ISSUE TWELVE
JULY - - - 1952

THE CANADIAN FISH CULTURIST

p17

Published at Ottawa by
The Department of Fisheries of Canada

Sept 27/52

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.

A Brief History of the Development of Limnological and Freshwater Fisheries Research in Canada

by

W. A. Clemens

Head, Department of Zoology, University of British Columbia

A considerable number of men have been responsible for the initiation of freshwater studies in Canada but the names of only a few may be mentioned here. The first of these probably was Professor Ramsay Wright, head of the Department of Biology, University of Toronto, who in 1892 in a report of the Ontario Game and Fish Commission urged the desirability of a systematic survey of the provincial waters. The second was Professor Edward E. Prince, who as newly appointed Commissioner of Fisheries of Canada advocated in 1893 in his first formal report to the Minister of Marine and Fisheries, the great need for fishery investigations and the necessity for a laboratory. A further report was made in 1894. Professor A. P. Knight of Queen's University brought the matter before the Royal Society of Canada in 1895, and the support of the British Association for the Advancement of Science was obtained in 1897. Professor Ramsay Wright was also very active in these affairs.

As a result of the various presentations, financial provision was made by the Canadian Government in 1898 and the Atlantic Biological Station was established under a Board of Management. A short time later the Biological Board of Canada came into existence replacing the Board of Management.

Biological Station at Go-Home Bay

In 1901, the Madawaska Club, formed by members of the Faculty of the University of Toronto, received a money grant from the Canadian Government and established a biological station at Go-Home Bay on Georgian Bay not far from Midland, Ont. The prime movers were Professor R. R. Bensley, Professor C. H. C. Wright and Professor W. J. Loudon. Without doubt, Professor Ramsay Wright was active in the initiation of the project.

In 1903, the Madawaska Club relinquished responsibility for the operation of the station to the then Department of Marine and Fisheries so that it might be associated with the Atlantic Biological Station. It thus came presently under the Biological Board of Canada. Professor B. A. Bensley was in charge from 1902 to 1910, Professor E. M. Walker in 1911 and 1912 and Professor J. W. Mavor in 1913. The station continued in operation until 1913 when it was abandoned for various reasons.

Following the closure of the Go-Home Bay Station, Dr. B. A. Bensley began to seek ways and means for establishing some permanent organization for the biological investigation of Ontario waters. Finally, in 1920, he was able to bring about the

---

The papers presented in this issue formed a symposium on "The Role of Research in Fisheries Management" presented at the meeting of the Canadian Committee on Freshwater Fisheries Research held in Ottawa on January 2, 1952.

formation of the Ontario Fisheries Research Laboratory within the Department of Biology of the University of Toronto. Dr. W. A. Clemens was given direction of the laboratory and in that year Dr. J. R. Dymond was appointed assistant-director of the Royal Ontario Museum of Zoology and ichthyologist of the laboratory. The first location for field work was Lake Nipigon.

These two organizations, the Biological Board of Canada (now the Fisheries Research Board of Canada) and the Ontario Fisheries Research Laboratory have had a very great influence in the development of limnological and freshwater fisheries research in Canada. The former has undertaken and supported investigations in every province. It is pertinent to point out that the support of the idea of fisheries research came from the biologists of the universities and it was these biologists who gave of their time, thought and energies to the advancement of the work. This close association of the universities with the work of the Board has been continued to the present day with very great advantage both to the Board as a government organization and to the universities.

Many Trainees Join University Staffs

The latter (the Ontario Fisheries Research Laboratory) has trained young men who have gone out to positions in nearly every province. Very many of its trainees have joined the staff of the Fisheries Research Board of Canada at Nanaimo, B.C., Winnipeg, Man., and St. Andrews, N.B., and a considerable number the staffs of various universities, including those in British Columbia, Alberta, Saskatchewan, Western Ontario and New Brunswick.

But not all the training of freshwater biologists or limnological and freshwater fisheries research has been centred at or stemmed from the University of Toronto. More or less intensive programmes developed in many other universities either perhaps influenced to some degree by the activities of the Fisheries Research Board of Canada or the Ontario Fisheries Research Laboratory, or possibly quite independently. Programmes, for example, have been developed at the University of Manitoba, under Dr. O'Donoghue and Professor Wardle; the University of Western Ontario, under Dr. Detweiler; McMaster University, under Dr. Warren; Queen's University, under Dr. Knight and Dr. Curran; McGill University, under Dr. Willey; Dalhousie University, under Dr. Hayes; and the University of New Brunswick under Dr. Cox and Dr. Argue.

A more recent development has been the establishment of provincial organizations for the investigation and management of the freshwater fisheries. All the provinces except New Brunswick, Prince Edward Island and Newfoundland now have, or are in the process of forming, such organizations. In addition the Canadian Wildlife Service has instituted an organization for the study of fishery problems in the National Parks.

It is 60 years since Professor Ramsay Wright advocated a study of Ontario's waters. From a situation of practically no laboratories and no investigators there has been a development to a condition of about 20 laboratories and at least 100 investigators. In the early days, acquisition of knowledge concerning limnology and freshwater fisheries was slow; today it is proceeding at a very rapid rate.

Two types of organizations are involved in the field of fishery conservation. On the one hand there are the universities which are concerned primarily with fundamental research. On the other hand there are the government organizations concerned to a large degree with application.

To the universities largely falls the duty of providing much of the fundamental information and its synthesis. This obligation they should be able to accept because of their organization, their body of graduate students and their extensive library facilities. The universities should consider carefully their research programmes and plan sound programmes in fundamental researches because the governmental organizations need the results for sound application. It is most gratifying that the National Research Council and the Research Council of Ontario are supporting fundamental researches at the universities.

To the governmental organizations falls the duty of application and they should plan their application projects carefully and make provision for determining accurately the results of procedures put into effect.

The two fields of endeavour cannot and should not be completely divorced. Most organizations do have outlooks or programmes which combine the basic and the applied, but the development of the governmental organizations has more or less precipitated the desire for application. However, the great value of fisheries research lies in providing an understanding of nature's processes so that intelligent adjustments may be made to them. In these adjustments, the number of effective management practices may be relatively few. A careful consideration of the role of research in fisheries management is therefore both timely and appropriate.

BACK ISSUES WANTED

Such has been the demand for "The Canadian Fish Culturist" that the only back numbers now available are issues No. 11 and No. 12. Many requests continue to be received for earlier issues. Should any of those in receipt of "The Canadian Fish Culturist" have no use for their back copies we would appreciate the return of them to the Director, Information and Educational Service, Department of Fisheries, Ottawa, Canada.

Administration and Research

by

A. L. Pritchard and W. M. Sprules
Conservation and Development Service, Department of Fisheries of Canada

The title of the symposium of which this paper is a part was chosen in order that the role of research in fisheries management could be assessed and through critical review insure utilization of its full potential in future contributions to the development of sound management practices. It was suggested that each paper consider the subject under the following three sub-headings and stress one of these:

1. What has research done?
2. What are the present trends and future of research in management?
3. What does the administrator think of research?

The content of this paper is primarily to answer the provocative query presented by the last sub-heading.

In any discussion such as this, terms should be defined at the outset or, at least, the interpretation being placed on them should be indicated.

According to the Shorter Oxford Dictionary "research" is given two meanings: (*a*) "to look for facts" and (*b*) "to look for a solution to a problem". The former can be considered to define fundamental or "pure" research and the latter, applied research. Just as it is impossible to completely segregate these definitions because looking for facts might be a part of looking for a solution to a problem, so fundamental research can and, in fact, must form a part of applied research.

According to the same source, administration is (*a*) management, (*b*) management of public affairs, (*c*) management and disposal of an estate and (*d*) service. These selected meanings clearly indicate that administration is synonymous with management and thus an administrator may be considered a manager. Although the dictionary does not specifically refer to resources in its definition of administration, we might assume that management of a resource is similar to that of an estate—something willed to us—and therefore administration of a resource becomes the management and disposal of that resource. Since all will agree that the intent is not to dispose of the resource per se, the reference to disposal may imply the responsibility for distribution and disposal of the product, in this case fish, which must be assumed by the administration.

The term "service" as applied to administration indicates another duty. The administrative body associated with a scientific organization should be prepared to give aid to the scientists in any way to enable them to pursue their research relatively unhampered.

Relationship Between Administration and Research

From the definitions submitted, it is apparent that research is a part of the administration of any resource. It is true that research may constitute a large proportion particularly if it is considered to embody the findings of specialists other than biologists such as chemists, engineers, economists, lawyers, sociologists and others. The art of reconciling all the opposites of any problem—political, social, economic and other phases—must not be discounted and in this, the administrator must be adept to be successful.

The Time Factor

Undoubtedly one of the most obvious differences between administrators and research workers lies in the consideration given to the time factor. The administrator generally works under pressure and must act now. Scientists, on the other hand, like to be free to set their own pace, feeling that if their efforts are rushed, the quality of their contribution will suffer. Fault cannot be found with these different attitudes. Administrators recognize the soundness of the scientist's desire to have time and freedom to carry out a thorough investigation. On the other hand, the scientist should recognize that administration must go forward, and to effect this advance time must be "of the essence". The solution, which would satisfy the desires of both groups, would seem to be adherence to a middle "time-path".

Attitude to "Directed Research"

Another difference between administrators and scientists seems to be the attitude toward "directed research". The administrator is confronted with problems, generally on short notice, which require additional scientific information for solution. At such times the administrator desires to direct the activities of the research organization toward such top priority problems but often the scientists appear hesitant to accept the commission although during periods of national emergency scientists of all types do take up the challenge to seek solutions to problems of vital importance, often with time a limiting factor, and pursue directed research with the same zeal which is displayed when fundamental research is being followed with a free rein. When natural resources are at stake the emergency is still national but in a restricted sense, since failure to produce data which would ensure sound management practice, could mean the loss of a valuable resource rather than the loss of a country.

Desire for "Informed Guesses"

Still another difference, perhaps also related to the time factor, lies in the desire of the administrator to have available for use, interim conclusions or "informed guesses" at a comparatively early stage in any investigation while the scientist rightly wishes to be absolutely sure of his findings before drawing any conclusion. There is little doubt, however, that there are many occasions when the scientist, having accumulated groups of data which suggest an hypothesis, could make an "informed guess" which should be passed on to his administration for background information. This should be accepted with full realization of its limitations. It may not be necessary for the administrator to use this immediately but if, as often happens, it is necessary to take a stand, a better decision will result through availability of this information. At least the administrator would take the step with more confidence than would be possible if the scientist did not provide him with such an "informed guess".

If properly handled, it is unlikely that the scientist's professional reputation could be damaged as a result of following the procedure outlined above. The "informed guess" would be submitted as a progress report only and not for circulation or publication. Publication would follow the completion of his research at which time the work would receive the criticism of other workers in the field. Only at this time would the scientist's professional reputation be under consideration. It is interesting to surmise what might happen should the "informed guess" prove to be wrong and yet have been used as the basis for a decision made by administration. The responsible administrator will have used this information fully realizing its possible limitations and will be prepared to rise or fall with the decision he has made. The scientist should not be held directly responsible. The fact that the guess and the decision proved to be wrong would no doubt initiate further action and an impetus would be given to related research. The subsequent concentration of effort would likely lead to an early discovery of additional facts which would solve the problem. Thus the original guess, although wrong, would be directly responsible for the resultant progress and the original investigator's reputation would not be damaged but enhanced.

It should not be implied that administrators advocate the establishment of management practices based on "informed guesses" alone. If final conclusions are available, they should certainly be used. On the other hand in some cases management procedures seem essential now rather than later when it may be too late to save the resource. The administrator during his active period must become expert in the art of the possible and lives with his contribution. Like the actor, his worth dies with him. On the other hand, in many cases the scientist, like the poet, may leave a monument to posterity—a reputation, a valuable treatise or a scientific law. Too often he is unrecognized during his active period and is unable to live with his contribution.

Sound Recommendations for Administrator

Although the common objectives of fisheries research such as ascertaining fundamental biological data, determining life histories and effects of environmental factors on certain species and the development of management techniques are recognized by scientists, other objectives of extreme importance are sometimes forgotten. One of these is to provide sound recommendations, based on the findings of research, for the use of the administrator. Generally, a scientific report is submitted consisting of methods, data and conclusions. The conclusions in many cases are not recommendations and the administrator is left with the task of interpreting the data and conclusions to fit his problem. This is not an efficient procedure since the scientist is familiar with his subject and is most competent to interpret the data fully and provide recommendations for desired action. His data or conclusions could be distorted by forcing someone less capable to perform this duty. Fortunately, the recent swing toward applied research in fisheries has done a great deal to alleviate this problem. Now administrators are usually supplied with a series of recommendations which may be readily considered, modified if required and translated into practice within a comparatively short time.

Under the present system the scientist is dependent on the administrator, in one way or another to insure a supply of funds for the continuation of his research. Natural resources are a public responsibility and money required to employ and outfit the scientist must come from public funds. The administrative body should be specially trained to provide this service and acts as liaison between the research worker and the source of funds. To carry out this task it seems essential that the administrator must be supplied by the scientist with concise recommendations for improvement of the status of the resource based on the findings of his research. Early application of results, or a suggested practical application by the scientist makes it much easier to obtain funds. Experience has shown that support is readily forthcoming if the contributing body, in this instance the public, can be shown that there is a possibility of dividend payment on the investment either for self, community or country.

Value of Demonstrating Management Practices

The value of demonstrating management practices even on a small scale, cannot be overestimated. In most cases regulations concomitant with management of a resource in some way affect the industry. Industry has a large investment dependent on the resource and thus it is difficult for it to take a long-range view of the value of conservation unless the necessity for this can be demonstrated. Once the demonstration is made through application of scientific results and the value of the practice becomes demonstrable or evident, most industries will back the measures to the fullest extent. One proven application will do much more to convince the public and the industry of the value of research and management practices, than two or more worthy treatises which do not go beyond the publication of data and theory stages and which can only be properly assessed or interpreted by specialists in the particular science.

Although there have been instances when administrators and scientists were prone to discount each other's work and value in the management of our fisheries resource, it is now commonly recognized that both are essential and their work interdependent, since generally a single solution to a mutual problem is required.

What Has Research Done?

Certainly a most significant contribution to fisheries management has been made by scientists through the wealth of knowledge pertaining to the habits, requirements, distribution, movements and availability of many species, which has resulted from research programmes carried out across the country.

There are many examples of this important contribution and to list these would be a tremendous task. However, the Great Slave Lake investigation and experiment is worthy of special mention in the field of freshwater fishery research. In this instance preliminary limnological investigations were carried out followed by population studies and finally through the co-operative researches of several scientists, estimates of excess crop were made and sound recommendations were submitted to the administrative body, which led to the development of one of our most important freshwater fisheries. A great deal of valuable information relative to the management of a fishery resource has been obtained from this research and if the practice initiated withstands the trials of time, a pattern may well be formed for the successful management of many inland lakes of commercial importance.

Present Trends and the Future of Research in Management

The term management has become linked with the administration of natural resources only recently but an historical review of the development of any resource shows that controls of one kind or another have been applied from early times. Generally these were intended to insure preservation, but often they were not too soundly based. Today the pressing need for management in our fisheries is recognized since experience has shown that without proper management the resource may decline. There are several well-known instances of specific species where the decline has proceeded to at least economic extinction.

The modern concept of conservation as applied to renewable resources, includes within the definition of the term such expressions as "wise use" or "sustained yield" which indicate that a crop is produced and that the excess crop should be harvested. Management may be described as any practice which is based on the control of any factor which might affect the resource, with a view to maintaining or increasing the yield. The present trend is toward environmental control and improvement. This has shown most encouraging results, perhaps better than were obtained from methods previously followed.

The future trends which may be followed in the management of any resource cannot be forecast exactly but it is obvious, from the contributions that have been made and from an appreciation of the many scientific data which are wanting, that research will continue to be of paramount importance in forming a solid framework on which improved management practices may be based. Such investigations must be carried out by scientists specially trained in modern research methods. However, if advances are to be made quickly, it would appear that there must be more thought given to the application of results, for management implies action and thus is dependent on application.

What Does the Administrator Think of Research?

The administration of any natural resource cannot be efficiently performed unless those responsible have available the most recent scientific data pertaining to the resource. In every instance, the administrator recognizes his limitations in connection with the procurement of such data and acknowledges his dependence upon specially trained scientists and the findings of research. Experience has shown that administrative policies based on the findings of sound research withstand the pressure of criticism much more readily than those formulated without such a basis. For these reasons the administrator should openly commend the scientist for his worthy contributions and conversely should criticise a research or contribution which in some way falls short of the possible goal. The goal should, however, not be that set by the administrator but the one which could have been attained had the scientist submitted definite recommendations even if these fell into the category of an "informed guess".

The administrator fully appreciates the contribution of research but perhaps views it in different perspective from the scientist engaged in its prosecution. To the administrator it is part of a whole which must be fitted into a sequence which should consist of three stages:

1. The fundamental research stage in which the scientist gathers facts and assembles them to form hypotheses.
2. The "pilot plant" stage where the hypotheses are tested in the field under the supervision of the scientist.
3. The applied stage where action is taken to implement the findings on a general scale with a view to the maintenance of improvement of the resource.

Too often reference is made to the expression "administration versus research", which implies conflict. There is no struggle. One cannot exist without the other. Let us properly associate these in the future and refer to "administration *and* research" in order to stress the fact that each is essential to the development of sound management of the resource.

A forward step, which should dispel any possible idea of incompatability between the administrator and the scientist, has been taken recently with scientists accepting administrative positions. It seems that administration has presented a challenge to these individuals and incited them to accept additional responsibilities in the hope that they might have an opportunity to apply scientific knowledge and contribute more directly to the formation of necessary legislation and regulation, which lead to sound management practices.

The Role of Research in the Management of Freshwater Fisheries in British Columbia

by

P. A. Larkin
British Columbia Game Commission

There are at least three organizations in British Columbia that are interested in applying research findings to freshwater fisheries management:

1. The Department of Fisheries of Canada; with the Pacific Biological Station of the Fisheries Research Board of Canada as its research division and the Fish Cultural Development Branch of the Department's Conservation and Development Service for application of research findings to management of salmon in fresh water stages.
2. The International Pacific Salmon Fisheries Commission. Research and application of research to management of sockeye salmon of the Fraser River system.
3. The British Columbia Game Department. Research and application of research to management of sport fisheries chiefly in non-tidal waters.

These organizations are not comparable insofar as the division of interest into research and management is concerned.

The Pacific Biological Station and the Fish Cultural Development Branch are presumably complementary in the research and management phases of salmon culture. At the present time, the Fish Cultural Development Branch (and the International Salmon Commission and the British Columbia Game Department) is largely occupied with fisheries problems attending the many and varied recent industrial and power developments in British Columbia. Research findings on the effects on fisheries of industrial and power developments have been borrowed from nearby states such as Washington, Oregon and California, but there is a notable lack of information on the environmental physiology of salmon. This lack is reflected in the recent planning of extensive investigation of upstream and downstream migration by the United States Fish and Wildlife Service in conjunction with various state agencies.

Except for obvious protection measures such as screening of irrigation diversions and elimination of obstacles in streams, lake and stream improvement work has not been developed by the Fish Cultural Development Branch, possibly because of the lack of published information on the success or failure of the many techniques that have been suggested or attempted.

Significance of High Mortalities

Research at the Pacific Biological Station has provided valuable insight into many aspects of the life history of salmon, particularly indicating the significance of high mortalities in fresh water stages, but there have been few attempts to evaluate province-wide problems and to turn the research findings into the production of more salmon. For instance, work at Cultus Lake has suggested that netting of squawfish may result in higher escapement of smolts, but this study has not been evaluated or attempted at the province-wide management level.

Recently, the Pacific Biological Station and the Fish Culture Development Branch have devised extensive plans for collecting information on representative salmon streams and as the synthesis of this material indicates the common and important problems, the research and improvement programmes will no doubt be given new impetus. In this regard particular optimism might be placed in the avenues of management suggested by the intensive studies on factors affecting survival in the egg and fry stages. Application of such studies on a scale sufficient to affect commercial production is contemplated in the near future.

Intensive studies at Lakelse are notable for the plan for evaluation of trout and salmon interrelations—a study which is greatly needed as a preliminary step in the establishment of management programmes satisfactory to both commercial and sport fishing interests.

