squawfish, carp and peamouth chub) had succumbed prior to checking at 48 hours. All caged fish at a Toxaphene concentration of 0.10 p.p.m. died before 96 hours had elapsed. It was noted that a few individuals of a species exhibited remarkable ability to resist the lethal effects of Toxaphene for a prolonged period, while the remainder of the individuals of the same species died more quickly. In Gallagher Lake, one whitefish and one sucker were netted 19 days after the chemical treatment; in Spectacle Lake two caged carp were alive after four days (one was still alive one month later, but died before being checked at six weeks). In Alleyne Lake, one live sucker was netted three weeks after treatment. Gill netting, ($\frac{3}{4}$ inch to $3\frac{1}{2}$ inch mesh) undertaken two to three weeks after treatment showed that all fish had been killed, with the exception of those in the above-mentioned lakes. Simultaneous live cage tests with rainbow trout in Alleyne and Taylor Lakes (0.01 p.p.m.) produced 100 per cent mortalities within a five day period, while controls in adjacent lakes produced almost 100 per cent survivals.

In May, eight to nine months after the poisonings, gill net sets did not produce a single fish in any of the treated lakes. Live cage tests (rainbow trout) produced 100 per cent mortalities within two to seven days, with one exception, in all lakes. Although some of the cages were not checked until the seventh day, it was obvious that the fish had been dead for some time. In Lady King Lake two live cages were utilized; one was set at a depth of five feet and the other at a depth of about 15 feet. After seven days the five foot cage contained no live fish, while the 15-foot cage had a 60 per cent survival after 13 days. This particular lake is the only experimental lake which has a continuous inflow and, since the temperature of the inlet stream (55°F. on June 5) was considerably cooler than that of the lake surface (64°F. on June 5), it is probable that, owing to density difference, the non-toxic inlet waters diluted or replaced the deeper chemically treated waters thereby creating a more favourable enviroment for the survival of fish at that depth. Tables 2 and 3 summarize the results of the Toxaphene treatments on fish.

Table II

Results of Toxaphene Treatments on Fish Within 4 to 120 Hours After Poisoning.

Name of Lake	Fish Present		Initial Results
Alleyne (0.01 p.p.m.)	Sucker R. Trout		24-48 hours. Many dead suckers some still in distress
Taylor (0.01 p.p.m.)	Sucker [1] Squawfish [1] Carp [1]	Peamouth chub [1] R. Trout Shiner	96 hours. All fish in cages dead.
Gladstone (0.03 p.p.m.)	Sucker [1] Squawfish [1] Carp [1]	Peamouth chub [1] R. Trout Shiner	12 hours. Dead shiners and trou many fish in distress.
Round (0.03 p.p.m.)	Carp		72 hours. No live fish observed.
Gallagher (0.07 p.p.m.)	Sucker Squawfish Shiner Perch	Peamouth chub Lake chub Whitefish Kokanee R. Trout	96 hours. No live fish observed.
Spectacle (0.07 p.p.m.)	Sucker [1] Squawfish [1] Carp	Peamouth chub [1] Shiner	120 hours. All caged fish dead. Except 2 carp [2].
Summit (0.10 p.p.m.)	Sucker Squawfish Carp	Peamouth chub R. Trout Shiner	4 hours. Many dead trout and shiners. Distress noted in others. 48 hours all caged fish dead.
Lady King (0.10 p.p.m.)	Squawfish Shiner Peamouth chub	R. Trout Sculpin	24 hours. No sign of fish life.

[1] Fish held in cages. [2] Dead in 1 to 2 months.

Table III

Results of Toxaphene Treatment on Fish 2 to 3 Weeks and 8 to 9 Months After Poisoning.

