ANNUAL REPORT

GREAT LAKES FISHERY COMMISSION

1957

GREAT LAKES FISHERY COMMISSION

MEMBERS — 1957

CANADA	UNITED STATES
A. O. Blackhurst	D. L. McKernan
W. J. K. Harkness	Claude Ver Duin
A. L. Pritchard	Lester P. Voigt

SECRETARIAT

N. S. Baldwin, Executive Secretary
Edith McPherson, Secretary

GREAT LAKES FISHERY COMMISSION

Established by Convention
between Canada and the United
States for the Conservation of
Great Lakes Fishery Resources.

ANNUAL REPORT

FOR THE YEAR

1957

1319 N. University Ave.
Ann Arbor, Michigan,
U. S. A.

INTRODUCTION

The Great Lakes Fishery Commission was established by the Convention on Great Lakes Fisheries between Canada and the United States, ratified on October 11, 1955. The Commission has two major responsibilities: the first, to develop co-ordinated programs of research on the Great Lakes and, on the basis of their findings, recommend such actions as will insure the maximum sustained productivity of stocks of fish of common concern; the second, to formulate and implement a program to eradicate or minimize sea lamprey populations in the Great Lakes.

The Commission was organized in April 1956 and began its activities on July 1, 1956. It is composed of six members, three from the United States and three from Canada.

Canadian Commissioners are:

A. O. BLACKHURST, *Manager*
Ontario Council of Commercial Fisheries
Port Dover, Ontario
W. J. K. HARKNESS, *Chief*
Division of Fish and Wildlife
Ontario Department of Lands and Forests
Toronto, Ontario
A. L. PRITCHARD, *Director*
Conservation and Development Service
Department of Fisheries
Ottawa, Ontario

United States Commissioners are:

D. L. MCKERNAN, *Director*
Bureau of Commercial Fisheries
United States Fish and Wildlife Service
Washington, D. C.
CLAUDE VER DUIN, *Manager*
Chamber of Commerce
Grand Haven, Michigan
L. P. VOIGT, *Director*
Wisconsin Conservation Department
Madison, Wisconsin

The Commission is assisted in its program planning by a Scientific Advisory Committee of four scientists, two from each country under the chairmanship of the Executive Secretary. Committees representing the fishing industry, sportsmen, government agencies, and the public at large have also been established to advise each national section.

Lake trout have been practically eliminated in Lake Huron and Lake Michigan. The early establishment of lamprey control to prevent elimination of the remaining lake trout fisheries in Lake Superior has, therefore, become the Commission's main concern. The commercial production of lake trout from Lake Superior fell to one-half of the long-term average in 1956 and to about one-third in 1957. Fewer mature fish are appearing in the catch and the danger that reproduction will soon be seriously reduced is becoming very real.

At the present time, the control program is based on the use of electrical barriers which prevent the sea lamprey from reaching spawning areas in streams. Periodic examinations are made of the streams above the barriers to determine their effectiveness. Streams with suitable spawning areas which are not now used by sea lamprey are kept under close surveillance. The Commission's agents, the Bureau of Commercial Fisheries, U. S. Fish and Wildlife Service, and the Fisheries Research Board of Canada, receive considerable assistance in stream surveys and barrier operation from provincial and state agencies. Several of these agencies conduct research on problems related to sea lamprey control and restoration of lake trout.

In 1957 both agents continued research to improve existing control techniques and develop new ones. The behavior and habits of the lamprey were studied. The strength and pattern of electrical fields required to block their spawning immigrations upstream and associated problems concerned with guiding lamprey and fish into traps were investigated. In April 1957, the Commission, after considering the high cost of extending the barrier construction to Lake Huron and maintaining the network on the three upper Great Lakes, decided to concentrate its efforts on Lake Superior in order to make certain that lamprey control on this lake was as thorough and efficient as possible. Plans were laid to continue the construction program on Lake Michigan and limit work on Lake Huron to a survey of tributaries to locate those used by spawning lamprey.

A steady advance in the development of a chemical control technique was climaxed by a successful field test in October 1957 of one of a group of related nitrophenols. The selective action of these compounds had been discovered in a 3-year screening of some 6,000 chemicals to find some which at low concentrations were lethal to lamprey larvae but harmless to other fish. Two of the compounds, which appeared to offer the best prospects and could be produced commercially, were selected for further testing. One was applied to a small stream tributary to Lake Huron where it destroyed 96 percent of the young lamprey without significant injury to the other fish.