The International Sockeye Salmon Commission has directed the greater part of its management programme on the basis of investigation and survey findings pertinent to the recurrence of dominant year classes and the times of migration of the runs of salmon to the various tributaries of the Fraser. Thus the commercial fishery for sockeye is regulated as far as possible to allow adequate escapement of each run. Similarly, the time of migration in relation to water temperature and the subsequent success of spawning and hatching has been emphasized in assessing effects of industrial and power development. In addition, attempts are being made to rehabilitate runs (for example in the Quesnel system) but to a large extent these efforts are not based on previous experience of the factors concerned with perpetuation of runs.

Surveying Sports Fisheries Problems

The British Columbia Game Department has set up a Fisheries Research Group which is largely concerned at the present time with surveying sports fisheries problems with the object of indicating lines of research which would lead to productive management practices. To a large extent the survey work is directed to examination of the relationship between lake productivity and quality and quantity of sport fish produced, although other surveys on life histories of the fish, surveys of parasites and studies of environmental physiology, are being sponsored or assisted. Several lines of research which may eventually indicate sound practices of improvement have been prompted by the surveys to date. The following are typical:

1. Most oligotrophic British Columbia lakes are conspicuously deficient of profundal crustacea such as *Mysis relicta*, *Neomysis mercedis* and *Pontoporeia affinis*. Research studies on temperature, salinity and oxygen tolerance have given encouragement to the experimental transfers of these organisms to British Columbia lakes.
2. Pursuant to the work done by Mottley on Paul lake the relation between lake productivity, population size and rate of growth has been surveyed in a large number of British Columbia lakes. Accordingly, a number of experimental stocking programmes have been started, and preliminary results have suggested that stocking may be highly effective in many lakes in which there are inadequate spawning areas.

A research programme of directly applicable nature has recently been conducted by the Institute of Oceanography at the University of British Columbia. The

Consolidated Mining and Smelting Company planned power development on Trout Lake and mining mill operations on Kootenay Lake and in each instance a study of the current distribution in Kootenay Lake was required. The Institute developed a picture of water movements by the study of temperature distributions and these findings will be reflected in recommendations to the company.

Some of the greatest research needs in British Columbia fisheries management at present are best classified in the fields of environmental and internal physiology. The great progress of these studies in the past few years at the University of British Columbia, chiefly under Dr. W. S. Hoar, has been most fortunate and has given promise of the development of many new and ingenious management possibilities. The researches of Dr. E. C. Black and Mrs. Black in these fields are also notable.

In the overall picture of the role of research in freshwater fisheries management in British Columbia one might observe that a considerable quantity of research material is at hand and many organizations are beginning to venture more broadly into the field of management. The first result has been the realization of new and different research needs. As yet there are relatively few instances in which research has been applied to the amelioration of existing conditions and in which economically justified benefit has been demonstrated.

The Role of Research in Fisheries Management in the Prairie Provinces

by

Richard B. Miller
Professor of Zoology, University of Alberta

The title of this paper should read "in Alberta" rather than "in the Prairie Provinces". I can write with first-hand knowledge only of Alberta and pressure of other duties has prevented me from taking time to study the situation in Saskatchewan and Manitoba. However, the problems of management are very similar in the three provinces and what is true in Alberta should hold very well for the other two provinces.

Preliminary Surveys

The first task in fisheries management is a routine one. It consists of collecting standard limnological data on the lakes and streams of the area; and also sampling the fish populations of the waters in order to obtain a rough idea of species present, their distribution, rates of growth, feeding and spawning habits. Next comes the administrative task of deciding what is the most desirable use of each lake and stream or group of lakes and streams; i.e., what species to stock, if any, the resolution of conflicting interests of sportsmen and commercial fishermen; setting poundage limits and net sizes in commercial areas, and seasons, size and catch limits in angling areas. These are complex and often difficult problems which require both the experienced administrator and the biologist to solve. In most cases the solution must be a compromise between economic or political interests and biological interests (a fact which the enthusiastic biologist should learn early in his career).

In the development of a management procedure based on preliminary biological surveys, many problems arise which cannot be settled because not enough facts are at hand. In this way research problems are born and the biologist proceeds from general surveys to intensive work on specific problems. These problems fall generally into two groups, management procedures in commercial fisheries and management procedures in sport fisheries. The remainder of this paper will deal with some of each of these kinds of problems. But first, it should be said, that, in the Prairie Provinces, scientific fisheries management is in its infancy; for the most part, the work is still in the preliminary survey stages and the research problems, though pressing, are only beginning to be tackled. This lack of progress is not due entirely to the short time that has elapsed since work began; a large part of it is due to the enormous areas involved and the small number of biologists available; in the Prairie Provinces Dr. D. S. Rawson and I are the only two biologists who have been working on fisheries problems for any great time. Recently we have been reinforced by the Central Fisheries Research Station of the Fisheries Research Board of Canada in Winnipeg (1945), but little of its time is spent on provincial administrative problems.

Management Procedures in Commercial Fisheries

The lakes of the prairies produce whitefish as their most valuable crop, with ciscoes, pikeperch, perch and pike as secondary crops. North, in the forested areas, and on the Precambrian shield, the whitefish are joined by lake trout as the principal crop. The role of research in these fisheries is the solution of the following problems: proper size of mesh of gill nets, total annual poundage that may be safely removed, length and date of closed seasons, best methods of handling the catch, the use of the hatchery, effects of one-sided exploitation of lakes (i.e., do suckers increase when their competitors, the whitefish, are removed by fishing?), and other problems many of which boil down to the perennial problem, the determination of that elusive quantity, the optimum yield. On the prairies, and in certain other areas, a major problem exists in the parasite, *Triaenophorus crassus*, which has a profound effect on the marketability of whitefish and ciscoes. As a review of this whole situation is currently being prepared, and as it is a lengthy subject, no further mention of it is made in this paper. Some of the problems mentioned above are now discussed.

What is the optimum yield? It is up to the research worker in fisheries to give some advice to the administrator on how many fish should be removed each year from each lake, and what sizes or age groups should be included in the catch. Nowhere has research proceeded far enough to answer this problem for any one fishery (with the possible exception of the Pacific halibut fishery). The answer will be different for each species of fish, possibly in each lake or type of lake. It is determined by growth rates, natural mortality rates and rates of recruitment of young fish. If these rates were constant for any fishery the optimum catch might readily be determined as Dr. W. E. Ricker has recently pointed out. Unfortunately, these are not constants but seem to be, at least partly, a function of fishing pressure. In Alberta, Pigeon Lake was used in an experiment to obtain facts useful for determining the optimum catch (or maximum sustained yield). A brief review of the Pigeon Lake work may not be out of place here. This lake, of about 25 square miles, contains whitefish, suckers, pikeperch, pike and perch. Since 1918 the whitefish have been fished commercially; the average annual yield up to 1940 was 179,000 pounds, and the range 150,000–200,000 pounds. In 1941 the 150,000 pound limit on the catch was removed and more or less unrestricted fishing was allowed. The catch rose spectacularly to over three times the previous annual average and remained there for six years; the seventh year intensive fishing failed to get large returns, i.e., the fishery had collapsed. The catches are shown in Table 1.

Table I.

Whitefish Produced in Pigeon Lake, 1941-1950

Year	Catch (lbs.)	Year	Catch (lbs.)
1941	582,900	1946	350,000
1942	354,600	1947	160,000
1943	340,000	1948	closed
1944	485,000	1949	closed
1945	411,000	1950	66,000

In 1948 and 1949 the lake was closed; in 1950 fishing was again permitted on a small scale.

All fishing was done with 5½-inch, stretched mesh, gill nets. A total of 1,594 fish were removed throughout the experiment as samples. From these the age composition and growth rate of the catch were determined. In 1942 the catch was of five- and six-year-olds. In October, 1947, when the fishery collapsed, 74·5 per cent of the fish were two-year-olds. These two-year-olds were mature spawning fish; in 1942 the fish did not mature until their fourth or fifth year.

The fish increased considerably in growth rate. In 1942 a three-year-old was 13·7 inches (fork length) and about 1·5 pounds in weight; in 1947 a three-year-old was 16·5 inches long and weighed 2·2 pounds. Since 1947 the growth rate has decreased again to almost the 1942 level; this is due to a very large population of unexploited young fish.

This experiment, still in progress, has yielded some information of value to management. Thus, the critical point in the fishery appears to be when the 5½-inch nets take over 35 per cent four-year-old and younger fish. It is also clear that a lake may be overfished with large-mesh nets; this is because as the older fish are taken, the more recent year classes increase in growth rate until the nets take them at a younger age; this process continues until the limit of growth rate increase is reached, at which point only one- and two-year-old fish remain in the lake. Finally this experiment demonstrates that recruitment rate and growth cannot be regarded as even approximate constants for purposes of calculating the optimum catch.

(It is interesting to note that Lake Wabamum, similar in size to Pigeon Lake, also collapsed after six years of overfishing; in 1942, the year after its collapse, 69 per cent of the fish were four-year-olds or younger.)

Another study which has a bearing on the problem of the optimum catch has been the Lesser Slave Lake cisco experiment. In an effort to control *Triaenophorus* infection the tullibee of Lesser Slave Lake have been exploited almost without restriction since 1940-41. Catches rose to over one and one-half million pounds in the first year of the experiment; they continued between 1·5 and two million to 1946–47 when the catch increased to 3·5 million and has remained at that level. The tullibees have responded by greatly increased growth rates and by spawning at younger and younger ages (until now they mature in the second summer). In spite of this response the population has become younger and younger; in 1941 the catch was largely five, six- and seven-year old fish; now it is of 80–90 per cent two-year-olds and has been since 1947. In spite of this critical situation the fishery continues productive although it appears that a spawning failure would cause a collapse in one year. In 1941 a study of this fishery based on catch curves and growth rates would have led to the conclusion that exploitation was at a maximum; however, the fishery has proven it could stand three times as much pressure over a long period.

It is apparent from the foregoing two experiments that an important role for research in fisheries management is the elucidation of population dynamics in commercial fisheries.

Mesh Sizes

The problem of gill net sizes is bound up with the optimum catch; there is some evidence that mesh size is not as important as formerly believed; i.e., if a given mesh size takes fish before they reach spawning age, the population will adjust to the situation and begin spawning at younger ages. However, mesh size is important in that it determines the size of fish taken for the market. The best mesh size must be a compromise between the best size of fish for the market and the biological factors in the lake. Research is required on the effect of different mesh sizes; such research is really part of the large problem of population dynamics. Optimum mesh sizes may be calculated on the assumption of constant rates of growth and mortality (Ricker's method); Dr. W. A. Kennedy has done this for Lake Manitoba. However, such calculations are open to question because of the probable variable nature of the assumed constants. Actual experiment is needed.

Research is also needed on the effect of thread size and the use of different materials such as linen, cotton, and nylon. It appears from present knowledge that as finer thread is used greater catches result and these increased catches are due to smaller and younger fish being taken.

Role of the Hatchery

The commercial hatchery for whitefish and pikeperch is still in wide use. Research in Alberta on the whitefish hatchery over a period of more than ten years and including seven lakes has shown conclusively that, in lakes where whitefish spawn, the hatchery is without measurable effect. Of the seven lakes studied some were planted in even-numbered years and others in odd-numbered years. Variations in year class strengths proved to be the same in all lakes, irrespective of stocking history; the variations appear to be related to climatic factors. As a result of this work the Alberta whitefish hatchery was closed.

Trouble Shooting

A large part of a fishery biologist's time is occupied with what is best described as "trouble shooting". It is my understanding that Saskatchewan has appreciated that a research man cannot continually desert a project to engage in trouble shooting, and have included personnel in their administration specifically for such work. The trouble-shooter is a biologist that the administration leans on when a ticklish political situation develops; such situations are conflict of interests between commercial fishermen and fur farmers or between either the latter or former and anglers, or perhaps all three interests may be involved. Often a disinterested appraisal of the facts from the biological viewpoint reveals that no real conflict exists. While such work is hardly research it is valuable and necessary. Occasionally a true case of conflicting interests may turn up. Then it is the biologist's task to advise which interest is to be excluded. This may involve research in the true sense. One interesting example is Cold Lake on the Saskatchewan-Alberta border. At one time a mecca for lake trout sport fishermen it degenerated to a mediocre commercial fishery for whitefish with the occasional trout turning up. An investigation of the growth rates of the whitefish and trout convinced the administrations of both provinces that the lake would be more valuable if the sport fishery for lake trout could be restored. The lake was closed to commercial fishing in the belief that the lake trout would come back. There is some evidence that this belief will be justified.

Management Procedures in Sport Fisheries

The problems of sport fish management are too numerous and complex to cover in detail in this paper. In order to narrow the field to the point where it may be dealt with adequately, I have restricted my discussion to trout streams. Alberta, in particular, has many thousands of miles of excellent trout water on the eastern slopes of the Rocky Mountains. This water is of incalculable value to the prairie farmer for irrigation; power interests are also involved. The sport fishing value of the water is, unfortunately, of secondary importance, perhaps not real, but certainly fancied. Here the role of the fishery biologists is to try and salvage as much fishing as possible in waters used for power and irrigation. Often, if advised in time, the management of large water projects will provide for fishing interests as far as they are able. Dates of raising or lowering impoundment levels may be altered to suit spawning and/or migrating habits of fish; fish ladders may be installed if needed. Dr. Rawson, in a study of the Bow River impoundments, found no evidence that the alterations in the river had seriously reduced fishing; in fact, the additional acreages of water could well lead to increased fishing as it obviously has in the Tennessee Valley.

In the management of unaltered trout streams there is room for a great deal of research. The standard management procedure such as hatchery stocking, legal minimum size limits, closure of feeder streams and closed seasons are based largely on tradition; there is little or no evidence of their value. Many research projects could arise from a study of the efficacy of these standard procedures. Some of them I wish to discuss a little more fully.

The Use of the Hatchery

Since the hatchery is the most expensive tool in modern sport fish management, it is clearly the duty of the fishery biologist to see that it is operated efficiently; this involves testing the efficacy of the procedures commonly used. Little such testing has been done in Canada. In the United States a large body of evidence now exists showing that trout stocked in streams which support spawning wild trout do not survive. Even large trout, over seven inches, seldom come through the first winter. Here is a problem for the biologist; why do these trout die? In Alberta a biological station has been set up as a joint project of the University and the Government. The station is located on the east slope in typical trout stream country. Trout of varying hatchery backgrounds have been planted in a test stream in three-quarter-mile enclosures. Each trout so planted has been weighed and given a numbered Petersen tag just before planting. The trout have been recaptured and reweighed as often as possible and, of course, all mortality has been recorded. It has been found that, of legal-sized trout, about one-third died in the first two weeks following planting due to exhaustion in the new environment. The survivors steadily lose weight; this weight loss seems to result from unsuccessful competition with wild trout in the stream. After 40 days the hatchery fish stop losing and, by 100 days, have almost regained planted weights. However, they are thin compared to wild trout and in no condition to winter. Smaller trout suffer more severely; about half die of exhaustion in the first two weeks; the survivors die of starvation by freeze-up. The question arises, is this death from exhaustion or slow starvation a property of hatchery fish or would any fish (e.g. "wild" trout) transplanted to a new environment suffer in a similar fashion? The station answered this question during the summer of 1951 by transplanting tagged, wild trout to an experimental stream enclosure. Such trout did not die of exhaustion; they did lose a small amount of weight, negligible in comparison to the amount lost by hatchery fish. Thus it is the hatchery which produces weak trout. It is up to the fishery biologist to develop hatchery procedures which will produce strong trout.

We [illegible] Trout [illegible] 5 [illegible] old

Legal Size

The enforcement of a minimum size for "keeper" trout is a time-honoured management procedure. It is designed, presumably, to allow fish to spawn at least once before capture. ? The biologist can clearly perceive that this is a fallacious policy. It is his duty to gather proof of the fallacy and convince the administrators (and the public). For example, in one Alberta trout stream trout seldom reach eight inches; they mature and spawn at lengths of five inches and weights of 1·5 ounces. No trout could be legally taken. In another stream, part of the same drainage, trout reach 10 inches and a pound in weight in their second summer; in certain lakes the trout reach 2·5 pounds in their second summer; such trout are immature. The eight-inch minimum allows their capture, but they have not spawned. The law is obviously absurd. To be biologically sound each tributary would require a separate legal minimum.

But is it sound to protect immature fish? In Alberta streams it has been found that annual mortality is at least 60 per cent. Thus, of 100 trout as fry, 40 survive to yearlings, 16 survive to two-year-olds, six survive to three-year-olds, not quite three to four-year-olds. If four-year-olds are mature, and therefore legal, it means the angler has a chance at less than three per cent of the population; further, it means the angler is forced to select from the brood stock for his creel. He is being forced to deplete the most essential part of the population. It would be more logical to make the angler select from the more abundant younger fish.

As a result of the foregoing facts and arguments, the size limit has been removed in Alberta. It is now up to the biologist to look for any changes in stream population which may result from this move.

The Feeder Stream Theory

The belief that main-stream trout move into tributaries to spawn has led to the almost universal practice of keeping tributaries closed in the belief that they "stock" the larger rivers. Research in Alberta has shown that this is not true. River dwelling trout do not spend their youth in tributaries; while the parent trout may ascend tributaries to spawn the resulting young desert the tributaries as fry or fingerlings. Small fish commonly seen in tributaries are not younger than the fish in rivers; they are mature tributary-dwelling trout which grow more slowly than fish in the rivers.

Closed Seasons

[illegible]

Should sport fish be protected during spawning? There seems no logical reason for the answer to be yes. The custom of closing streams during spawning appears to have arisen from the conspicuousness of the gonads at spawning time; anglers note the ripe eggs and feel it a shame to kill a potential mother. However, the potential young lost by killing a fish in June are of the same quantity and just as dead as if they were killed in September (in, for example, a brook trout). As no Alberta sport fish guard their eggs or young no reason for protection is evident. Alberta is now trying year-round fishing on some waters. The values of such a policy are simplified law enforcement and the elimination of the opening day "beating" which streams formerly received; in general the distribution of fishing pressure is more even.

New Management Procedures

So far, on the prairies, the role of the biologist has often been the detection of fallacies in existing methods. He has ridiculed the hatchery and pulled management legislation to pieces. To be of real value, the biologist must contribute something constructive to sport fish management. It has already been suggested that it is up to the biologist to find out how to grow strong fish in hatcheries. It is also up to the biologist to search for and test new watershed management procedures. For example, a new scheme will be tried in Alberta beginning in 1952. The east slope has been divided into areas according to the growth rate of the fish. Slow growth areas are subdivided into thirds; one third will be open each year; in this way each third of the area will receive two years rest out of every three in the hope that natural reproduction and growth will restore an attractive angling population. Fast growth areas are divided into halves. Each half will be open one year and closed the next. By careful choice of areas it is hoped to provide maximum fishing in every part of the province without endangering future supplies.

Summary

Given the title "The Role of Research in Fisheries Management", it is necessary to write a paper of book-size to give anything approaching adequate treatment. But when the paper is one of nine others, all to be presented the same afternoon, adequate treatment is manifestly impossible. The discussion in this paper has, therefore, been confined to certain aspects of the commercial fisheries of the Prairie Provinces and to the sport fishery for trout on the east slopes of the Rocky Mountains in Alberta. The main roles of research brought out in the paper may be summarized as follows:

A. Preliminary survey of resources both sporting and commercial; based on the survey, tentative assignment of seasons, quotas, creel limits, etc. The recognition of major research problems and the laying of plans for their attack.

B. Commercial fishery research problems.

1. Research into the dynamics of fish populations designed to yield information on: proper mesh size of gill nets, thread size and thread material in gill nets; proper age composition of the commercial catch; effect of exploitation of favoured fishes on their less-favoured competitors; effect of fishing pressure on growth rates, mortality rates and recruitment.
2. The solution of the *Triaenophorus* problem.
3. The value of the commercial hatchery.
4. Wisest use of a fishery (conflicts between commercial fishermen, anglers, fur breeders.)

C. Sport fishery research problems.

1. How to rear hatchery fish that will survive in streams.
2. Search for new trout stream management methods to replace useless legislation on minimum sizes, closed feeder streams, protection during spawning.
3. The best use of reservoirs and impoundments created primarily for irrigation and/or power.