Name of Lake	Fish Present		2-3 Weeks After Treatment		8-9 Months After Treatment	
			Gill Net Sets	Live Cage Tests	Gill Net Sets	Live Cage Tests
Alleyne..... (0.01 p.p.m.)	Sucker R. Trout		21 days one sucker[2]	After five days all dead	No fish	Fifty days 100% mort.
Taylor...... (0.01 p.p.m.)	Sucker[1] Squawfish[1] Carp[1]	Peamouth chub[1] R. Trout Shiner	20 days no fish	After five days all dead	No fish	Seven days 100% mort.
Gladstone... (0.03 p.p.m.)	Sucker[1] Squawfish[1] Carp[1]	Peamouth chub[1]	20 days no fish		No fish	Five days 100% mort.
Round...... (0.03 p.p.m.)	Carp		16 days no fish		No fish	Two days 100% mort.
Gallagher.... (0.07 p.p.m.)	Sucker Squawfish Shiner Perch	Peamouth chub Lake chub Whitefish Kokanee R. Trout	19 days, one whitefish,[2] one sucker[2]		No fish	Seven days 100% mort.
Spectacle.... (0.07 p.p.m.)	Sucker[1] Squawfish[1] Carp[1]	Peamouth chub[1] Shiner	19 days no fish		No fish	Seven days 100 % mort.
Summit..... (0.10 p.p.m.)	Sucker[1] Squawfish[1] Carp[1]	Peamouth chub[1] R. Trout Shiner	20 days no fish		No fish	Two days 100% mort.
Lady King... (0.10 p.p.m.)	Squawfish Shiner Peamouth chub	R. Trout Sculpin			No fish	Seven days 100% mort. and 40% mort.

[1] Fish held in cages. [2] Re-netted 74 days after treatment—no fish

Bottom Fauna

An evaluation of the effects of Toxaphene on bottom organisms was attempted. Samples (six inch Ekman dredge) consisting of 30 pre-poisoning and 70 post-poisoning dredgings were taken from each lake. Limitations of this type of sampling preclude quantitative analysis of the data. Qualitative results, however, are summarized in Table 4.

Shrimp (*Gammarus* or *Hyallela*) were taken from six of the eight lakes prior to treatment, but were absent in subsequent dredgings following poisoning. Further observations on the sensitivity of shrimp to Toxaphene were provided by placing shrimp from a nearby lake into cages in Round and Lady King Lakes eight to nine months after poisoning. The cages were set at a depth of about 15 feet and checked after a period of six days. All shrimp in the Round Lake cages were dead; no mortalities were noted in the cage in Lady King Lake. The results from Lady King are undoubtedly associated with the inflowing stream and the depth at which the cages were set

Table IV

Occurrence of Bottom Organisms in Toxaphene Treated Lakes Before and After Poisoning.

("x" Indicates Presence of the Particular Form "–" Indicates that the Lake Was Not Sampled, While "o" Indicates that the Organism Was Absent in the Samples).

Organism	Alleyne (0.01)	Taylor (0.01)	Gladstone (0.03)	Round (0.03)	Gallagher (0.07)	Spectacle (0.07)	Summit (0.10)	Lady King (0.10)
	A B C	A B C	A B C	A B C	A B C	A B C	A B C	A B C
Shrimp	– o o	x o o	– o o	x – o	x o o	x o o	x o o	x o o
Midge Larvae	x x x	x x x	x x x	x – x	x x x	x x x	x x o	x x o
Aquatic Earthworms	x x x	x x x	x x x	x – x	x x x	x x x	x x x	x x x
Leeches	o o o	o o o	x x o	o – o	o o o	x o x	x x x	o o x
Mayfly Nymphs	o o o	x x o	x o o	x – o	x o o	x x x	x o o	o o o
Dragonfly and Damselfly Nymphs	x o o	x x x	x x x	x – o	x o o	x x x	x o o	o o o
Freshwater Snails	x x x	x x x	x x x	x – o	x x x	x x x	x x o	x x x

A—Before treatment.
B—One month after treatment.
C—Nine months after treatment.

Midge larvae (*Chironomidae*) were present in all lakes initially as well as one month after application of Toxaphene. Nine months after treatment midge larvae were absent from Lady King and Summit Lakes (0.10) but present in the other lakes. This indicates that at a concentration of 0.10 p.p.m. Toxaphene, midge larvae are either eliminated or greatly reduced in abundance, with death apparently occuring somewhere between one and nine months.

Aquatic earthworms (*Oligochaeta*) were present in all lakes before and after treatment. Leeches (*Hirundinea*) although not taken in all samples were found in the two 0.10 p.p.m. Toxaphene treated lakes nine months after poisoning. It would therefore appear that these forms are unaffected at even the highest concentration of Toxaphene used in the experiments.