The success of this experimental application, and the growing evidence of the rapid deterioration of the Lake Superior trout fishery,

caused the Commission to reconsider its control program again in December 1957. The use of the chemical technique in Lake Superior streams would destroy young lamprey before they entered the lake, and thus reduce pressure on remnant stocks of trout almost immediately. Electrical barriers would not achieve the same effect before 1960–61, for although spawning had not occurred in recent years in many of the rivers, young lamprey, representing the hatches of several years were still present from earlier spawnings. In view of the risk that some populations of lake trout would be eliminated and difficult to replace, and the possibility that chemical treatment might supersede electrical barriers as a control method in some situations, the Commission urged its rapid development in the current fiscal year. It accordingly stopped barrier construction on Lake Michigan in 1958 and diverted funds and personnel to the chemical treatment of Lake Superior streams.

The restoration of lake trout may be as difficult as the control of the sea lamprey. The Commission has, therefore, given considerable attention to the development of a lake trout restoration program. Although there have been a number of studies assessing planting procedures, more are required to insure that restoration is carried out rapidly and efficiently. The need to stock Lake Superior remains to be determined, but it is obvious that spawning populations in Lake Michigan and Lake Huron can only be established by introducing hatchery produced fish. At the present time, hatchery facilities in the upper Great Lakes area can produce approximately 2 to 3 million lake trout yearlings annually. Production is presently limited by the number of lake trout eggs available. In past years eggs had been obtained from Lake Superior, but now, with the scarcity of mature fish, other sources must be found. In order to insure a future supply of eggs brood stocks are being developed in the hatcheries and a search for other sources in inland lakes has been started by federal, state and provincial agencies. The Commission established a Special Committee on Lake Trout Rehabilitation with representatives from federal, state and provincial agencies in the upper Great Lakes area. It assigned a member of its secretariat the task of developing and co-ordinating the program with the assistance of this committee. The Commission also recommended that planting of lake trout in the Great Lakes be considered experimental and that controls be established to provide an objective appraisal of results.

Several meetings of scientists were held during 1957 to review programs of research not related to sea lamprey control. Many of these programs have developed only recently and are accordingly concerned largely with methods of obtaining representative samples of fish populations in order to follow and understand the fluctuations

in abundance. Associated with these investigations are studies of migrations, feeding habits and hydrographic conditions.

A bibliography of Great Lakes fishery literature was begun in 1957 by the Commission under a contract with the University of Toronto. Copies of the bibliography will be provided groups carrying out fishery research on the Great Lakes for ready reference to results of past research.

Remarkable co-ordination has been developed by research agencies through informal committees. Although the program of general research on the Great Lakes is still far below the level desirable, the work underway and the problems selected for initial study by the research groups are of prime importance and present a sound approach to an understanding of the fishery.

INTERIM MEETINGS AND ACTIONS

In the period following the 1956 Annual Meeting and preceding the 1957 Annual Meeting, the Commission met on three occasions to familiarize itself with developments in lamprey control and to revise its program accordingly.

Milwaukee, Wisconsin—April 16–17, 1957

The Commission, after learning with regret of the resignation of Mr. John L. Farley, began its meeting under the temporary chairmanship of Dr. A. L. Pritchard. The Commission decided that Dr. Pritchard, the Vice-Chairman, should continue to act until the United States Section had decided whom from its members it would recommend for the chairmanship of the Commission.

The Commission reviewed the 1957–58 program for lamprey control and research which had been approved at the Annual Meeting and made no changes. It agreed that the United States be asked to contribute 69 percent of the cost of the total program, estimated at $1,367,000, and Canada 31 percent. The Commission requirements for administration and general research, estimated at $50,000, were to be shared equally by the two countries.

The program and estimates for fiscal year 1958–59, which had received preliminary consideration at the 1956 Annual Meeting, were again submitted by the Scientific Advisory Committee with minor modifications. The program called for the operation of 109 electrical barriers on Lake Superior, 107 on Lake Michigan and 53 on Lake Huron; the construction of 65 barriers on Lake Huron and 24 on Lake Michigan. The estimates also provided for the reconstruction of 10 barriers on Lake Superior. Research in 1958–59 included fundamental studies of all phases of sea lamprey life history to discover facts which might lead to different or improved methods of control. The use of chemicals selectively toxic to sea lamprey had shown promise and further investigation of this potential control technique would stress the effects of physical and chemical properties of water on the biological activity of these compounds. It was estimated that approximately $1,870,500 was required to carry out the lamprey program and $50,000 to maintain the Commission's headquarters.

The Commission was advised that about $450,000 would be required to complete construction of the electrical barrier network on the upper Great Lakes. The annual operating expenses would then be increased by approximately $340,000. The program cost could exceed $2,000,000 in 1958–59 and again in 1959–60 if the barrier network was to be completed. On the basis of operations as currently

practiced about $1,500,000 would be required annually to maintain the network in operation, although research and technical advances might reduce the costs.