The Role of Research in Fisheries Management in Ontario from the Research Point of View

by

F. E. J. Fry

Ontario Fisheries Research Laboratory, Department of Zoology, University of Toronto

The activities in fisheries research as carried on in Ontario may be broadly divided into three strata. The most fundamental and generalized attacks are made by the University groups of which there are five, one at each of the Universities and one at the Royal Ontario Museum of Zoology. These are supported by the Provincial Department of Education, the Research Council of Ontario, the Ontario Department of Lands and Forests and the National Research Council.

These University groups are engaged in unravelling the facts of life in the aquatic world. They are determining how many kinds of animals and plants there actually are in our waters. They are learning how these organisms live together in their aquatic communities. They measure the amount of sunlight, the sole and still mysterious source of energy for the maintenance of all life, that reaches the lake surface and penetrates into the depths below. They determine the amounts of the minerals which are essential to the life of animals, and plants, that leached from the watershed, circulate from one organism to another for a while and then are ultimately deposited on the bottom or pass down to the sea.

The second stratum of researches comprises those which are aimed at solving problems that have particular reference to a geographical region, the Province of Ontario. These are carried out for the greatest part by the Research Division of the Ontario Department of Lands and Forests. For example, the fisheries group in this division gather information on the life histories of our important game and commercial fishes. At the present time they are investigating the spawning of lake and speckled trout with particular reference to the conditions on the spawning beds and the effect of changes in water levels.

The effects of fishing on various stocks of fish are also being investigated. A large scale experiment on commercial and coarse fish is being carried out by the Research Division in South Bay, Manitoulin Island.

A third major project, which has occupied the Research Division in recent years, is a thorough test of the effects of commercial fertilizer on the growth of fish and the plants and animals which support them. These tests were particularly necessary from a regional point of view since our relatively infertile and ice-bound lakes present conditions greatly different from the southern ponds in which most of the original work on fertilization was carried out. It has turned out that fertilization according to recommended procedure is most unsuitable for our waters. In consequence, research here on this subject is seeking ways of modifiying fertilization practices to suit our special needs. At the present time attention is being given to liming of lakes in the lime-poor Precambrian Shield region.

The third division of research responsibility—that of more limited investigations of local situations to help in the immediate application of a management practice—is being dealt with in the following article, so will not be included here.

These three divisions of the responsibility for research appear to represent a very real and valuable outcome of the principle of division of labour rather than just the chance result of administrative convenience, for the results in each field as outlined find their practical application in the next. The results of fundamental research have their immediate practical application in higher education where they provide background which enables research workers engaged on regional problems to attack these in the most efficient manner open to their generation. The results of the regional investigations provide the local investigator with an outline of events which can often be rapidly modified to provide a full understanding of the local situation. Thus all steps are essential and all properly should be carried out by different personnel for it is the rare human who can operate on more than one plane of thought.

The Role of Research in Fisheries Management in Ontario from the Management Point of View

by

H. R. McCrimmon and K. H. Loftus

Fish and Wildlife Division, Ontario Department of Lands and Forests

In the consideration of this matter, which forms part of a symposium at the 1952 meeting of the Canadian Committee on Fresh Water Fisheries Research, we shall attempt in this paper to evaluate some past and present management practices employed within the province on the basis of their scientific justification. In this way we intend to reveal some of the important gaps in biological knowledge which are required for the development of a sound management programme. The procurement and analysis of the required data, we feel, should be to a large extent the responsibility of research organizations in the future.

As the following remarks pertain primarily to the Province of Ontario, it should be noted that the problem of fisheries management, formerly the duty of the Department of Game and Fisheries, has taken on greater significance since 1946 when it became the responsibility of the newly formed Division of Fish and Wildlife of the Department of Lands and Forests. This division, a management organization, may not be expected to undertake basic research although projects of a research nature pertaining to local management are undertaken from time to time. The pre-1946 staff of two fisheries biologists has been expanded some eightfold as an important step towards inauguration of an up-to-date management plan. Further expansion is anticipitated until sufficient field biologists are available to administrate local fisheries management throughout the province.

A number of the fisheries management tools which are employed within the province will now be discussed under the general headings of regulations, fish culture, and habitat improvement.

Regulations

Regulations, one of the earliest attempts at fisheries management, have been based to a considerable extent on pure supposition, or on laws used with doubtful justification in other provinces and countries. As a result, regulations have undergone continuous change in recent years and revision must continue as scientific discrepancies are proven through further research.

Among the oldest regulations are those governing creel limits, size limits, and closed seasons. Those imposing limit restrictions have been adopted largely on the false basis of public demand, rather than on the sound basis of a crop to be harvested by a known number of fishermen. The regulations covering size limits (or minimum lengths) are scientifically based for most species to the extent that in most waters the harvested fish are at least "one-time" spawners. The actual effect on the ultimate fish production has not been satisfactorily demonstrated.

The regulations setting creel limits may tend to reduce wastage resulting from excessive captures in certain waters but, as is the case with size limits, laws of these types cannot be justified until indices are provided through research whereby management officers can readily determine the productivity of waters.

Regulations concerning closed seasons are based on a knowledge of spawning characteristics of each species and appear basically sound in eliminating fishing pressure at a time when each species is concentrated and easily exploited. Again, the actual effect on fish production has not been proven to any extent and may be worthy of research. A point which should be considered is the utilization of species of fish generally available to the angler only during the spawning season, for example, pickerel and rainbow trout in the Great Lakes and tributary streams. To what extent should these species be utilized while on the spawning beds?

Alternate closure of lakes in Algonquin Park has resulted from research studies of the Ontario Fisheries Research Laboratory. This management tool has not been generally applied to other waters.

Fish sanctuaries have been set up in Georgian Bay and several other Ontario waters but the actual value is more-or-less pure supposition. This practice of permanent closures of areas of lakes inhabited by both coarse and game fish must be investigated and its value assessed.

Regulations governing commercial fisheries pertaining to mesh size are generally based on a combination of scientific fact and economic value. Facts are still lacking which would permit the management of commercial fisheries on a continuous yield basis.

Fish Culture

Through the years hatcheries have been sold to the public as a sound and necessary management tool. In recent years their value has been disputed by both scientists and laymen, but insufficient research has yet been completed to prove their positive or negative value to conscientious administrators.

The actual operation of hatcheries in Ontario has improved through the utilization of scientific data coupled with the experience of non-technical men in hatchery operation. Methods of handling eggs, young fish, control of hatchery diseases, and the like, have reduced mortality within hatcheries to a minimum. Further research into the development of cheap and nutritious foods is desirable.

The value of hatcheries as a management tool may be assessed only by the usefulness of its products. Failure to determine the effectiveness has to an extent been the fault of administration which, through a lack of trained personnel and an apparent lack of initiative until recently, has made little attempt to determine the results of either stocking new waters (introductions) or restocking waters with existing populations of the same species. At any rate, before the use of hatchery products may form a justified place in the provincial fisheries management programme, research must be undertaken to ascertain the survival of all ages of fish which may be stocked from eyed-eggs to yearling or even mature fish. These studies must analyse the effect of environmental or habitat conditions on survival, and must present the results in a manner which may be readily utilized by management officers. The Atlantic salmon study in Ontario has been a research of this type in demonstrating the importance of effect of habitat on survival.

The stocking of northern Ontario lakes from aircraft has been used advantageously Techniques in handling fish, particularly aeration, have been developed. The stocking of northern virgin lakes offers an excellent opportunity for needed survival studies.

In considering hatchery products, management officers are interested in the possibility of developing hybrid fish which are more adaptable to environmental conditions and of proven value to a fishery.

Habitat Improvement

Habitat improvement has not received the attention in Ontario which is found in neighbouring American States, although the first sound steps towards a province-wide control of pollution have been taken.

Undoubtedly stream improvement and watershed work in southern Ontario is desirable from the fisheries standpoint, but is too large a project to be undertaken alone and must develop through co-operation with other conservation agencies. Reforestation carried out under the Department of Lands and Forests for many years has made perhaps the greatest single contribution, but its overall effect on stream temperatures, flooding, erosion, and silting is scarcely felt.

Pertaining to lakes, little has been done other than the possible value of controlling water levels. Pertaining to streams, it has not been found practical or economical to undertake many of the improvement methods recommended in American publications until such time as their value has been clearly demonstrated. A limited control over the construction of new dams is aimed at preventing further obstructions to migrating fish.

Regarding pond management, trout ponds have been developed and improved through techniques such as coarse fish removal, weed control, and fertilization. However, a definite lack of knowledge concerning the development of farm ponds for warm water game fish, food fish, and minnows, under northern climatic conditions remains a serious gap in the southern Ontario fisheries management programme. Definite research studies are required and may well be a co-operative effort between research and management.

Included within the problem of habitat improvement must be the question of population manipulation, i.e., restoration and maintenance of the proper balance of species of fish in a body of water, and the eradication of undesirable species. Techniques in Ontario include netting, chemical eradication, and intensive angling. Although these methods are used with favourable results in the management of small trout ponds, the relatively extensive coarse fish removal programme carried out in larger bodies of water in various parts of the Province is based on little more than optimistic speculation. Research and management may well join in a study of this problem. Management officers are awaiting with interest the results of the experiment of this nature currently being conducted by our partner in Ontario, the Research Division, at South Bay.

General Conclusion

This paper has made no attempt to cover all current management practices, but rather has undertaken to stress a number of those procedures which have received more-or-less general acceptance in Ontario although the ability to predict their effectiveness is lacking.

From these considerations it must be concluded that most practices employed within Ontario under the guise of fisheries management tools do not enjoy the benefit of adequate scientific knowledge. The Fish and Wildlife Division, with its expanding staff of biologists, is now approaching a position where it may examine its own management procedures and assess the relative importance of research studies which may be undertaken. There is no reason to doubt that definite progress can be made through the adoption of a policy of continuous investigational management over a period of years. This demands the close integration of research and management organizations in the study of problems of mutual interest.

Future Prospects for Valuable Development in this Field

by

K. H. Doan

Central Fisheries Research Station, Fisheries Research Board of Canada

To attempt to predict the importance in the next five years or so of fisheries research in the management of fish is to risk confusing forecasting with hope. The needs of the fisheries vary throughout Canada, and it has been very difficult to achieve a national picture. Information was sought by the questionnaire method and I am deeply obliged to those who assisted. Since this paper represents a synthesis of opinions, various persons may recognize some of their contribution as a direct quote. The questionnaire listed about 75 items grouped into ten categories, and these have been reviewed with no priority of order.

The planting of hatchery raised fish is conducted without serious question of results in some regions, while in others the whole procedure is shaded with doubt or has even been abolished. Hatcheries are useful if some estimate can be made of their economic value, i.e., of relating the cost of producing a fish to the actual recovery by the angler or commercial fisherman. Hatcheries may make significant contributions where fishing is intense, where new species are desired, where it is wished to re-establish a former species, or where no natural reproduction exists. The trend in hatchery plantings will continue towards larger fish but the techniques of planting and the results to be derived from the practice will come under increasing scrutiny. In British Columbia the rearing and planting of salmon is still in the discard as a general practice, but in special instances fry and eggs may be useful to supplement or rejuvenate runs. Fish physiologists would unanimously, I suspect, declare themselves favourably inclined towards fish hatcheries as a source of experimental material.

Interest in Fish Genetics

New species of fish may be useful for the occupation of waters whose native inhabitants succumbed to changed ecological conditions, but it is believed that the former activity in introducing exotics will not be equalled in the future. There is some interest in fish genetics, either to produce hybrids or to produce strains of regular fish which may be more amenable to harvesting or management. To be able to alter the age at which fish migrate, to destroy the urge to migrate, to increase fecundity, growth rate, etc., might be desirable for some species in some regions. Only in the prairies and in Ontario have transfers of wild fish been made to any extent, but this may be practiced more in the future for pike, perch, and smallmouth bass. Semi-artificial rearing in natural ponds or in impoundments has been mostly successful where tried, and only the lack of good locations may limit this in the future.

The efficiency of propagation has been insufficiently studied, so that knowledge of the optimum stock of spawners required to maintain a fisheries is inadequate, and legislation designed to achieve this is based mostly upon theory. The importance of this matter varies locally and the need of extending spawning grounds by the removal of obstructions, the provision of fishways, regulation of water supply and level, and the artificial provision or culture of suitable bottom seem to be more important for trout and salmon than for other fish. Although expensive, it is believed that the preservation and extension of natural spawning grounds will contribute much to propagation. Seemingly conflicting interests—lumbering, canals, hydro-electric power, drainage, irrigation, sewage disposal and fisheries—must work together more harmoniously in the future if the best water use is to be achieved. Although sometimes small in monetary value, the fisheries are often important, but difficult to evaluate as in the tourist industry. Sometimes obstructions can have a positive value, such as preventing undesirable fish like the carp from gaining access to new range.

The reduction of over-population of fish is only of local application, since it is believed that in most of our accessible fresh waters the harvest is adequate or could be increased without trouble. The use of nets to reduce crowded stocks of fish is not very effective. Poison is sometimes better but more expensive and will probably not be applied on a large scale in the near future.

Research on methods to increase the survival of young, the growth of fish, and the total production of lakes and rivers will be of importance where there is a proven lack of natural fertility of the water such as in northern areas. Some research upon the fertilization of water by the use of chemicals has been done but the results have been limited, and the need of additional facts is indicated. Such practice, more effective in southern climates, may have limited results in our colder climate. The effects of controlling predators and competitors upon the increased survival of the desirable fish are not generally very clear-cut and controlled experiments will be required to clarify predator-prey relationship. This practice, if and when developed, may give good results for some fisheries, such as British Columbia salmon, and elsewhere against sea lamprey, eels, etc. Increased survival may also be attained by the removal of obstructions which limit the passage of young fish to their growing areas or future fishing grounds.

There would seem to be a field in the future for methods of utilizing fish which are now insufficiently harvested, such as by the development of new sports, and new methods of fish preparation, by-products, and markets, so that all kinds of fish may be taken from the water at a rate commensurate with their ability to produce, rather than having selective fishing for only a few desirable species. There will be slow progress in educating anglers to fish more for sport and less for food, and to refine their tackle, but this doubtless will receive more attention.

In the matter of quality there have in the past been arguments over the relative merits of native versus hatchery fish for planting. Although some tests have been made that showed an inability of hatchery fish to compete with and survive against wild stocks after planting, it is likely that more such experiments will be undertaken. Perhaps hybrid strains with greater vigour may be developed in the hatcheries. The whole matter of fish parasites and diseases has generally been considered unimportant in nature, although the hatchery manager must be skilled in these matters. A notable exception is a tapeworm infection in whitefish which occurs in some lakes in central Canada, and is a matter of considerable economic importance still requiring research into such practices as population manipulation, chemical treatment, and fish processing by filleting, canning, etc. In wholesale modifications of fish populations more research is needed on their ecology, and there is still room for the development of chemicals for the treatment of natural waters if comparison is made with the proliferation of insecticides that have arisen from research in economic entomology. Besides new processing methods for the elimination of parasites, every effort towards the production of high quality fish (by the industry) should be encouraged.

Detailed Knowledge Lacking

The field of environmental control offers one of the greatest opportunities for fish management, yet when any factor is examined closely a dire lack of detailed knowledge is soon evident. No methods of environmental control can be developed thoroughly without research upon the reactions of fish to various environmental factors. The maintenance of satisfactory water temperatures in nature, of erosion and bank stability for turbidity control, of high water tables in the soil, and the prevention or alleviation of floods, are all directly related to forest cover and water use. Parts of Canada that are still "new" have suffered little alteration of natural conditions, but in more highly developed sections of the country, man's activity in agriculture and industry have wrought extensive changes in the conditions under which fish must survive. It is believed that efforts towards the maintenance and restoration of natural conditions are essential to ensuring stocks of fish. Perhaps in only local and extremely valuable fisheries will there be much application of artificial structures such as low dams, current deflectors, artificial cover, rip-rap, mechanical and chemical control of turbidity, removal of excess aquatic vegetation, snow removal and pollution control. There is a definite trend towards experimental biology and towards the study of behaviour patterns, and these must be elucidated before they can be synthesized with environmental variables into management methods. Worthy of note are the steps that have been taken, and will continue to be developed, to preserve natural waters amid Canada's expanded oil industry.

Regulation of the catch, usually by legislation, has long been a favourite administrative procedure, but it would appear that research interest will be directed towards this more than in the past. There was almost unanimous opinion that accurate measures of catch are essential for attaining optimum yield in commercial and sport fisheries. There is considerable open-mindedness amongst fishery biologists about mesh size in commercial fisheries, and it is to be expected that more experiments will be conducted to see what effects smaller meshes may have upon stocks and yields of fish. Even in sport fishing, there is some inclination to review critically the efficacy of catch, size, and season limits with perhaps a view towards liberalization or elimination of these. Such limitations are now in effect without any sound factual basis. It might eventually be shown that maintenance and improvement of environment has more to do with fish production than limitation of catch. Some experiments are already under way to study the effect of the simultaneous harvesting of fish by commercial and sporting interests, but the full practice of this may perhaps not be brought about locally because of political factors.

Just as the banding of waterfowl has led to sound knowledge of their migrations, so will the tagging and marking of fish contribute towards our knowledge of their movements in a medium where they are largely invisible to us. Recovery data will contribute to a knowledge of fish mortality so that the effect of man's take may be properly assessed in the natural cycle. This should lead to a more intelligent approach to the regulation of catch, and will perhaps indicate the necessity, or not, of such regulation. Correlated with currents and temperatures, the tagging studies may develop into one of the most important tools of fish management, and undoubtedly they will help in the interpretation of environmental effects and other influences upon fish production. Aside from this review, it has been noted that more emphasis is swinging towards study of the relationship of oceanography to fish movements and availability.

Only in densely settled portions of Canada does there seem to be any problem over access to fishing waters, since elsewhere in Canada the lakes and rivers are predominantly located on Crown Lands and in parks to which the public has access. The management of a few special fisheries may require the increased development of fishing sites, docks, camps, etc. This applies mostly to fisheries of recreational value, but the provision of harbours might be regarded as part of the management of commercial fisheries.

The general observation may be made that much of the past research in fisheries has been largely along lines of academic interest, and that with the limited resources for research we would be well advised to choose lines of research which are, perhaps, of less academic interest but of much more practical application. This practical application, however, must be predicated upon more factual knowledge, as noted in the discussion on environmental control. The rapid expansion of fisheries in recent years, both commercial and angling, has brought on a tremendous increase of fisheries problems and the realization by the fisheries authorities that their research background is remarkably shallow when direct questions are asked on the effects of various developments. The warning has been sounded that one cannot judge the value and practical significance of any factor affecting the production of a fish until it has been carefully studied or evaluated, particularly in relation to the whole early life-history, i.e., prior to the catching of fish. Some factor in the early life history might seemingly cause heavy loss and reduce the populations very appreciably. Its correction might seem a "must" yet there may be some factor, perhaps predation, coming to bear at a later stage which may very appreciably reduce the overall effect of the eradication or control of the previous limiting factor. Until then, when one has put together all the segments of the picture, one cannot too accurately assess the significance and importance of any one factor or phase involved in fisheries management.

The administrator, that is the fisheries manager, has at his disposal an array of facts which might be grouped in four classifications:—

(1) *No factual information*, but the setting up of a management plan on the basis of what appears to be a reasonable common-sense philosophical consideration of the case in point. If data or statistics are maintained and other regular and planned observations carried out on the management, this management programme in itself may constitute a basis for assessing its own value.

(2) *A limited amount of factual information arising from general or superficial investigation.* The sparse information employed in such a programme may arise from the early stages of a management programme set up on a theoretical basis or may be information of recorded or verbal nature arising from investigations carried out elsewhere in a similar field.

(3) *Factual information limited in character arising from a rather general type of ad hoc research.* This is perhaps the picture for the most advanced work in fisheries at the present time. The data arising from this category of research are probably very incomplete and may in fact be only a half-truth or less. A successful management programme based on research facts of this category will serve to substantiate the information, but some judgment must be exercised in using only data which promise some degree of success.

(4) *Facts arising as the result of basic research.* The spread between the approach to basic research and the approach to management is so wide that the results from any single unit of basic research have probably no value to applied management, and it is only as the result of a general accumulation of facts arising from basic research and their final integration and interpretation, that information from this source may be applied with value to management practices. It is important to emphasize that, in the final analysis, progress in fish management depends to a very great measure, if not completely, on this category, i.e., on basic research and the facts which arise from basic research.