Mayfly nymphs (*Ephemeroptera*) were taken in six of the lakes prior to treatment but were absent in subsequent samples from all lakes except Taylor Lake (0.01 p.p.m.). This suggests that mayfly nymphs are killed by Toxaphene concentrations of 0.03 and greater.

Dragonfly and damselfly nymphs (*Odonata*), although taken initially in most lakes, were absent in later samples taken from both the 0.10 p.p.m. and one of the 0.07 p.p.m.

treated lakes. It would seem that a concentration of 0.07 p.p.m. is near the upper limit of tolerance for this group. Lethal effect of 0.10 p.p.m. concentration was amply demonstrated in the case of Summit Lake where numerous dead dragonfly larvae were found one month after application of 0.10 p.p.m. Toxaphene.

Freshwater snails (Gastropoda) were taken in most dredgings and appear to have been unaffected by the dosages of Toxaphene used in the experiments.

Plankton

In order to determine the effect of various Toxaphene concentrations on the more important planktonic groups, qualitative plankton sampling was carried out. The results are summarized in Table 5. Nine months after treatment, rotifers, flagellates and diatoms were present in all samples, with the exception of diatoms in Spectacle Lake (0.07 p.p.m.) (This exception could have been due to sampling error). It is concluded that rotifers, flagellates and diatoms are not adversely affected by the concentrations of Toxaphene used.

Cladocerans were present in all of the lakes following treatment, although one of the two forms was absent in some instances. These results suggest that this group is unaffected by the concentrations of Toxaphene used in the experiment.

It may be seen from Table 5 that occurrence of copepods was erratic. It is suggested that seasonal variation in abundance together with sampling error accounts for these results. In any case, copepods were taken at all concentrations, which indicates that this group is also tolerant of the Toxaphene concentrations used. The available evidence strongly suggests, therefore, that Toxaphene at the concentrations applied in this experiment, has no significant effect on the major planktonic forms.

Table V

Plankton Samples Taken Before and After Toxaphene Treatment.

("x" Indicates Presence of Particular Form, While "o" Indicates its Absence).

Organisms	Alleyne (0.01)	Taylor (0.01)	Gladstone (0.03)	Round (0.03)	Gallagher (0.07)	Spectacle (0.07)	Summit (0.10)	Lady King (0.10)
	A B C	A B C	A B C	A B C	A B C	A B C	A B C	A B C
Cladocera:								
Daphnia	o x x	x x x	x o x	x x o	x x o	x x x	x o o	x x x
Bosmina	x x x	x x x	x x x	x x x	x x x	x o x	x x x	x x x
Copepoda:								
Cyclops	x x x	x x o	x x o	x x x	x x o	x o x	x x o	x x x
Diaptomus	x x o	o o o	o o o	x o o	x x o	x o o	o o o	x o x
Nauplius larvae	x x x	x x o	x x x	o o x	x x x	x o x	x o o	x x x
Rotifera	x x x	x x x	x x x	x x x	x x x	x x x	x x x	x x x
Mastigophora (Flagellates)	x x x	x x x	x x x	x x x	x x x	x x x	x x x	x x x
Bacillariaceae (Diatoms)	x x x	x x x	x x x	x x x	x x x	x x o	x x x	x x x

A—Samples taken before poisoning.
B—Samples taken one month after poisoning.
C—Samples taken nine months after poisoning.

Discussion

Toxaphene is an inexpensive and effective fish toxicant at all concentrations used in the experiment. Since complete kills were obtained even at the lowest concentration, additional treatments will be undertaken using concentrations of 0.005 p.p.m. and 0.0075 p.p.m. Although the lakes were toxic to fish nine months after treatment, it is anticipated that they will be clear within a few months (two of the lakes treated with 0.10 p.p.m. Toxaphene were successfully stocked with fish two years later). Undoubtedly lakes having a continuous outflow would clear much more rapidly.

Prolonged toxicity can be an advantage and disadvantage to the fisheries manager. It may put a lake out of production for a year or more, but it also assures a complete kill, a result which was not always achieved by the use of other fish toxins.

Results of these experiments do not support previous findings (Hemphill, 1954) in which it was stated that waters with a pH of 8.0 or higher treated with a concentration of 0.10 p.p.m. Toxaphene were planted with fish within four weeks. Perhaps the lake referred to had a high flushing rate or the concentration of 0.10 p.p.m. referred to the total amount of commercial product containing a low percentage of Toxaphene.