One contributor to this review expressed the thought that streams and freshwater lakes, when compared to the oceans, are individually and collectively very young, and that, therefore, the organisms found in them are essentially pioneer stock which do not, as yet, approach the full utilization of the biological potential of their environment. In future fish management, there might be room for the development of new strains of the existing pioneer stock and the introduction of "immigrant" marine colonies, so that freshwaters might be made to produce higher yields than they do at present.

Throughout Canada nearly all known fish management practices are in use, but mostly locally, and their use is on a purely theoretical basis which presumes that by their nature they should be of value. In few cases are there any facts to strongly support the practice, and in fewer cases are there any facts in the form of numerical data. It seems to be a safe assumption that fisheries management will have a very dim future indeed unless research is vigorously organized and driven to produce the many necessary facts and improved techniques on which sound and increasingly productive management must be based. Without successful long-term research there will be no successful long-term management. The prosecution of research which will supply these facts can only be accomplished with more trained men and money.

Acknowledgments

In addition to valuable comments that were made by Dr. W. J. K. Harkness, I wish to offer my thanks to the following who contributed observations and answered the questionnaire. In several instances the completed answers were a joint effort, although the names of some of the contributors do not appear. Mr. N. S. Baldwin, Dr. A. A. Blair, Dr. J. R. Brett, Mr. G. E. Butler, Dr. W. A. Clemens, Dr. J. P. Cuerrier, Dr. H. W. Curran, Dr. M. J. Dunbar, Dr. P. F. Elson, Dr. R. E. Foerster, Dr. W. S. Hoar, Mr. R. N. Johnston, Dr. W. A. Kennedy, Dr. P. A. Larkin, Mr. K. H. Loftus, Dr. H. H. MacKay, Dr. R. B. Miller, Dr. F. Neave, Mr. D. N. Omand, Dr. D. S. Rawson, Dr. W. B. Scott, Dr. M. W. Smith, Dr. W. M. Sprules, and Mr. W. H. R. Werner.

EDMOND CLOUTIER, C.M.G., O.A., D.S.P.
QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1952

ISSUE THIRTEEN
DECEMBER - 1952

THE CANADIAN FISH CULTURIST

Published at Ottawa by
The Department of Fisheries of Canada

CONTENTS

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

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

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

Transfer of Anaesthetized Adult Lake Trout by Means of Aircraft

by

Jean-Paul Cuerrier
Chief Limnologist, Canadian Wildlife Service, Ottawa

For stocking and restocking bodies of water, fish eggs, fry and fingerlings have been moved by a variety of means. Pack horses, packs on men's backs, railroad, steamship and aircraft have all been utilized. Aircraft, for example, have been extensively used in the Province of Quebec and in the states of New York and California. In the case of adult living fish, trucks and railroad cars equipped with water-filled tanks have been used most frequently as a means of transportation.

The Province of Manitoba transferred by air from Clearwater Lake to Cormorant Lake 1,100 and 1,000 adult lake trout in 1947 and 1948 respectively. These fish were moved over a distance of approximately 25 miles in Norseman and Husky aircraft equipped with water-filled tanks. These transfers necessitated 10 or 11 trips. An additional transfer of 1,000 adult lake trout was made in 1948 from Clearwater Lake to Manistikwan Lake; the distance between the two lakes is 50 air miles. (Information supplied by Mr. G. E. Butler, Department of Game and Fisheries, Province of Manitoba.)

Operation of 1951 Transfer

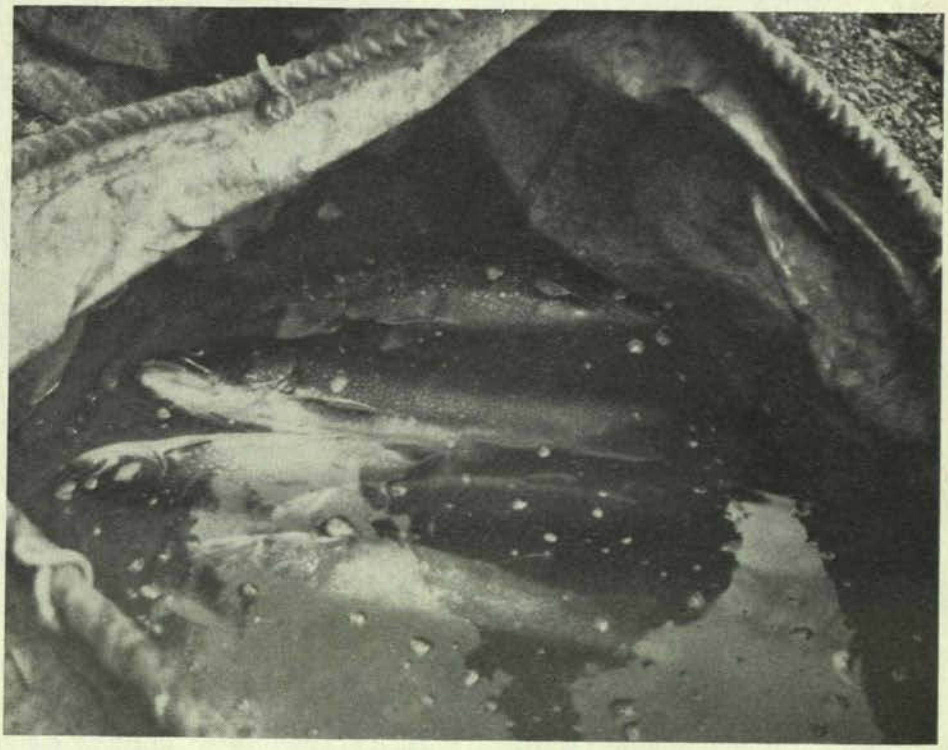
During the summer of 1951 a transfer of a large number of adult lake trout was carried out in Prince Albert Park, Saskatchewan, by the limnology section of the Canadian Wildlife Service. The background and the operation itself are discussed in this paper.

Investigations and reports indicated that an unbalanced population of lake trout, consisting of specimens weighing more than 10 pounds, was present in Crean Lake, Prince Albert National Park. As an attempt to re-establish a proper balance which would improve angling, it was recommended in 1949 that 400-500 adult lake trout each of about five pounds in weight should be released in Crean Lake. In Prince Albert Park, adult lake trout could be obtained only from Kingsmere Lake, or from Wassegam (Clearwater) Lake. There is no road connection with Crean Lake, so it was suggested that the fish be moved by aircraft.

An experiment was devised to investigate the possibility of moving fish anaesthetized and iced, rather than in water-filled tanks. This was based on the knowledge that fish can be kept alive when placed on ice under saturated oxygen conditions, that cold reduces the respiration rate of fish and that anaesthetic drugs reduce the activity and oxygen consumption of these animals. This experiment was carried out at Jasper National Park during the summer of 1950 with the assistance of the hatchery superintendent, Mr. W. C. Cable. Seven eastern brook trout of approximately three pounds each in weight were anaesthetized in a two per cent solution of urethane, placed in a wooden box with chopped ice covering the fish, particularly the head region, and subjected to a 75-minute trip over paved and gravel roads. When they were returned to the hatchery, the fish were placed in a tank with running water.

All seven fish recovered from this trip. It was then decided that the lake trout transfer scheduled for the following autumn could be performed with anaesthetized fish packed in ice in a wooden container, thus permitting the transfer of a maximum number of fish with the appropriation available for this project.

Wassegam Lake was selected for the capture of lake trout. This lake is located near the northeastern corner of Prince Albert National Park; it is practically inaccessible during summer and autumn except by air. According to Mr. Alex Pease, competent park guide who fished this lake commercially in 1928 and 1929 and accompanied anglers during recent years, and according to surveys carried out in the autumn of 1950, Wassegam Lake was inhabited by a dense unexploited population of lake trout.



Lake trout under anaesthetic in relay tank.

Plans were made during the summer of 1951. Operations began when a party of five, flown to Wassegam Lake, started extensive netting and angling for lake trout on September 17. Gill nets ranging from 1½-inch to 5½-inch stretched mesh were used.

At first the nets were visited, weather permitting, at frequent intervals throughout the entire 24-hour period. It was soon found that the largest catches of lake trout by gill nets were made between 6:00 p.m. and 12:00 p.m. The 1½-inch and two-inch mesh nets were the most successful in catching lake trout in the excellent condition required for survival in reservoirs and retaining pots. Large-mesh nets were abandoned after a few days because of the large number of fish that were being killed or seriously injured.

Nets Set in Shallow Water

The capture of lake trout by setting nets in shallow water, eight to 12 feet deep, was possible because these fish habitually feed in such depths in the latter part of September, when the spawning period is approaching. The lake trout caught ranged from one pound to 40 pounds (the latter being caught in a $1\frac{1}{2}$-inch-mesh net). Most of the fish seemed to be mature. The average weight of the fish released in Crean Lake is estimated at approximately five pounds, the greater number weighing between three pounds and 10 pounds. Chicken-wire enclosures, wooden reservoirs, and retaining pots made of coarse twine were used to keep the lake trout alive. Because of wind and wave action, it was found that retaining pots were the most suitable. When the number of fish in captivity approached 500, a radio message requesting the plane for a definite date was sent to the park superintendent at Waskesiu.

Transferring lake trout from relay tank into boxes for loading on plane.

A Norseman aircraft was chartered from the Saskatchewan Government Airways for the transfer. The entire operation may be described as follows:

Two canvas-fibre relay tanks were filled to a depth of six inches with an aqueous solution containing about three per cent urethane. The lake trout were then transferred with a dip-net from the retaining pots to a wooden reservoir near the shore. When required, they were caught by hand in the reservoir and placed in a galvanized wash-tub, in which they were carried quickly to a relay tank for anaesthetization.

From 20 to 25 trout were treated in a relay tank at one time. Adequate anaesthetization required four to five minutes. When lake trout were anaesthetized, they were rapidly placed, one by one, in a wooden box and covered, particularly the heads, with layers of chopped ice. The box was then placed on the plane. In the meantime lake trout transferred to the other relay tank had become anaesthetized and were ready for packing and loading. The empty tank was filled with another group of fish after the solution had aerated. When the loading was completed the plane was flown from Wassegam Lake to the south end of Crean Lake, an air distance of about 20 miles. At Crean Lake the plane was unloaded and the boxes were placed in shallow water. As each fish was transferred to a large wooden floating reservoir, the upper tip of the caudal fin was clipped. Some lake trout were also tagged with aluminum tags placed around the maxillary bone. When the fish in the reservoir started to swim, the offshore end of the reservoir was sunk with a few rocks, so that the fish could leave freely. The time for recovery was found to be from 30 minutes to somewhat less than two hours. Most of the fish had escaped from the reservoir within one hour.

In spite of wind and rough water, which were experienced when most of the transfers were being carried out, the average time required for a complete trip was approximately 75 minutes, measured from removal of the fish from the retaining pot at Wassegam Lake to the transfer to the reservoir at Crean Lake.

In seven flights 1,231 adult lake trout were transferred from Wassegam Lake to Crean Lake. Of this number, 1,110 trout recovered and were released. Losses amounted to 10 per cent of the fish moved. Total loss of fish caught in Wassegam Lake amounted to approximately 26 per cent, but this could be reduced, as a result of experience, in any such operation in future.

On October 7 operations were brought to a close and the party and equipment were flown back to Waskesiu.

Acknowledgments

The author wishes to thank the Prince Albert National Park superintendent for his interest in the project and his co-operation in planning and preparing the necessary material for the operations. Thanks are also extended to Messrs. H. Harrison, Alex Pease, T. Beale, J. Hiltz, and A. Boudreault, who took part in the operation. Special gratitude is due to Mr. Allen Hartley, pilot for the Saskatchewan Government Airways, for his co-operation in transferring the fish in the shortest time possible under the conditions that prevailed on these occasions.

Numerical Relations Between Abundance of Predators and Survival of Prey

by

W. E. Ricker

Fisheries Research Board of Canada

There is growing interest in control of predators as a tool in fishery management. Assessments of its usefulness will come only from repeated trials under varied conditions. A relatively small number of situations have already been examined. Some have given negative results; others show much promise. Even though the final answer must come from an actual trial, there are some simple theoretical considerations which will assist in assessing in advance the prospects of success. Used intelligently, they will help in selecting predation situations where control seems likely to be of real value.

Three Types of Predation

It is convenient to distinguish three types of numerical relationship between predators and a species of prey which they attack.

A. Predators of any given abundance take a fixed number of the prey species during the time they are in contact, enough to satiate them. The surplus prey escapes.

B. Predators at any given abundance take a fixed fraction of prey species present, as though there were captures at random encounters.

C. Predators take all the individuals of the prey species that are present, in excess of a certain minimum number. This minimum may be determined in different ways: (1) There may be only a limited number of secure habitable places in the environment, so that some prey are forced to live in exposed situations where capture is inevitable. The number of such secure niches may be partly governed by territorial behaviour of the prey. (2) The maximum "safe" density of prey may be the one at which predators no longer find it sufficiently rewarding to forage for them, and move to other feeding grounds.

The three situations above tend to intergrade, of course, but it is useful to keep their differences in mind.

Situation A

This is likely to occur when a prey species is temporarily massed in unusual numbers, for example, adult herring in spawning schools, or newly-emerged fry of pink and chum salmon going downstream. The main characteristic of such situations is that the number of prey eaten depends on the abundance of predators, but not on the abundance of prey. Hence such situations cannot last long, and the predators cannot make the prey in question their principal yearly food; otherwise they would almost surely increase in abundance and the situation would change to type B or type C. If a type A situation persisted for long, it would come to an abrupt end with the extermination of the prey.

Situation B

Here the number of the prey species eaten is proportional to the abundance of predators and to the abundance of prey. Unlike A, this type of predation can easily occur over long portions of the year; and the prey species may comprise the larger portion of the predators' annual ration. This situation was observed at Cultus Lake, British Columbia, for predation of squawfish, char, coho and trout upon fingerling sockeye, over a wide range of abundance of the latter (Foerster and Ricker, 1941).

Situation C

The classical example of this situation was described by Errington for bob-white in Iowa, where a given range would winter safely a fixed number of birds, practically independently of the number which were present in autumn, the surplus being taken by predators. Studies conducted from the Atlantic Biological Station of the Fisheries Research Board of Canada, St. Andrews, N.B., suggest that in some rivers predation upon Atlantic salmon parr tends toward type C, because a marked increase in the number of young fish planted was followed by only a relatively small increase in number of surviving smolts (Elson, 1950). In type C situations the predators must tend to have ample alternative foods, and they are often mobile so that they can leave an area where the food supply has been "cleaned up" for the season.

Relation of Abundance of Predators to Mortality Rate and Survival Rate in "Type B" Situations

Consider a prey species which is subject to type B predation over some part of its life history. Assume first that predation causes the whole of the mortality that the prey is subject to during that period. Then the prey species decreases in abundance according to the well-known exponential formula

$$N/N_o = e^{-it}, \qquad (1)$$

where: N_o is initial abundance, N is abundance at time t, $e = 2 \cdot 718 \ldots$, and i is a statistic representing the fraction of the prey which would be eaten in a unit of time if its abundance were held constant for that long; i is often called the instantaneous mortality rate.

Under the conditions postulated, instantaneous mortality rate is directly proportional to the abundance of predators. This can be illustrated by considering a situation where predators attack a prey population of 1,000,000 individuals under type B conditions, and they inflict losses corresponding to $i = 0 \cdot 8$, where the unit of time, t, is the whole season that predator and prey are in contact. Equation (1) indicates that in, for example, 1/1000 of the season, the predators will eat $i/1000 = 0.0008$ of the prey present, or 800 fish. During the next thousandth of the season, the predators eat $i/1000$ of the surviving prey, or $999{,}200 \times i/1000 = 799$ fish. The following interval they eat $998{,}401 \times i/1000 = 799$; then $997{,}602 \times i/1000 = 798$. This continues until all the thousand time-intervals have elapsed, at the end of which there are:

$$1{,}000{,}000(1 - 0 \cdot 0008)^{1000} = 472{,}400$$

survivors, or 47·2 per cent. What happens if the number of predators is doubled? In that event, during the first thousandth of the season twice as many fish will be eaten, i.e. 1,600, leaving 998,400. In the next thousandth the fraction eaten is likewise double, namely 0·0016; multiplied by the number of survivors this gives 1,597; and so on. At the end of the season $1{,}000{,}000(1 - 0 \cdot 0016)^{1000}$ survive, which is 201,900, or 20·2 per cent.

Thus doubling the number of predators doubles the instantaneous mortality rate (which is true generally), but it increases actual mortality by only $27 \cdot 0/52 \cdot 8 = 51$ per cent (which is true of only this particular example).

The general relation between predator abundance and actual mortality, or survival, is most conveniently expressed as:

$$\frac{p_2}{p_1} = \frac{\log s_2}{\log s_1}, \qquad (2)$$

where p_2 and p_1 represent two levels of predator abundance, and s_2 and s_1 are the corresponding survival rates for the prey. This expression can easily be derived from (1), since p is proportional to i, and $s = N/N_o$ when $t = 1$.

Formula (2) indicates that survival does not change in a simple inverse relation to number of predators. For example, in a situation where predators have been reduced to half ($p_2/p_1 = 1/2$), some typical values are shown below:

Original survival rate (s_1, as %)	Ratio of new to old survival rate (s_2/s_1)
0·01	100·
0·1	31·5
1	10·0
5	4·46
10	3·15
25	2·00
50	1·41
90	1·05
100	1·00

Schedules like this make it possible to estimate the beneficial effect of any given degree of predator reduction for type B situations. The principal lesson they teach is that predator control is more likely to be economically successful when survival rate is small to begin with (over the span of the prey's life history on which the predators in question operate). An easy assumption might have been that, by halving a predator population, we should double the survival of the prey. As matters actually stand, this much benefit will be gained only if mortality from predation is at least 75 per cent in the beginning ($s_1 = 25$ per cent). However if the initial mortality rate is greater than 75 per cent, then reducing the predators by half will more than double the number of survivors.

As a matter of fact, when mortality is initially great and survival small, quite startling improvements in survival can be achieved by means of very moderate reductions in predator population. Again using formula (2), we obtain the schedule below:

Original survival rate	Reduction in predators necessary to double survival rate
0·01%	7·5%
0·1	10·0
1	15·0
5	23·2
10	30·1
25	50·0
50	100

Presented in this manner, it is encouraging to discover that when survival is in the "medium" range from 1 to 10 per cent, it requires a reduction of predators by only one-third or less in order to achieve important benefits. This, in fact, is the range involved in Canadian attempts at increasing salmon production by predator control. In the sockeye salmon experiment mentioned earlier, the investigators were at first surprised at the magnitude of the improvement effected by quite a moderate decrease in predator abundance. However, this can have a discouraging as well as an encouraging aspect. For if a small decrease in predators results in important gains, then, equally, those gains can be wiped out by a subsequent small increase in predators, which might come from improved survival conditions for the young of the predators themselves.

Another general principle illustrated by the schedule above is that great fecundity is apt to be accompanied by a natural instability in population size, and particularly by marked variation in year-class strength. For example fish like the cod, which produce pelagic eggs to the number of 1,000,000 or so per female, may easily suffer average predation losses of the order of 99·9 per cent during their development and larval life. At that level, a 10 per cent decrease in abundance of predators causes a 100 per cent increase in strength of the year-class at the end of larval life.

The relationships above apply of course only when the whole of the prey's mortality is caused by predation. To the extent that other causes enter the picture, any given reduction in number of predators has less effect in increasing survival.

Control of Predators in Situations of Types "A" and "C"

The considerations developed above for type B situations apply equally to type A. There is an apparent difference arising from the fact that whereas, with type B, survival rate (s) is invariable from year to year for any given abundance of predators, in type A survival rate varies with abundance of prey. However, this does not change the nature of the effect which any given reduction of predators will have upon survival. Equation (2) will apply, whatever numerical value of s would be anticipated at the level of prey abundance existing in any particular year.

In type C situations, obviously the mathematical relations above do not apply at all, as long as they remain type C. The definition of C implies that changes in abundance of predators have no effect upon survival of prey; and for predator control to become effective it must first reduce the predators to the point where predation begins to change toward type B. This may be entirely feasible. In Elson's Pollett River experiment, removal of mergansers and kingfishers by shooting was sufficiently thorough to increase the survival from a heavy planting of young salmon four- or five-fold. This must mean that the predation situation had been changed; from one close to type C, it became type B or even type A, for whatever few birds managed to hang on or occasionally wandered into the area.

If we look at predation from the point of view of the predator rather than the prey, a broad distinction can be drawn between the warm-blooded and the cold-blooded carnivores. The former have a fairly constant food requirement, and hence are more likely to become involved in predation situations of types A or C. The great mobility of birds, and to a less extent of mammals, enables them to move quickly to localities where food is temporarily abundant (type A situations). At the same time they require a steady food intake to maintain body temperature and will quickly leave an area where food abundance is depressed so far that foraging does not provide their minimum needs (thus creating type C situations). Predaceous fishes, by contrast, have a much lower minimum ration per unit body-weight, and much greater flexibility in the amount of food they can consume and still live normal lives. Many of them must set up type B situations, in which they can take whatever food they encounter as often as they encounter it, and rarely find prey so abundant that any must be refused.

Literature Cited

ELSON, P. F. *Increasing salmon stocks by control of mergansers and kingfishers.* Fish. Res. Bd. Canada, Prog. Repts. (Atlantic), No. 51, pp. 12-15, 1950.

FOERSTER, R. E., AND W. E. RICKER. *The effect of reduction of predaceous fish on survival of young sockeye salmon at Cultus Lake.* J. Fish. Res. Bd. Canada 5(4), 315-336, 1941.

Two Poisoning Projects in Manitoba

by

George E. Butler
Department of Mines and Natural Resources, Winnipeg

In the streams and lakes of southern Manitoba, speckled or eastern brook trout, rainbow trout, or brown trout are not present in the wild or natural state, although two creeks flowing into George Lake in the Whiteshell Provincial Park now have eastern brook trout established through the planting of fish hatchery stock.

In Northern Manitoba eastern brook trout is native to many streams, including the Nelson, Weir and Limestone Rivers, Ten Shilling Creek, God's River, Island Lake River and perhaps at other places at present not well known. In south-eastern Manitoba there are waters which appear to be well suited for eastern brook trout habitat, and it would be most desirous to extend the range of this and other species of trout, by seeding with fish hatchery stock. However, repeated stocking with trout fingerlings from the Whiteshell Trout Hatchery, in lakes with natural fish populations, has produced to date only three known successful introductions. Contrasting this, in a small pond made by the building of a grade across a gully near the Whiteshell Trout Hatchery, speckled and rainbow trout have established themselves; have, according to observations of the fish hatchery staff, successfully reproduced, and have made excellent growth. The initial plantings in this case were from fry or fingerlings which appeared to be weakly when in the hatchery troughs.

Analyses of the stomachs of small northern pike taken in the creek near the hatchery have shown this species to be very partial to trout fingerlings. In almost every pike stomach examined, trout fingerlings, either speckled, rainbow or brown, or the remains thereof were found. This would indicate that certain lakes and streams might permit trout to grow to maturity but for the predator population of piscivorous fishes.

Telford Pond

With this knowledge as a base, a lake in a disused gravel pit situated near Telford, 91 miles east of Winnipeg, was chosen for an experiment with the use of derris root powder to eliminate the fish population with a view to planting trout when the poison subsided. The lake at the gravel pit has a surface area of approximately 5·5 acres and a maximum depth of 19 feet. It is spring-fed, or at least there is an underground seepage, and one outflowing creek, connected to the Whiteshell River system, flows both winter and summer. On June 11, 1947, 141 pounds of derris root powder was applied to the lake in paste form over the whole of the surface. Distribution was made with the use of a fire fighting pump and hose mounted on a barge which was towed from end to end of the lake. The pump was operated continuously and with the circulation of water and pressure of water from the nozzle of the hose, a good distribution of derris was made. The kill appeared to be complete and after the poison subsided, 5,400 brown trout fingerlings were planted in the lake on October 23, 1947. Tests with a seine net on August 10, 1948 showed that brown trout survived, and five specimens from 4 to 4½ inches in length were captured in two drags of the net. A more recent test, August 31, to September 3, 1951, resulted in the capture of eight brown trout including a female with fully developed ovaries.

Camp Lake

A second and somewhat more extensive experiment was conducted on August 8 and 9, 1950, at Camp Lake situated in the Whiteshell Provincial Park, in Sections 22 and 25, Township 9, Range 17 E.P.M. A map of Camp Lake showing depths of water is attached.

There are no roads which would permit driving to Camp Lake. It is approximately one-quarter of a mile north of Falcon Lake at the point where the portage road connects the two bodies of water. The portage rises steeply from Falcon Lake for the first 100 yards or so after which the upward slope is gentle to Camp Lake.

The area of Camp Lake is approximately 70 acres, its greatest depth, 46 feet and the greater part of the lake is between 32 to 40 feet in depth. The water is clear, the shores mostly precipitous granite rock with coniferous and deciduous trees growing to the water's edge. Water temperatures on August 10, 1950, were as follows: Surface 73·5° F., at depth of 35 feet; 50·0° F. in muck bottom—36 feet deep 43·0° F.

The quantity of powdered derris root required for Camp Lake was based on a formula prepared for Telford Pond by Dr. K. H. Doan. For Camp Lake the figures are as follows: Area, approximately 70 acres or 3,049,200 sq. ft.; volume (based on soundings), approximately 109,771,200 cu. ft.; weight of water, approximately 6,851,700,000 pounds; rotenone content of available powdered derris root quoted at 4·4%; concentration of available derris root powder required, based on 5 per cent rotenone content using 0·5 parts per million parts of water, 0·5684 parts per million; weight of powdered derris root required, 4,280 pounds.

When the order of 4,200 pounds of powdered derris root was received, it was described as Cube Powder with the following formula:

Active ingredients, including rotenone	5·73%
Other extractives	14·17%
Inert ingredients	80·10%

Thus the intended concentration of 0·5 parts per million of powdered derris root with a five per cent rotenone content may have been slightly increased.

All equipment for the work had to be portaged over from Falcon Lake. This included the carrying on the backs of eight or more willing workers of five canoes, 800 feet of lumber, two 3 h.p. gasoline engines, three 5 h.p. outboard motors, two 1½″ centrifugal pumps, one large tent, 100 feet of hose, one cement mixer, 4,200 pounds of derris root in 75 pound sacks, eight 40-gallon barrels, 20 gallons of gasoline and many other smaller items. Portaging was completed and all material and tools were at Camp Lake before the operation started. The day before the application was made, August 7, two rafts were built having two canoes for each raft, binding them together with 2 by 6-inch planks, 14 feet long, and then building a 16-foot top on each pair of canoes, using 1 by 8-inch lumber.

Building raft on two canoes at Camp Lake.

When the flat-top rafts were completed, a 3 h.p. engine and a centrifugal pump were set up on each, together with the necessary hose connections. The plan was to have on each raft two 40-gallon barrels of derris root powder in paste form, and a second barrel to which the intake of the pump was connected. Into this barrel, water and derris root paste were bailed in equal proportions to permit the solution to pass freely through the pump.

On the day of application, eight men participated in the work, six on rafts and two ashore. On each raft one man operated the outboard motor to propel the raft, one operated the nozzle end of the hose, spraying and spreading derris root solution as the raft slowly moved over the surface of the lake. One bailed water and derris root paste into the 40-gallon barrel connected to the pump, filling the barrel as fast as the pump lowered the derris liquid. When the two barrels of derris root paste were emptied, the rafts returned to shore base where a fresh supply of paste was ready to be loaded on to the raft.

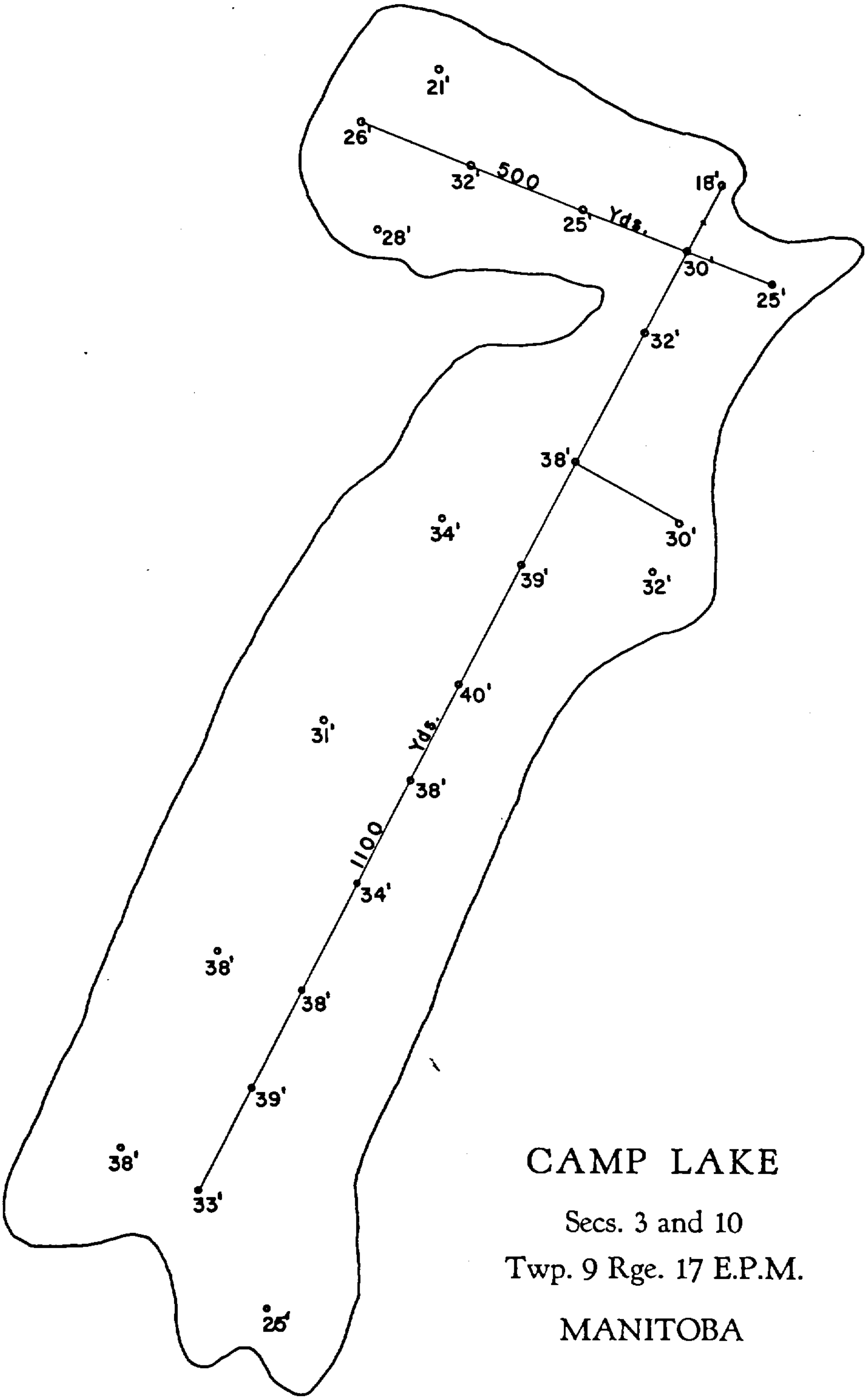
Immediately after the surface of the lake had been covered with derris solution, application at depth was made by trailing 50 feet of one-inch hose to which was attached a 20-foot length of ¾-inch iron pipe with ¼-inch holes bored through it at intervals of one foot. By trailing the iron pipe from the moving raft with the pump operating, a fairly effective application of derris root was made in the deeper parts of the lake. The application was completed in two half days.

Very shortly after the first spraying of derris solution, fish began to rise to the surface and drift ashore. They were mostly yellow perch, rock bass, pearl dace, spottail minnows and white suckers. Apparently no pike were present in the lake. When the application was made to the deeper waters, tullibee in dead or dying condition came to the surface in fairly large numbers.

One week after the poisoning of the lake, two gill-nets were set without result. Later, on August 29, a gill-net, 35 feet deep, 112 yards long, was set from surface to bottom and in it overnight two white suckers were taken. From these tests it would appear that the kill has been fairly complete, although there were a few white suckers left in the lake.

Deep water poisoning outfit.

Tests were next made with trout fingerlings enclosed in wire screen cages, to determine the toxic condition of the water. On September 22, nine rainbow trout fingerlings were submerged to a depth of 10 feet in Camp Lake. On September 25 the cage was lifted and five trout were living.



CAMP LAKE

Secs. 3 and 10
Twp. 9 Rge. 17 E.P.M.

MANITOBA

Surveys Br., Dept. M. & N. R., Winnipeg, July, 1951

On October 18, 1950, sufficient time had elapsed for the toxic properties of the derris root application to be completely dissipated and 40,000 rainbow trout fingerlings were planted in Camp Lake.

The next test was made on February 20, 1951, when 100 yards of 4¼-inch mesh gill-net and 100 yards of 3½-inch mesh gill-net were set under the ice and left for 48 hours. When these two nets were lifted, the total catch of fish was five white suckers, two being taken in the 4¼-inch mesh and three in the 3½-inch mesh. On July 1st, 1951, two gill-nets, each 100 yards long and 2⅞-inch mesh size were set in Camp Lake. After an overnight setting the nets were lifted. One net caught three rainbow trout and two white suckers, the other net one rainbow trout. The age of the four rainbow trout was 14 months, and the rate of growth was most satisfactory. Figures showing length and weight are as follows.

Specimen No. 1	Length 10″	Weight 290 grams (10·2 ozs.)
Specimen No. 2	Length 9⅞″	Weight 240 grams (8·4 ozs.)
Specimen No. 3	Length 10⅜″	Weight 300 grams (10·5 ozs.)
Specimen No. 4	Length 9″	Weight 204 grams (7·2 ozs.)

During the summer and fall of 1952, from May to October, numbers of anglers visited Camp Lake and enjoyed the catching of rainbow trout in southern Manitoba. In late summer specimens measuring 18 inches in length were taken which weighed from 1¾ pounds to two pounds.

Conclusion

The cost factor for the Camp Lake poisoning project worked out at 71·1 cents per acre foot according to the following figures:

No. of acre feet—2,660

Cost of 4,200 pounds derris powder	$1,646.92
24 man days labour	192.00
Cost of 8 barrels	24.00
20 gallons of gasoline	8.40
Hauling and trucking	20.00
Total	$1,891.32

Cost per acre foot—71·1 cents

Where it is desirable, where the cost factor will permit and the environment is suitable for trout, the removal of all other fishes in a small lake by poisoning and restocking with trout of suitable species is a procedure warranted in fish cultural practices in Manitoba, and derris root powder and other forms of rotenone are, therefore, most valuable fish cultural tools.

Additional Information on Eastern Brook Trout x Lake Trout Hybrids

by

J. E. Stenton
Park Warden, Banff National Park, National Parks Service, Ottawa

The successful hybridization of eastern brook trout (*Salvelinus fontinalis*) and lake trout (*Cristivomer namaycush*) has already been reported by the author (Stenton 1950). It is now desirable to present an account of further hybridization between these species and the available data on morphological characteristics of the hybrids.

The original cross male eastern brook trout and female lake trout was repeated during the autumn of 1948, and, in addition, the reciprocal cross was made. The percentage of fertilization and hatch in the first cross was as high as that of a true species, with no deformed fish appearing. The reciprocal cross also showed a large percentage of fertilization and hatch, but a large number of deformed fish were observed.

During the autumn of 1950 the original cross, male brook trout and female lake trout, was again carried out to obtain fry to plant in a virgin lake. Again the efficiency of reproduction was similar to that of the true species.

Early in November 1950, the hybrids of 1947, then in their third year and being held at the Banff hatchery, showed signs of having reached maturity and were observed to be digging redds in preparation for spawning. On November 8, an attempt was made to strip some of these fish and some eggs and milt were obtained. A further attempt was carried out on November 14, and more eggs and milt were secured.

Fifteen Mature Hybrids Fertile

Fifteen mature hybrids, out of 25 held at the Banff hatchery, were stripped and all appeared to be fertile. The remaining ten fish were not checked, but there is no reason to think that they were not fertile. Among the specimens used, 60 per cent were males and 40 per cent females.

It has been shown by earlier workers, Roosevelt (1880) and Green (1881), that a cross between the Pacific salmon, species not known, and the eastern brook trout produced good specimens but on examination all were found to be females. These two investigators, working independently and each unaware of the other's work, obtained strikingly similar results.

The fact that the hybrids held at the Banff hatchery have proven fertile is very encouraging, since most early workers who produced hybrids found them to be usually sterile (Foerster, 1935; Day, 1884, 1885 and 1886). As previously stated, the cross between male brook trout and female lake trout was repeated in the autumn of 1950, and eggs were secured from the hybrid fish. Data on eyeing and hatching of these eggs were collected. They are presented in Tables I and II. Temperature units, shown in these tables, are calculated on the average temperature and based on the formula of one temperature unit per day for each degree of temperature above 32°F. This system was formerly widely used by fish culturists, but Embody (1934) has shown it to be somewhat misleading and it is not now in general use. However, for the convenience of those still using this formula, the figures are included.

Data collected on losses incurred during incubation period and during the first free swimming stage are presented in Table III. The total loss among eggs and alevins is much higher among the hybrids F_2 than among hybrids F_1. About 30 per cent of the loss among hybrids F_2 is due to deformity in the development of the notochord.

Table I

Time and temperature data from fertilization to eyed stage of eastern brook trout x lake trout eggs, first generation (F_1) and of the hybrid eggs, generation (F_2)

Date of fertilization 1950	Generation	Appearance of first eye spots		Temp. to eyed stage	
		Date 1950	Number of days from fertilization	Average (°F.)	Number of units
Oct. 23	F_1	Nov. 27	36	41·6	345·6
Nov. 8	F_2	Dec. 16	38	41·6	364·8
Nov. 14	F_2	Dec. 22	38	41·6	364·8

It is to be noted that the natural hybridization of the two species is improbable, even if their spawning periods overlap, because of the great difference in their spawning habits.

It appears that the spawning of the hybrids follows the reproductive trend of the male parent (brook trout) in that they spawned in their third year of life, which appears normal for brook trout in this locality. On the other hand the lake trout (female parent) in this locality seldom reaches maturity under ten years of age. The ova, although not measured, were obviously of similar size to those of brook trout and were very much smaller than those of lake trout. The hybrids were observed to be digging redds, a characteristic of the brook trout not generally apparent in lake trout. The fact that these hybrids were confined to shallow hatchery ponds prevents any statement as to whether they would have migrated into spring surges or flows as do the brook trout or whether they would have spawned in deep still water as do the lake trout.

It is unfortunate that the progeny of the reciprocal cross, female brook trout x male lake trout, were disposed of since it would have been of great value to be able to determine if the genes of the male parent were dominant in this cross. Both Roosevelt (1880) and Green (1881) found, when the male parent was the larger species, that the ova of the hybrid females were too large to be normally extruded and that the vent had to be cut before they could be taken artificially. It would have been interesting to determine whether they would have proved to be sterile, or, if not, at what age they reached maturity. Green (1881) reported on such a cross but listed the male parent as a Lake Ontario salmon trout which leaves some doubt as to its true genus. He stated that these hybrids successfully spawned in their third year; however, Bean (1889) has cast some doubt on Green's work, which leaves this statement still unconfirmed.

Table II

Time and temperature data from fertilization to eyed stage of eastern brook trout x lake trout eggs, first generation (F_1) and of the hybrid eggs, second generation (F_2)

Date of fertilization 1950	Generation	Beginning of hatch		Temperature to beginning of hatch		Completion of hatch		Temperature to completion of hatch		Duration of hatching
		Date 1951	Number of days from fertilization	Average	Number of units	Date 1951	Number of days from fertilization	Average	Number of units	Period (No. of days)
Oct. 23	F_1	Jan. 2	71	41·3	660·3	Jan. 12	82	41·8	803·6	11
Nov. 8	F_2	Jan. 18	71	41·1	646·1	Jan. 28	83	41·4	780·2	11
Nov. 14	F_2	Jan. 25	71	41·6	681·2	Feb. 8	87	41·4	817·8	14

Table III

Losses during incubation and alevin stages of first (F_1) and second (F_2) generation hybrids (eastern brook trout x lake trout)

Date of fertilization 1950	Generation	Number of parents		Eggs obtained	Losses of eggs and fry			Number of fingerlings surviving
		Males	Females		During incubation	In alevin stage	Total	
Oct. 23	F_1	6 (a)	2 (b)	5,700	227 (4%)	1,198	1,425	4,275
Nov. 8	F_2	3 (c)	2 (c)	1,500	1,840 (27%)	1,480 (22%)	3,320 (49%)	3,410
Nov. 14	F_2	6 (c)	4 (c)	5,230				

(a) = eastern brook trout; (b) = lake trout; (c) = hybrids.