The British Columbia Research Council was approached concerning the factors which might control the rate of breakdown of Toxaphene in lakes and the possibility of applying chemical neutralizers. Apparently, Toxaphene breakdown is governed by a complexity of factors in which acidity, sunlight, temperature and bacterial action may be involved. It is doubtful that breakdown could be governed by a specific chemical compound.

In general, Toxaphene shows promise as an inexpensive and effective fish toxicant, its value increasing as more information is collected on minimum doses and length of toxicity.

Acknowledgements

The authors gratefully acknowledge the guidance of Dr. C. C. Lindsey in planning the experiment, and the ingenuity of Stuart B. Smith in the design and construction of the distribution equipment. Invaluable assistance was also provided by Departmental personnel especially John Balkwell in applying the chemical.

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1954. Toxaphene as a fish toxin. Prog. Fish. Cult. Vol. 16, No. 1, pp. 41-42.

Abstract

Eight alkaline lakes in British Columbia were treated with Toxaphene at concentrations ranging from 0.10 p.p.m. to 0.01 p.p.m. Effects on fish, bottom fauna and plankton were evaluated. Most of the fish were killed in all concentrations within the first 120 hours. While a few fish were gill-netted, two to three weeks after treatment, none was netted in any of the lakes eight to nine months after poisoning. The lakes were still toxic to fish nine months after treatment as determined by live cage tests. Amphipods (shrimp) were eliminated at all concentrations and were still absent nine months after treatment. Dragonfly and damselfly nymphs were killed at a concentration of 0.03 p.p.m., while midge larvae were killed at concentrations of 0.03 p.p.m. and greater. No consistent adverse effects were noted with respect to plankton. Toxaphene was indicated as being an effective and economical fish toxicant; further work is being carried out with respect to more dilute concentrations and length of toxicity.

Review of Literature

"*Freshwater Fishery Biology*," by Karl F. Lagler, Wm. C. Brown Company, Publishers, Dubuque, Iowa, 1956; 434 pp., 214 figures. Cloth bound. $6.75.

The new enlarged edition contains the same 25 chapters and six appendices as that of 1952 volume, but fortunately several errors and omissions in the previous edition were corrected. However some minor omissions still exist. For instance, on pages 390-402 in *Appendix F*, dealing with the economic classification of freshwater fishes, several are not considered as sport species. In reality the following are taken regularly on hook and line and provide pleasant recreation: smelt, brown bullhead, American eel, sauger and American shad. To this list should be added two species of Pacific salmon (*Oncorhynchus*), coho and chinook (or spring), which are taken on line not only for sport but for commercial purposes as well. In the same *Appendix F*, it is not very clear to us why some anadromous fishes such as sturgeon species (*Acipenser*) are included in the list but others such as tomcod (*Microgadus*), or striped bass (*Roccus saxatilis*) are excluded. Moreover, several species of freshwater fishes are omitted from the list.

In chapters XVIII and XIX, dealing with *Fishery surveys of lakes*, some modern equipment such as echo sounding machines and bathy-thermographs should be mentioned. The section dealing with the *Methods of marking of fish* should be extended to include more recent types of tags, descriptions of which appeared after the publication of the review by Rounsefell and Kask (1946). In the section on *Enumeration of fish eggs* (pp. 106-111), the findings and techniques of more authors, especially recent ones, should be incorporated. A special section on stages of maturity of fish will be equally useful. Also, it would be advantageous for students to have the scientific term added after the common name under each figure of freshwater fishes, mentioned on pages 23-58.

The scientific nomenclature found in *Appendix F* (pp. 388-403) is up-to-date, including all new changes[1] in names of fishes, which were mostly suggested by Dr. R. M. Bailey.

Minor omissions, enumerated above, do not depreciate the real value of this book, already well-known from its earlier editions. Therefore, it is the reviewer's pleasure to recommend to everyone Dr. Lagler's volume, as a very useful and comprehensive treatise on freshwater fishery biology. Numerous illustrations, clear and comprehensive text, selected references at the end of each chapter, good paper all add to the attractiveness of the book. This new revised and enlarged editon is a "must" for every university library and biology teacher's desk—*Vadim D. Vladykov, Department of Fisheries, Quebec.*

[1] The reviewer, however, does not agree with many changes proposed by Dr. Bailey.