Note = "Alevin stage" here denotes the period from hatching until absorption of the yolk sac and commencement of free swimming.

Preparing to Spawn Again

In early November of 1951, the adult hybrids at the Banff hatchery were preparing to spawn again. Thus they follow the tendency of the male parent (brook trout) in that they apparently spawn every year, unlike lake trout, which in some northern lakes appear to spawn only every second or third year (Miller 1947).

The general colour of the first-generation hybrids between brook trout and lake trout, when three years old, may be described as follows: the back is dark olive-green with numerous pale vermiculations; the sides are bluish-silver and the belly white. There are numerous lemon-yellow and pale pink spots along the sides above and below the lateral line. The leading edges of the paired fins and of the anal fin are white, and the remainder of these fins are pale orange in colour, with the pectoral fins being dusky towards the forward edge. The dorsal fin is dark and heavily spotted. The tail is truncate as in the brook trout, but the body is elongated as in the lake trout. From the foregoing it becomes apparent that both parent species have left undeniable marks on the coloration and form of their progeny. The red spots and blue halos common to the brook trout are absent. Figure 1 illustrates the pattern of the vermiculations and the side spots.

Taxonomic measurements given in Table IV, made on four specimens of each of the parent species and four specimens of their F_1 hybrid progeny, show that the hybrids have a slight leaning towards characteristics of the lake trout female parent. Ten out of twenty-three of the measurements and counts favour the lake trout while six favour the brook trout side; the balance, nine, appear as intermediate between the parent species.

The vomerine teeth have the same location in all specimens examined, i.e. on the head of the vomer bone only.

The maxillary length, as shown in this table, is used instead of the upper jaw length as recommended by Hubbs and Lagler (1947), as the measurements shown refer only to the maxillary and not the total length.

Table IV

Counts and proportional body measurements of lake trout, eastern brook trout and hybrids

$$\text{Body parts} = \frac{\text{Body measurements}}{\text{Fork length}} \text{ x } 1000$$

—	Species		
	Lake Trout (1)	Eastern Brook Trout (2)	Hybrid (3)
Fork Length (mm.)	346·25	326·0	345·5
Weight—ounces	14·25	12·75	14·0
Proportional Measurements			
Caudal Peduncle Length	6·4	6·3	6·1
Caudal Peduncle Depth	14·1	11·3	14·0
Body Depth	5·0	4·5	5·3
Head Length	4·1	4·6	4·3
Snout Length	14·6	14·2	15·7
Orbit Length	19·0	23·7	23·0
Eye Length	24·3	27·7	26·6
Maxillary Length	10·0	9·3	9·3
Maxillary Extends Beyond Eye	173·1	40·8	34·6
Length of Dorsal Fin Base	9·9	8·4	9·5
Length of Longest Dorsal Fin Ray	7·5	8·5	8·0
Length of Anal Fin Base	11·8	9·6	11·8
Length of Longest Anal Ray	11·3	11·9	12·1
Length of Longest Pelvic Fin Ray	8·9	9·4	8·6
Length of Longest Pectoral Fin Ray	6·0	7·1	6·4
Predorsal Length	2·2	2·4	2·2
Width of Tail Spread	3·6	3·8	5·8
Counts			
Number of Dorsal Fin Rays	11·0	10·0	11·0
Number of Anal Rays	11·0	9·0	10·0
Number of Gill Rackers	17·3	14·0	14·0
Number of Branchiostegal Rays	14·0	10·0	11·0
Number of Pyloric Caeca	105·5	31·8	76·0
Number of Lateral Line Scales	194·5	227·8	210·8

(1) 4 specimens = 2 males and 2 females; age: 3 and 4 years old.
(2) 4 specimens = 2 males and 2 females; age: 2 years old.
(3) 4 specimens = 3 males and 1 female; age: 3 years old.

The alevin stage of the brook trout-lake trout hybrids was completed on February 7, 27 days after hatching. Feeding of this group began on February 8. On February 28, after 21 days of feeding, this group showed an average length of 31 mm. and were feeding vigorously.

The alevin stage of the hybrid progeny was completed on February 26, 18 days after hatching. This group began to feed on February 27. On March 19, after 21 days of feeding, this group showed an average length of 22 mm. The alevins of the second generation hybrids appeared weak and puny in comparison with the first generation hybrids; close inspection however, showed them to be about the same size as the alevins and fingerlings of true brook trout.

The last measurements taken, on May 8, 1951, showed that the first generation progeny of brook trout and lake trout parents, averaged 38 mm. in length, and the second generation progeny of hybrid parents, averaged 28 mm. in length. Both groups were feeding well at this time.

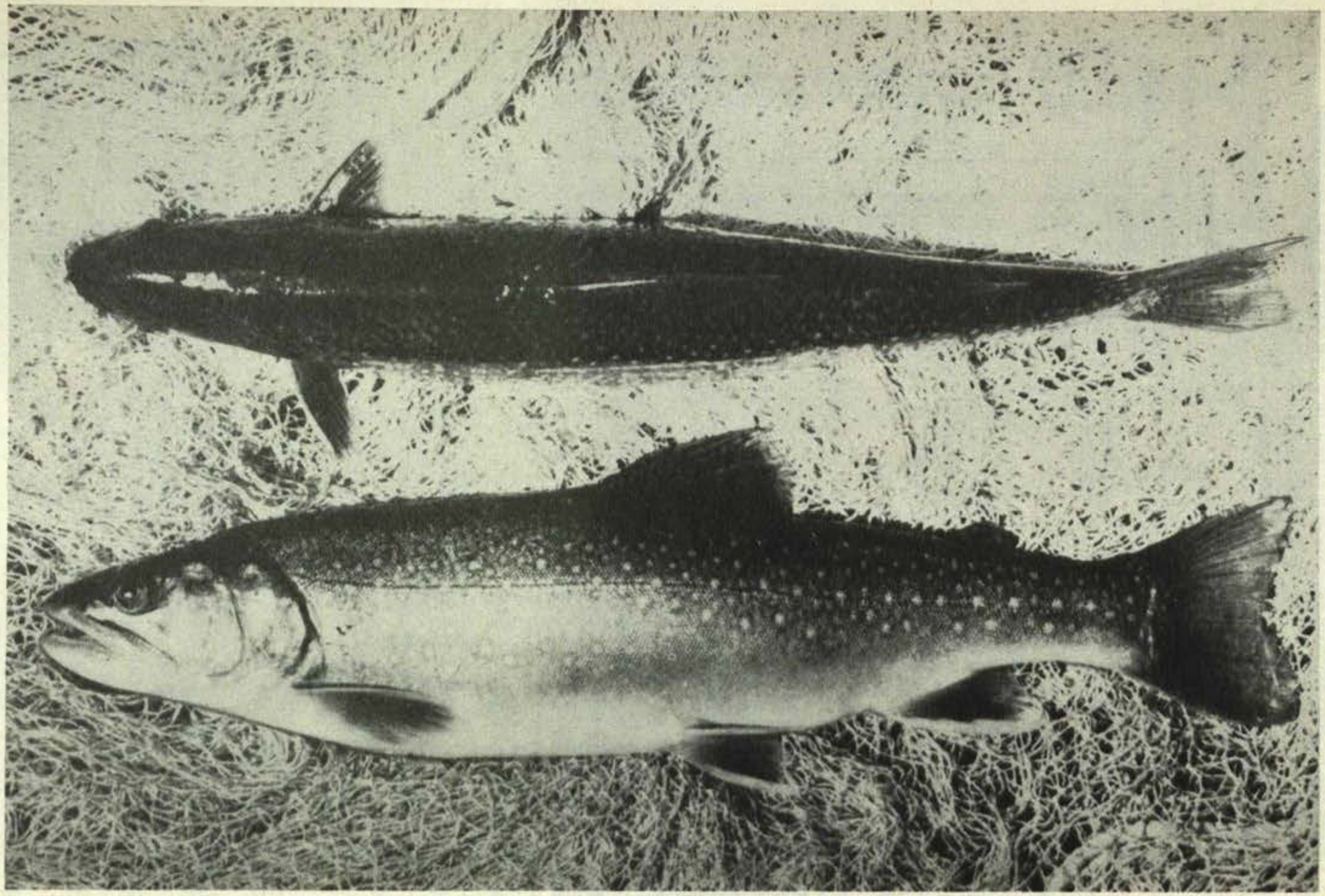


Figure 1. Lake trout-eastern brook trout hybrids. Fish Hatchery, Banff National Park, July 22, 1950.
Top: male immature; 13 inches, fork length; weight, 15 ounces. Bottom: male mature; 13·5 inches, fork length; weight, 15·5 ounces.
(Photo. by J.-P. Cuerrier)

Acknowledgments

My sincere thanks to the following persons: Mr. A. C. Colbeck, Superintendent, Banff Hatchery, and his staff who made the hatchery data available; Dr. R. E. Foerster, Pacific Biological Station, Nanaimo, B.C., who lent old literature pertaining to hybrid trout; Dr. D. S. Rawson, University of Saskatchewan, Saskatoon, Saskatchewan, for the loan of literature, for age determinations of lake trout, brook trout and hybrid and for helpful criticism and suggestions; Jean-Paul Cuerrier, Canadian Wildlife Service, Ottawa, for reading and criticising the manuscript.

Literature Cited

BEAN, T. H. 1889. *Hybrids in Salmonidae.* Trans. Amer. Fish. Soc.

DAY, F. 1884. *On Races and Hybrids among Salmonidae.* Parts I-III. Proceedings London Zoological Society.

— 1885. *Ibid*, part IV. Proc. London Zool. Society.

— 1886. *On Hybridization of Salmonidae at Howietoun.* Report 55 Meeting British Assoc. Adv. Science.

EMBODY, G. C. 1934. *Relation of Temperature of the Incubation Period of Eggs from Four Species of Trout.* Trans. Amer. Fish. Soc., Vol. 64.

FOERSTER, R. E. 1935. *Inter-Specific Cross Breeding of the Pacific Salmon.* Trans. of the Royal Society of Canada. Sec. 5.

GREEN, S. 1881. *Hybridizing Fish.* Tran. American Fish Cultural Association.

HUBBS, C. L., and K. F. LAGLER. 1947. *Fishes of the Great Lakes Region.* Cranbrook Institute of Science. Bulletin 26.

MILLER, R. B., and W. A. KENNEDY. 1948. *Observations on the Lake Trout of Great Bear Lake.* Journal of Fisheries Research Board of Canada, Vol. VIII, No. 4.

ROOSEVELT, R. B. 1880. *Hybrids.* Tran. American Fish Cultural Assoc.

STENTON, J. E. 1950. *Artificial Hybridization of Eastern Brook Trout and Lake Trout.* Canadian Fish Culturist, No. 6.

Moricetown Falls Biological Survey—1951

by

W. R. Hourston and J. W. Stokes
Department of Fisheries of Canada, Vancouver, B.C.

Moricetown Falls, B.C., long regarded as an obstruction in the path of the salmon and steelhead runs, attracted the attention of the local Fisheries Inspector as early as 1928. The inspector who visited the falls in early autumn noticed that the water levels were low enough to hinder the upstream migration of salmon over the middle of the falls and that only a small number were able to ascend the side channels without being captured by the Indian fishery. The inspector further noted "There are, however, quite a number of sockeye above the falls and I do not wish you to think that the grounds will not be seeded on account of the falls at Moricetown, but I do believe a good deal of improvement could be made there, and in a case such as at present, where the water level is very low, possibly a number of sockeye that come late would more easily reach the spawning grounds."

As a result of this report a portion of the falls was blasted out in an effort to ease the situation. However, the efficiency of this remedial measure was never fully ascertained.

No further investigations were conducted at Moricetown Falls until the Fisheries Research Board of Canada set out to study the falls as part of the Skeena River Salmon Investigation. For three years, from 1945 to 1947, water levels were recorded, the Indian fishery observed, tagging experiments conducted and the behaviour of each species at the falls noted.

From the investigation it was shown by Milne* that the falls delayed the migration of all four species of Pacific salmon indigenous to the Bulkley River system, the degree of blockage varying with each species and increasing in severity with the advent of low flow conditions. Of the three years studied, water conditions in 1945 were the most adverse, particularly after August 20, and it was found that the sockeye salmon were delayed an average of 6·7 days and the coho salmon an average of 27·4 days. The spring salmon, which arrive at the falls early in the season, encounter little difficulty in ascending the crest of the falls but the pink salmon, later arrivals, are faced with the most adverse flow conditions and it was observed that only a few of the earliest arrivals succeeded in surmounting the obstacle.

The report concluded by recommending the provision of suitable fishways to facilitate the passage of salmon during the low water periods.

Plans Made for Two Fishways

This report was studied by engineers of the Department of Fisheries of Canada, following which plans were drawn up for the construction of two fishways that would (1) pass fish successfully at all levels at or below the critical low water periods, (2) be

---

*Milne, D. J. "Moricetown Falls as a Hazard to Salmon Migration." Bull. Fish. Res. Bd. of Can. 86: 1-16, 1950.

sufficiently large to accommodate the peaks of the runs and (3) be of a type that would not require the fish to jump.

Another factor which had to be considered was the possibility that future power developments would affect the headwaters of the Morice River to such a degree that the flow of water in the river would be reduced considerably. This reduction in flow would in turn lengthen the critical low water conditions at Moricetown Falls and further delay the upstream migration of the salmon for an average of ten days each year. This factor helped influence the decision to construct the fishways and so assist the salmon over the falls.

By October 1950 construction crews had assembled their equipment at Moricetown and commenced the building of the fishways. This work continued throughout the winter and was completed a few days before the spring freshets covered the fishways with the heavy spring run-off.

With the 1951 runs of salmon being able to take advantage of the fishway facilities it was decided to test their efficacy by duplicating as closely as possible the tagging experiments conducted by the Fisheries Research Board during the years 1945-47. In addition it was anticipated that during the period of low flow in August and September water conditions would permit the actual observation of salmon ascending the fishways. With this view in mind a survey crew was established at Moricetown Falls early in July, 1951.

Methods

The salmon were obtained for tagging by means of dip nets operated at the various locations shown in Figure 1. Dropping water levels throughout the tagging period necessitated the occasional relocation of the netting sites.

Petersen type tags were attached below the dorsal fin by means of a non-corrosive nickel pin. In addition to the tag number and date of capture, the length (fork), sex and condition of the salmon were recorded and a scale sample taken.

Water levels were recorded daily by means of a graduated line lowered from the traffic bridge to the surface of the water.

A maximum-minimum thermometer was installed below the falls from which daily readings were taken.

During the early part of the sockeye run a number of salmon were tagged and released above the falls for the purpose of estimating the population of this species that spawn in the upper reaches of the Nanika River tributary to Morice Lake. The silty nature of this river and the lack of a suitable trapping site had effectively prevented a tagging programme for such a study during the preceding two years. It had been decided therefore to combine the testing of the fishways with an analysis of the Nanika population, the tags to be retrieved on the spawning grounds during the spawning period September-October.

In conjunction with the tagging programme white flash or counting-boards were installed at the exits of both fishways as an aid in observing those salmon that had ascended. Frequent spot counts were made at these two stations and on August 17-18 a complete count of all salmon passing through the left-bank fishway during a 24-consecutive-hour period was carried out.

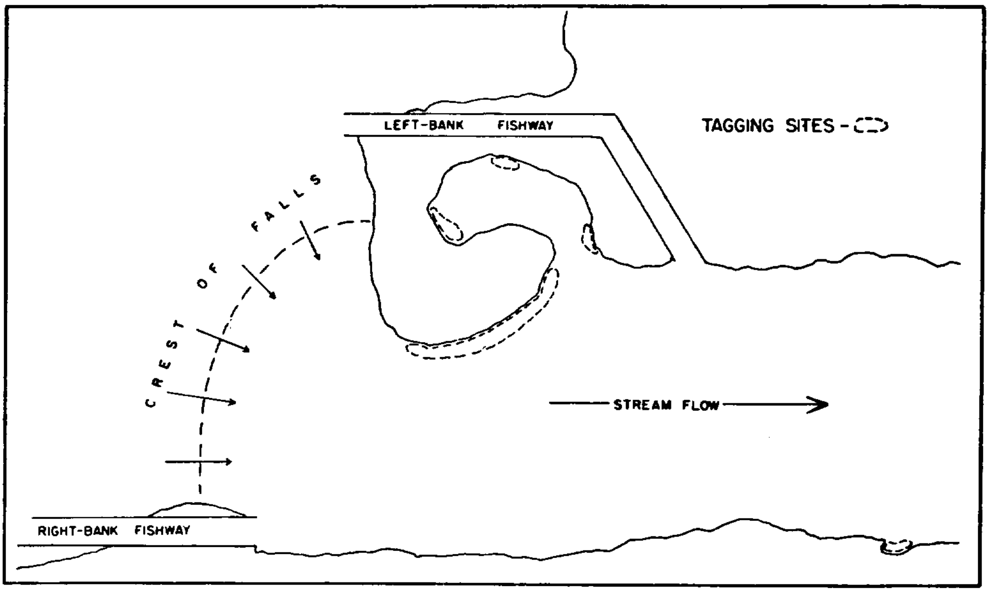


Figure 1. Salmon-tagging sites at Moricetown Falls

Since the return of tags from below the falls indicates only the relative periods of delay a trap was installed at the left-bank fishway exit for the purpose of trapping the tagged salmon and thereby ascertaining the absolute period between tagging and ascent of the fishway. Unfortunately this device proved unsuccessful due to the fact that the salmon would not pass through but rather tended to accumulate below it and finally returned back down the fishway. A total of nine tagged coho, however, were recovered by this method before the trap was removed.

To eliminate selective gaffing for tags by the Indians no reward was paid for their return. The Indian fishery was kept under close observation, however, and all tagged fish gaffed were examined and the numbered tag retrieved. The Indians proved very co-operative in this respect and it was felt that all tagged fish caught by them were examined.

Results

From July 17 to August 31 a total of 1,685 salmon were tagged and released at Moricetown Falls. Of these, 763 were released above and 922 below the falls. The number of each species of salmon tagged, the location of release and area of recapture is presented in Table I.

Of the 474 sockeye released below the falls 35 or 7·6 per cent were recovered at the falls either by the Indians or the tagging crew. Of the 761 sockeye released above the falls 12 were recovered at the falls, indicating that a certain number of these sockeye released above dropped back below the falls again.

There were 11 sockeye tags recovered at points other than at Moricetown Falls or the Nanika spawning grounds. Five were from the vicinity of Hazelton (30 miles below Moricetown), on the Bulkley River; one from the main Skeena River; one from

Table 1

Number of Salmon Tagged at Moricetown Falls, 1951, where released and recovered

Species	Number Tagged	Released		Recovered					Total Recovered
		Above Falls	Below Falls	At Falls		Below Falls[1]	Above Falls	Spawning Grounds	
				By Indians	By Taggers				
Sockeye	1,235	761	474	35	12	7	4	190	248 (20·1%)
Coho	441	2	439	6	5	1	9[2]	0	21 (4·76%)
Pink	9	0	9	0	0	0	0	0	0
Totals	1,685	763	922	41	17	8	13	190	269 (15·9%)

[1] *Below falls refers to recoveries from areas below Moricetown village.*

[2] *These nine Coho were captured in a trap at the left bank fishway exit.*

Table II

Sockeye Tagging Returns at Moricetown Falls, 1951

Date	Number Tagged	Number Recovered	Number of days out														
			0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
July 15	10	0															
16	11	3		1	2												
17	44	0															
18	45	5				5											
19	11	0															
20	21	1		1													
21	20	1							1								
22	53	3				1		1		1							
23	71	2		1			1										
24	47	0															
25	110	0															
26	142	1				1											
27	165	2			1				1								
28	123	13		2	2	6	1		1			1					
29	114	11	3	1	4	1		1			1						
30	45	1										1					
31	33	0															
Aug. 1	7	0															
2	17	0															
3	41	0															
4	31	0															
7	5	1															1
11	4	0															
13	3	0															
14	17	2				1				1							
15	15	0															
17	18	1			1												
18	1	0															
19	1	0															
20	1	0															
21	7	0															
26	1	0															
Totals	1,235	47	3	6	9	16	2	2	3	2	1	2	0	0	0	0	1

a pool below Moricetown Canyon; one in Kathlyn Creek (15 miles above Moricetown); one in the Telkwa area (40 miles above the falls); two in the Morice River near Owen Creek (70 miles above Moricetown).

With reference to the sockeye tags recovered at the falls, Table II shows the number of sockeye tagged daily, the number recovered and the number of days between tagging and recovery for each tag. These data are also illustrated graphically in Figure 2.

A comparison between the days out for sockeye during the period 1945 through 1947, before installation of the fishways, and 1951, when the salmon could make use of the fishway facilities, is shown in Table IV. Included also in this table are data relating to the duration of the run plus the date of critical low water levels during the four years.

The 24-hour count of all fish ascending the left bank fishway was started at midnight August 17, and terminated midnight August 18. It was found that with the white flash board in place at the outlet of the fishway there was sufficient illumination to enumerate all salmon ascending the ladder. A graph showing the number of salmon per hour that ascended the fishway is presented in Figure 3. Additional 24-hour counts were planned but unfortunately turbid water conditions precluded this. However, several counts of from one to five hours duration were made on both fishways. In all, a total of 2,028 salmon were counted through the right bank fishway in a total of 24 hours and 2,958 counted through the left bank fishway in a total of 72·5 hours.

Of the 439 coho released below the falls 11 (2·4 per cent) were recovered at the foot of the falls either by the Indians or the tagging crew. The two released above the falls were not recovered.

Table III

Coho Tagging Returns at Moricetown Falls, 1951

Date	Number Tagged	Number Recovered	Number of days out														
			0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Aug. 14	9	2							1	1							
15	50	3			1		1		1								
16	0	0															
17	46	1									1						
18	64	3			1	1								1			
19	36	2			1										1		
20	12	2		1				1									
21	38	1	1														
22	21	2				1	1										
23	5	0															
24	29	1	1														
25	46	1			1												
26	34	1				1											
27	8	0															
28	13	0															
29	20	1			1												
30	0	0															
31	10	0															
Totals	441	20	2	2	4	3	2	1	2	1	1	0	0	1	1	0	0

Table IV

Comparative Tagging-Recapture Intervals at Moricetown Falls Prior to and Following Fishway Installation, with related data

Year	Species and size of sample	Duration of run	Critical low water level	Average time between tagging and recapture[1]	Authority
1945	Sockeye 153 Coho 12	June 26-Aug. 27 Aug. 13-Oct. 5	Aug. 20	6·7 days 27·4 days	Fisheries Research Board
1946	Sockeye 164 Coho 8	June 27-Sept. 3 Aug. 26-Oct. 10	Sept. 3	5·1 days 13·0 days	"
1947	Sockeye 101 Coho 27	July 3-Aug. 23 Aug. 13-Oct. 5	Critical low not reached	5·5 days 10·0 days	"
1951	Sockeye 47 Coho 11	July 9-Aug. 26 Aug. 1-Sept. 13	Aug. 3	4·1 days 3·7 days	Dept. of Fisheries Fish Cult. Dev. Br.

[1] *The interval is that between tagging and recapture at the tagging site below the falls.*

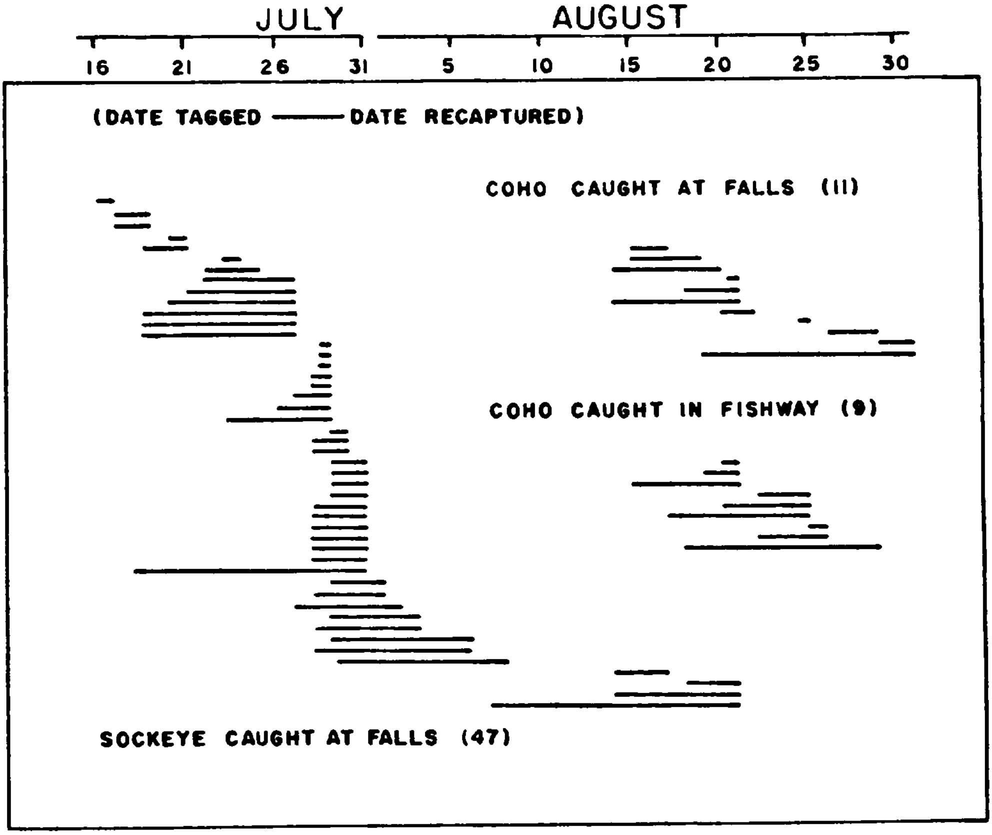


Figure 2. Number of days out for sockeye and coho salmon tagged at Moricetown Falls in 1951

There were ten coho tags recovered at points other than the foot of the falls. Of these, nine were taken at the exit of the left-bank fishway and one at Mission Creek (25 miles below Moricetown). These data are tabulated in Table I.

With reference to the tags recovered at the falls, Table III presents the number of coho tagged daily, the number recovered and the number of days between tagging and recovery for each tag. These data are also illustrated graphically in Figure 2.

A comparison between the days out for coho during the period 1945 through 1947, before installation of the fishways, and 1951, when the salmon could utilize the fishways, is shown in Table IV.

No recoveries were made of the nine pink salmon tagged and released below the falls. This species was not present at the falls in any large numbers during the period of tagging, the peak arriving some time later thereby accounting for the small number tagged.

The water levels during the 1951 tagging period, recorded by lowering a graduated line from the traffic bridge to the water surface, have been converted to water surface elevations with reference to a datum established in the canyon by the Department of Fisheries, and are presented in Figure 4. Dr. Milne's report had shown that water conditions during 1945 were the most adverse of the three years studied, so for purposes of comparison gauge heights during this year are also illustrated in Figure 4.

The mean daily water temperature at Moricetown Falls during the 1951 tagging period is presented in Figure 5.

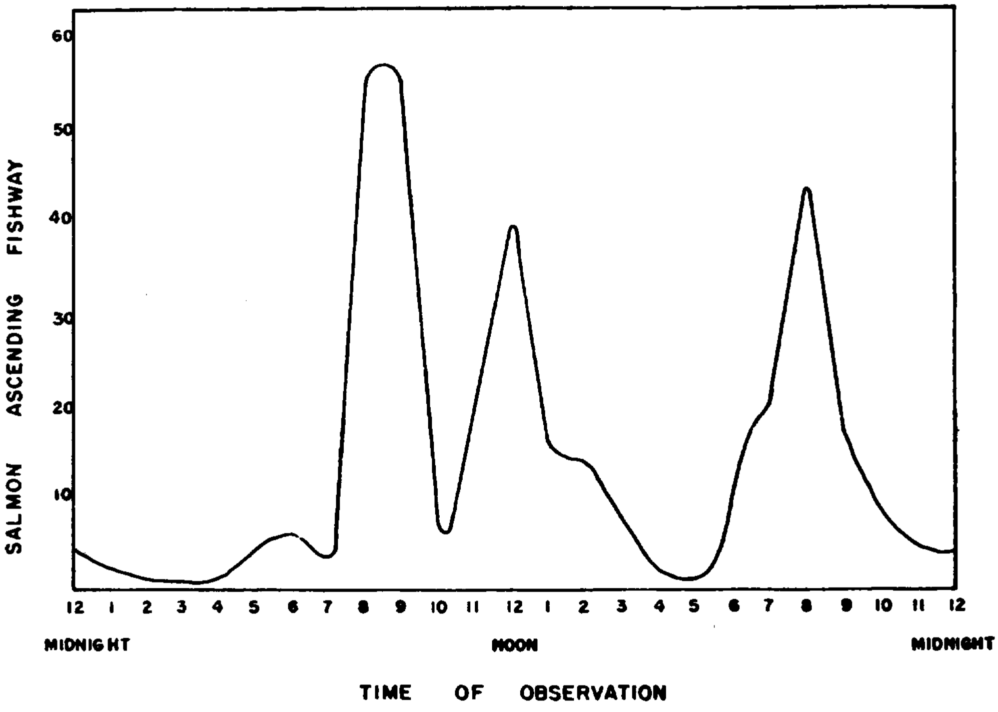
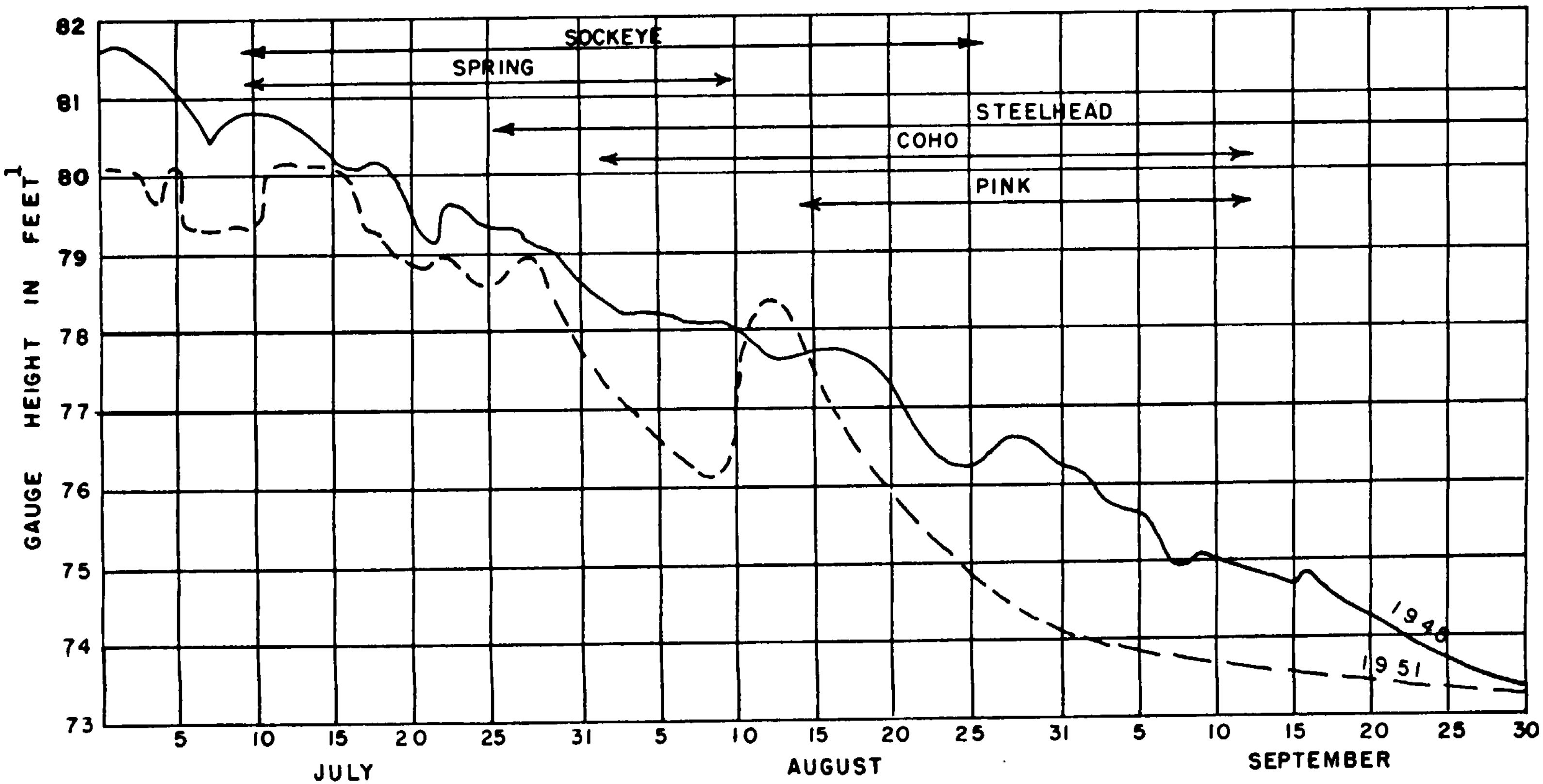


Figure 3. Number of salmon per hour ascending the left-bank fishway at Moricetown Falls during a 24-hour period August 17-18, 1951



---

[1] *Gauge heights calculated with references to datum established in the canyon by the Department of Fisheries.*

Figure 4. Gauge heights at Moricetown Falls, 1945 and 1951, and period of salmon and steelhead migration, 1951

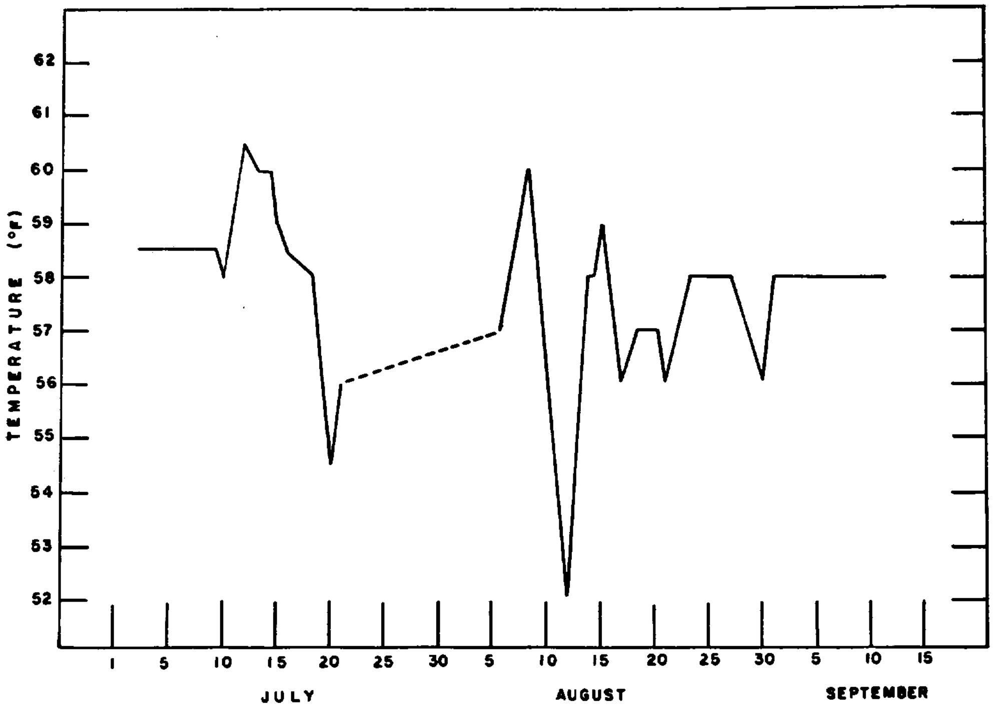


Figure 5. Daily mean water temperatures at Moricetown Falls in 1951

Discussion

The success of the fishways in easing the passage of sockeye salmon at Moricetown Falls is illustrated in Table IV which compares the average time between tagging and recapture for the four years during which tagging was carried out at this location, viz.: 1945-47 and 1951. It will be noted that the average of 4·1 days in 1951 is the shortest period of the four years studied. Figure 4, which compares the river elevations in 1945 and 1951, illustrates this point more graphically for it will be seen that in 1951 flow conditions at the falls were considerably more adverse than in 1945, the worst year recorded by the Fisheries Research Board surveys. If the fishways had not been in operation in 1951 there could be little doubt that the flow conditions during the latter part of the sockeye migration would have caused considerable delay at the falls.

The recovery below the falls of 12 of the 761 sockeye released above the falls indicated that a certain number of this group dropped back after release. While the fish were released into relatively quiet water some "fall backs" were expected since handling during tagging excites the fish to a considerable extent. The fact that 1·4 per cent of those released above were recovered below whereas 7·9 per cent of those released below were recovered below, would indicate that the majority of sockeye released above continued their upstream migration.

The results obtained from the coho tag returns offer further proof of the assistance rendered by the fishways in easing the passage of fish at Moricetown Falls. Although water conditions were worse in 1951 compared to 1945 the average time between tagging and recovery was 3·7 days in the former year compared to 27·4 days in the latter year. This period is considerably less even than the average of 13·0 and 10·0 days delay recorded in 1946 and 1947 respectively, when water conditions were considerably better than in 1945. The bulk of the coho were tagged subsequent to the occurrence of water levels which were considered critical in 1945, yet the returns indicate little delay.

The recovery of nine coho in the trap in the last pool of the left-bank fishway in the average time of 4·5 days after tagging is a measure of the absolute period between tagging and ascent of the fishway. When it is considered that these fish were tagged during the period of adverse water conditions at the falls, then the fishways definitely facilitated their passage past the obstruction.

A further point of interest is a comparison between the percentage of tagged sockeye and coho salmon returned by the Indian fishery during the years 1945-47 and in 1951. In the former years 15 to 25 per cent of the tagged sockeye and 6 to 18 per cent of the tagged coho were returned by the Indians, whereas in the latter year 5·7 per cent of the tagged sockeye released below the falls and 1·6 per cent of the tagged coho were returned at the falls. While it is not possible to compare the relative fishing intensity, nevertheless, it is an indication that the fish were not schooling-up below the falls where they would be susceptible to gaffing.

With reference to pink salmon, considerable numbers were reported spawning above the falls in 1951 whereas in former years relatively few of this later running species were able to surmount the obstruction.

The 24-hour count of salmon ascending the left-bank fishway (Figure 3), indicated two pronounced peaks of activity, one in the morning and one in the evening, with considerable activity exhibited during the noon period. The periods of least activity occur during the early morning and late afternoon.

The following data on the condition of the salmon tagged was obtained. Out of 1,235 sockeye 9 per cent bore gaff marks, 7·4 per cent net marks and 3·1 per cent miscellaneous scars and bruises. Out of the 441 coho salmon tagged, 4·1 per cent bore gaff marks, 2 per cent net marks and 5 per cent scars and bruises.

The mean daily water temperature records illustrated in Figure 5 indicate that no abnormal temperature conditions were encountered by the salmon throughout their migration period. The mean high of 60·5 degrees Fahrenheit recorded on July 12 is well below the upper temperature tolerance limit of Pacific salmon.

The sockeye salmon population was estimated at 53,600. This estimate was derived from the return by the Indian fishery, of 35 (5·7 per cent) of the 1,235 sockeye tagged. In arriving at this figure a correction was made for the number of sockeye that were released above the falls, but which dropped back below and were therefore available for capture by the Indians.

Summary and Conclusions

A tagging programme was carried out by the Department of Fisheries of Canada at Moricetown Falls during the period of salmon migration in 1951. The purpose of the programme was to test the efficiency of the newly completed fishways installed as a result of an investigation during the years 1945-47 by the Fisheries Research Board of Canada from which it was determined that the falls delayed the migration of salmon.

Sockeye, coho, and pink salmon were tagged and released below the falls and in addition, a number of tagged sockeye were released above the Falls in conjunction with a study of the Nanika River spawning population.

Water level and temperature records were maintained for comparison with similar records compiled during the period 1945-47 by the Fisheries Research Board investigation.

The average time between tagging and recovery for sockeye salmon in 1951 was found to be 4·1 days. During the years 1945-47 this period was found to be 6·7 days, 5·1 days, and 5·5 days respectively.

For coho salmon the average time between tagging and recovery was 3·7 days in 1951. An average period of 27·4, 13·0, and 10·0 days respectively was determined for coho salmon during 1945-47.

Of the three years studied by the Fisheries Research Board water levels in 1945 were the lowest and conditions during this year were considered the most adverse for passage of salmon. The 1951 water levels were found to be lower than in 1945, particularly during the period of the coho migration.

During the years 1945-47 the Indians returned 15 to 25 per cent of the tagged sockeye salmon and 6 to 18 per cent of the tagged coho salmon. In 1951 the Indians returned 5·7 per cent of the tagged sockeye released below the falls and 1·6 per cent of the tagged coho salmon.

It is thus concluded that the fishways were successful in assisting the migration of salmon past Moricetown Falls, particularly under conditions of low flow in the Bulkley River.

Fertilization and Predator Control to Improve Trout Production in Crecy Lake, New Brunswick

by

M. W. Smith
Fisheries Research Board of Canada, Atlantic Biological Station, St. Andrews, N.B.

A study conducted over a number of years on eight Charlotte County lakes, of which Crecy is one, showed that the annual yield of trout (*Salvelinus fontinalis*) to the anglers averaged only 0·58 pounds per acre, and that introduced hatchery trout contributed little to this low yield (Smith, 1952). By virtue of drainage from an area of non-productive soils, the supply of nutrient salts in the waters of these lakes is poor. The infertility of the waters is viewed as a primary and obviously important factor in determining the low yields of trout.

The extent to which the yield of trout to anglers might be improved by overcoming, even if temporarily, the deficiency in the supply of nutrient salts by means of artificial fertilization has been explored at Crecy Lake. In the course of the investigation there was evidence that beneficial effects of the fertilization upon the yield of trout were being masked by bird, mammal and possibly eel predation. Apparently such predators of fish as the loon, kingfisher, otter and others were being attracted to Crecy Lake by a consistent annual stocking with trout which provided as good, if not better, fishing than found by these predators in neighbouring lakes. These observations led to an extension of the Crecy Lake programme on fertilization to include measures of predator control.

This article is preliminary in character. An account of the effects of fertilization upon the limnological conditions in general and a more complete presentation of the action of the fertilization and predator control upon the yield of trout in particular will be presented at a later date. Other preliminary reports have already been published (Smith, 1948a, b).

Crecy is a headwater lake on the Bocabec River system, Charlotte County, southwestern New Brunswick. It has an area of 50·4 acres (20·4 hectares) and a mean depth of 7·8 feet (2·4 metres). Since the maximum depth is only 12·5 feet (3·8 metres), the waters of the lake are subject to mixing throughout by winds of even moderate velocity. The lake has a volume of $17 \cdot 18 \times 10^6$ cubic feet ($0 \cdot 49 \times 10^6$ cubic metres). Additional limnological data for this lake may be found in a previous publication (Smith, 1952).

Actions Taken

1. *Annual Creel Census*

A man has been stationed on the lake for this purpose during each angling season since 1943 with the exception of 1945 when the lake was closed to fishermen. Data have been obtained upon the number of marked and unmarked trout killed, the number of anglers, the time spent in angling whether trout were taken or not, and the length, weight and sex of the fish. Almost all fishing has been from boats that landed at one point, which arrangement has favoured a thorough census.

2. *Stocking with hatchery-reared trout*

Since the stock of native trout in the lake was limited, additional trout were introduced to assure as complete utilization as possible of any improved trout-producing capacity that might result from the fertilization. Yearling trout, marked by fin-clipping, were planted in 1944 and 1945, and both marked yearlings and fingerlings thereafter annually. The hatchery trout have been planted sufficiently late in the season so that they have not been subject to angling until the following year. These trout have been supplied by the Fish Culture Development branch of the Department of Fisheries of Canada from the hatchery establishment at Saint John, N.B.

3. *Fertilization of the lake*

On June 19 and 20, 1946, one ton of ammonium phosphate fertilizer (11-48-0) and 500 pounds of potassium chloride (60 per cent K_2O) were spread over the surface of Crecy Lake, principally over the littoral areas. The application amounted to 6·5 pounds of the fertilizers per acre-foot, or 0·39 mg. of phosphorus (P), 0·21 mg. of nitrogen (N) and 0·27 mg. of potassium (K) per litre of water. The total phosphorus (P) content of the water just prior to fertilization averaged 0·016 mg. per litre. The fertilizers were donated by the New Brunswick Resources and Development Board.

4. *Erection of fish barrier and trap in outlet of lake*

Of the yearling trout (675) planted in Crecy Lake in the late fall of 1944, anglers captured 12 individuals during the following season in a small pond on the outlet of the lake. When the yield of trout fell off markedly in 1948 (Table I), movement of planted trout from the lake was considered as a possible factor contributing to the decline. To obviate this factor a fence of galvanized wire ($\frac{3}{8}$-inch mesh) was placed across the outlet immediately below the lake in July, 1948, before the annual stocking was made. A year later a trap was incorporated into the barrier to assess the number of trout that might attempt to leave the lake. The fence and trap have been maintained effectively throughout all seasons of the year.

Only nine yearlings and one fingerling of the stock planted in 1949 attempted to run from the lake. Of the introductions made in 1950, 2·5 per cent of the fingerlings (168) and 6·1 per cent of the yearlings (41) were taken in the trap. These observations suggest that migration from the lake was not a prominent factor in the disappearance of the planted trout before the barrier was erected. It is pertinent that the yield of trout continued to decline in 1949 (Table I) although escape of trout from the lake was prevented.

5. *Control of fish-eating birds and mammals*

The diminishing yield of trout to the anglers from 1947 to 1949 was associated with an increase in the number of visits made to the lake by fish-eating birds and mammals. Attempts to curtail the activities of these predators were initiated in early August, 1949. Control measures have consisted of shooting and trapping under permit as many predators as possible and, failing this, frightening them from the lake, in either case before they have had the opportunity to feed. The control has increased in effectiveness with time. To be as effective as it has been, constant attention has been required from a technician resident on the lake.

6. *Trapping of eels in the lake*

The capture of 897 eels in the trap in the outlet during the fall of 1949 disclosed a greater abundance of these fish in Crecy Lake than was formerly appreciated. (A good proportion of these eels would doubtless have left the lake in 1948 if they had not been prevented from so doing by the fence.) The eel is the only piscivorous fish in the lake aside from the trout. To determine if their number could be reduced appreciably and thereby the control of trout predators extended, a programme of trapping eels in baited traps set in the lake was begun in 1950. The numbers of eels taken in this manner were 369 in 1950 and 78 in 1951. These captures, although they comprised quite large numbers when consideration is given to the size of Crecy Lake, by no means depleted the stock of eels in the lake. This is shown by the following numbers of eels which were taken in the outlet trap when they attempted to migrate: 105 during the fall of 1950; 55 during April, 1951; 357 during the fall of 1951. The eel is catadromous, and limnetic populations of the species are primarily recruited from the elvers that annually enter fresh waters from the sea; accordingly the best eel control would be to prevent the entrance of the young into the lake. A barrier dam was erected in the outlet in the spring of 1951 with this objective. The efficacy of the measure has not yet been demonstrated and in any case its action has no bearing upon the data presented here.

Results of Fertilization

The yield of trout and the rate of their capture from Crecy Lake were appreciably greater in 1947, the year following fertilization, than had been experienced previously (Table I). Much of the improved yield may be ascribed to the excellent growth made by the introduced fingerlings. From September, 1946, to May and June, 1947, these trout increased in mean fork length from 3·2 to 8·5 inches (8·2 to 21·7 cm.) and were accordingly a suitable size for angling when yearlings (Table III). Of the 425 trout taken in 1947 by the anglers, 254 (60 per cent) were from this planting.

Since no marked fingerlings were introduced into Crecy Lake prior to 1946, a direct comparison of the growth rate of this size of stock before and after fertilization is not possible. There is good evidence, however, that the fertilization resulted in a decidedly faster growth rate by the fingerlings than would have been realized normally.

Table I

Yield of trout to anglers from Crecy Lake

Year	Number caught	Number per rod-hour	Pounds per acre	Kilograms per hectare
1943	166	0·45	2·2	2·5
1944	148	0·5	1·45	1·6
1946	139	0·6	1·4	1·6
1947	425	1·0	3·55	4·0
1948	110	0·3	1·6	1·8
1949	39	0·15	0·9	1·0
1950	264	0·6	2·9	3·2
1951	1,441	1·4	6·4	7·2

Table II

Percentage survival of planted trout to anglers' creels

Year planted	Stock	Number planted	Number subsequently caught	Per cent survival to anglers
1944	yearlings	675	6*	0·9
1945	yearlings	812	83	10·2
1946	yearlings	659	111	16·8
1946	fingerlings	6,701	286	4·3
1947	yearlings	675	26	3·85
1947	fingerlings	6,684	52	0·8
1948	yearlings	675	12	1·8
1948	fingerlings	6,575	5	<0·1
1949	yearlings	674	201	29·8
1949	fingerlings	6,633	129	1·9
1950	yearlings	675	306	45·3**
1950	fingerlings	6,750	1,333	19·7**

**12 additional individuals were taken from pond on outlet of Crecy Lake.*
***to June 16, 1952.*

Fingerlings from the same hatchery stock that was planted in Crecy Lake in 1946 were also introduced during that year into Gibson Lake, which lies in the same area of Charlotte County and in many respects of morphology and character of water is similar to the former lake. Gibson Lake was not fertilized and there the growth in length of the introduced fingerlings from August, 1946, to May, 1947, was only from 2·9 to 4·4 inches (7·4 to 11·1 cm.). It is also significant that no yearlings were found among the 453 trout taken from Crecy Lake by the anglers in 1943, 1944 and 1946, before fertilization. The assumption is made that, as yearlings, trout were not large enough to be taken, or if taken were not retained by the anglers. This situation was found to obtain generally in Charlotte County lakes (Smith, 1952).

An improvement in the growth of trout planted as yearlings also followed the fertilization (Table III). However, the improved growth rate by the planted fingerlings to the point that they were of suitable angling size during the year following their introduction is considered the more important result of the procedure. Introductions of hatchery trout to overcome deficiencies in stocks of native fish is most economical when good returns to the anglers are realized from planting fingerlings. It develops all too frequently, however, that because of various adverse conditions the survival of planted fingerlings to fishermen's creels is discouragingly poor. Recourse may be had to rearing the trout to angling size under artificial conditions before distribution on what is largely a put-and-take basis, relegating the natural aquatic environment to a holding rather than a producing area. The fertilization of Crecy Lake resulted in a sufficiently better growth of fingerling trout to shorten appreciably the period during which they were subject to natural mortalities before being cropped by the anglers. Of the fingerlings planted in 1946, 4·3 per cent were subsequently captured by the fishermen. This percentage in itself is small but viewed as a survival of planted fingerlings to anglers' catches is noteworthy for waters of the area, as well as elsewhere (Shetter, 1939; Smith, 1952).

Table III

Growth of planted trout

Stock and year of planting	Mean fork length in centimetres (Number in sample in brackets)				
	When planted	When angled 1st year after planting	Increment in one year	When angled 2nd year after planting	Increment in two years
Yearlings......... 1944	28·3±1·79 (41)	—*		31·2 (5)	2·9
1945	19·2±2·19 (77)	25·6±1·63 (66)	6·4	32·3±2·10 (12)	13·1
1946	21·3±1·54 (108)	28·9±1·27 (111)	7·6	—**	
1947	21·4±1·61 (53)	31·0±1·92 (26)	9·6	—**	
1948	16·2±1·30 (60)	30·2±3·46 (11)	14·0	—**	
1949	18·7±1·82 (60)	26·8±1·71 (181)	8·1	36·5 (7)	17·8
1950	18·5±1·83 (239)	25·0±2·45 (278)	6·5	32·7 (2)	14·2
Fingerlings....... 1946	8·2±1·09 (49)	21·7±1·30 (244)	13·5	32·4±1·87 (25)	24·2
1947	7·4±0·95 (76)	23·5±1·95 (32)	16·1	33·3±1·67 (15)	25·9
1948	6·1±0·84 (175)	21·4±1·95 (23)	15·3	30·6 (2)	24·5
1949	6·6±0·79 (67)	19·0±2·16 (60)	12·4	25·9±3·09 (68)	19·3
1950	8·4±1·29 (55)	17·0±2·06 (905)	8·6	23·3±2·51 (287)	14·9

**Lake not open to angling in 1945.*

***None captured.*

Results of Predator Control

The better yield of trout to anglers which was realized in 1947 did not persist, and in 1948 and 1949 the anglers' catches fell off markedly to below pre-fertilization levels (Table I). The survival of both the planted fingerlings and yearlings to the anglers was poor (Table II). (There was evidence from gill-netting and from the carry-over of planted trout into the second year from their introduction that the poorer yields in 1948 and 1949 reflected correspondingly lower trout populations in the lake.) Yet as may be seen in Table III, the growth of the fewer trout captured by the anglers was good, for the most part an improvement over those taken in 1947. The beneficial effects of the fertilization were no doubt still being experienced, but also contributary to the continuing fast growth of the trout was less competition for a common food supply.

As we have already noted, the declining yields of trout in 1948 and 1949 were associated with an increased predation by fish-eating birds and mammals, and perhaps by eels as well. Attempts at predator control, which these observations prompted, were begun in 1949 and the first stocks of planted trout that could have been affected appreciably were those introduced into the lake in that year and initially subjected to angling in 1950. It is shown in Table II that a greater percentage of these trout, especially those planted as yearlings, survived to the anglers' creels. With a continuance of bird and mammal control at a more effective level and extension of the programme to the trapping of eels on the lake in 1950, still better results were obtained with respect to both survival and yield of hatchery trout. Of the yearlings put into the lake in 1950, 45·3 per cent were subsequently taken by the anglers (Table II). We consider it more noteworthy, however, that 19·7 per cent of the fingerling stock survived to the fishermen.

Coincident with a greater survival of planted trout, the growth rate was depressed (Table III). It would appear that a condition of over-population had almost been reached—over-population from the viewpoint of the desirability of having planted fingerlings attain a suitable size for angling during the next year, i.e. as yearlings.

Discussion

However effective fertilization may prove to be as a procedure to improve trout production in natural lakes in certain situations, there are difficulties and definite limitations to its general application.

1. Fertilization is obviously of no value if applied to a lake that presents an adverse chemical environment for trout.

2. So far as we can visualize at the present time the cost of the fertilizer limits the size of the lake that can be treated, even if there were assurance that a given dosage would result in an improved trout production. Interpretation of what is a reasonable cost is subject to a divergence of opinion, but it should be borne in mind that we are primarily concerned with a sport fishery whose value cannot be gauged by the worth of the fish as food.

3. Unwanted fish in a trout lake will also benefit from any increase in the fish-producing capacity. On the one hand there are species that are competitors and predators of trout and, on the other, forage fish that are trout foods. In many Maritime lakes yellow (*Perca flavescens*) and white (*Morone americana*) perch, eels (*Anguilla rostrata*) and certain other species are inimical to trout. Control of such fish is indicated in order to realize at all fully the beneficial effects upon trout production that may accrue from artificial fertilization.

4. A sufficient supply of young trout to capitalize upon a higher productive level after fertilization is prerequisite. Where because of poor spawning facilities young native trout are scarce, transplantations from other waters or plantings from hatchery stocks are required and may on occasion present difficulties.

5. Fertilization to be effective implies creating or intensifying a condition of eutrophy, even if no more than temporarily. Blooms of phytoplankton occur where they have not previously been noted (Smith, 1948; Langford, 1950). Decomposition of the increased amounts of organic matter increases or causes hypolimnial deficits in

dissolved oxygen and depressions of winter values at all levels when lakes are icebound. A marked reduction in the amount of dissolved oxygen may be helpful to the phosphorus exchange in some lakes by presenting conditions suitable for the reduction of ferric to the more soluble ferrous phosphate (Einsele, 1938; Hayes, 1951), but this is no compensation for depletion of oxygen to the point that fish are killed. Almost complete winter-kills of fish were experienced in fertilized lakes in Michigan (Ball, 1950). However, at Crecy Lake the mean dissolved oxygen content was reduced to a low of only 6·8 ml. per litre (71 per cent saturation) during the winter following the fertilization. A greater but yet not severe deficit was found two years later at the end of a winter season with greater ice and snow cover on the lake. On March 29, 1949, the mean content was 5·8 ml. per litre (62 per cent saturation). Fertilization to attain maximum eutrophication without too serious reduction in dissolved oxygen is a nice manipulation of the limnetic environment which is certainly not yet fixed by prescription.

Physical difficulties involved in patrol and costs, increasing with increasing size of lake, present the most serious limitations to control of fish-eating birds and mammals. However, something quite short of complete control may prove worthwhile. Our experience at Crecy Lake demonstrated that to approach complete control close attention was required, and that patrol on the ordinary workaday basis would have been ineffective since so many of the predators visited the lake in the early daylight hours and to a lesser extent in the evening.

A scientific permit is required to destroy throughout the year those fish-eating birds that come under the protection of the Migratory Birds Convention Act.

Conclusion

Notwithstanding the considerable number of technical and biological problems involved in the development and practical application of artificial fertilization and predator control as means of improving trout angling in natural lakes, the results obtained at Crecy Lake are encouraging. The improvements in the anglers' catches of trout that followed both fertilization and predator control on that lake are sufficiently clear-cut to warrant further application in other similar non-productive waters.

Literature Cited

BALL, ROBERT C. 1950. *Fertilization of natural lakes in Michigan.* Trans. Amer. Fish. Soc., Vol. 78 (1948) 145-155.

EINSELE, W. 1938. *Über chemische und kolloidchemische Vorgänge in Eisen-Phosphat-Systemen unter limnochemischen und limnogeologischen Gesichtspunkten.* Arch. Hydrobiol., Bd. 33 :361-387.

HAYES, F. R. 1951. *On the theory of adding nutrients to lakes with the object of increasing trout production.* Canadian Fish Culturist, No. 10, pp. 32-37.

LANGFORD, R. R. 1950. *Fertilization of lakes in Algonquin Park, Ontario.* Trans. Amer. Fish Soc., Vol. 78 (1948) 133-144.

SHETTER, DAVID S. 1939. *Success of plantings of fingerling trout in Michigan waters as demonstrated by marking experiments and creel censuses.* Trans. Fourth N.A. Wildlife Conf. 1939, pp. 318-325.

SMITH, M. W. 1948a. *Preliminary observations upon the fertilization of Crecy Lake, New Brunswick.* Trans. Amer. Fish. Soc., Vol. 75 (1945) 165-174.

1948b. *Fertilization of a lake to improve trout angling.* Fish. Res. Bd. Can., Prog. Rept. Atl., No. 43, pp. 3-6.

1952. *Limnology and trout angling in Charlotte County Lakes, New Brunswick.* J. Fish. Res. Bd. Can., Vol. 8 (6) 383-452.

Abstract

by

F. E. J. Fry

Associate Professor of Limnology, University of Toronto

MEYER, P. F. 1951.
Ein neuartiges Impulsgerat fur die Elektrofischerei.
Der Fischwirt: Nr. 3.

This article describes brief tests with a new model of electric fishing apparatus designed for use in ponds and streams. The device makes use of a fluctuating D.C. current and operates from a 12-volt battery. The advantages stated for the apparatus are its lightness (approx. 15 lbs. without the battery, 50 lbs. with battery, dry cells may be substituted for the storage battery to reduce the weight) and its safety from an electrical standpoint. The apparatus is stated to be equal in effectiveness to a 3 to 5 K.W. apparatus of the types formerly available. Its sphere of effectiveness is 10 to 15 feet. The fish are attracted to the positive pole and are removed by a dipnet as they become narcotized. Three or four day's fishing may be carried out without recharging the battery. The apparatus is built by Messrs. Kreutzer-Peglow, Hamburg 8, Postfach 1281.

Three trials are reported: in a pond three feet deep, a stream about 15 feet wide and five feet deep, and a pond 16 feet deep. All were successful. The major disadvantage encountered was that the larger fish may be harmed if allowed to approach too close to the positive pole, a thumb switch is installed on the electrode rod to guard against this. When fishing over deep water, it is necessary to be able to see down at least five feet since fish swimming up to the electrode are stunned and will sink before they can be seen if the water is not sufficiently transparent.

A copy of the article abstracted above is on file in the library of the Ontario Fisheries Research Laboratory.

EDMOND CLOUTIER, C.M.G., O.A., D.S.P.
QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1953