The Scientific Advisory Committee submitted the following statement regarding extension of the program:

> The magnitude of the cost of this program has caused the Scientific Advisory Committee to consider whether barrier construction should be completed on all lakes above Lake Erie without first seeing the results of a full scale operation on Lake Superior. There is a difference of opinion as to the degree of certainty for success in ultimate control to be achieved by existing methods. We feel the difference of opinion should be brought to the attention of the Commission.
>
> Limitation of barrier construction beyond the program for 1957–58 would hold expenditures at about $1,400,000 annually for a period of some five years. Meanwhile, the necessary information on, and rights to, barrier sites on Lake Huron streams could be obtained. Research on ammocoete life history and habits and further developmental work on control methods could be completed. By awaiting results on Lake Superior, much more definite and stronger recommendations could be made to the Commission for specific action.
>
> It should be realized that this test in Lake Superior will require at least five years. Should the methods as now in use be found effective in Lake Superior, valuable time will have been lost in achieving control in the remainder of the Great Lakes, a matter that is of major importance to the fishing industry. However, the Lake Michigan control network, which which is scheduled for completion in the 1957–58 fiscal year, will be in operation. The question, therefore, is whether we should proceed with the Lake Huron construction plans as scheduled or whether this work unit should be delayed until more background is available.

On the basis of this statement the Commission announced that the program should concentrate on Lake Superior to make certain that the sea lamprey control operations there were thorough and efficient. The control network in Lake Michigan should be completed and surveys of streams on both sides of Lake Huron should proceed but barriers on Lake Huron should not be built. A revised estimate of $1,450,000 for the 1958–59 program was made.

Problems of lake trout restoration were discussed and the possibility that an early maturing stock could be selectively bred and introduced into Lake Huron considered. The Great Lakes Fishery Investigations of the United States Fish and Wildlife Service submitted a report on trout hatchery facilities in the upper Great Lakes and on planting procedures which gave best survival of planted Stock (page 66).

The Commission adjusted the proportion of the two installment payments to its agents in order that they could meet the comparatively heavy expenditures made in the first part of the fiscal year by amending Section V (d) of the Financial Regulations to provide receipt of contributions and payment of contract obligations on the basis of

three-quarters of the total on July 1, and one-quarter of the total on January 1.

London, Ontario—June 5, 1957

Contracts with the Fisheries Research Board of Canada and the Bureau of Commercial Fisheries of the United States Fish and Wildlife Service were reviewed and referred to the Chairman and Vice-Chairman for final approval. A contract with the University of Toronto for the preparation of a bibliography of Great Lakes literature was approved. The bibliography, which would cover 2,000 to 2,400 items of literature dealing with the fisheries of the Great Lakes, would be prepared on cards cross-indexed by author, subject, and locality. Reference would also be made on the cards to one library in the United States and one library in Canada where the paper could be consulted. Ten copies of the bibliography would be prepared and distributed to agencies undertaking fishery research on the Great Lakes. The cost of the contract for the first year was $12,000.

The Commission approved the 1958–59 program, revised in accordance with the Commission's decision at the previous meeting, in the amount of $1,464,750. The revised program provided for the construction of 9 electrical barriers on Lake Superior and 24 on Lake Michigan, the reconstruction of 12 barriers, which were not functioning efficiently, and the operation of existing barriers. An amount of $100,000 was included in the estimate to purchase chemicals for experimental treatment of streams to destroy young lamprey. Provision was made to continue surveys of Lake Huron streams to locate spawning runs of sea lamprey and research projects as originally proposed.

The Commission, in considering organizational matters, elected Commissioner Voigt to the chair left vacant by the resignation of John L. Farley. Mr. Norman S. Baldwin was appointed Executive Secretary, replacing Dr. James W. Moffett who had served in that capacity since the Commission was organized in 1956.

Rogers City, Michigan—September 24, 1957

The Commission met briefly in Rogers City following an inspection of work being carried out on chemicals selectively toxic to sea lamprey at the Hammond Bay Laboratory of the Bureau of Commercial Fisheries.

Mr. Donald L. McKernan, Director of the Bureau of Commercial Fisheries, United States Fish and Wildlife Service, who had recently been appointed to replace Commissioner Farley, was officially welcomed by the Chairman.

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ANNUAL MEETING

AGENDA

1. Call to order by Chairman.
2. Introduction of advisory groups.
3. Adoption of agenda.
4. Approval of past minutes.
5. Press relations.
6. Reports of contracting parties:
   (a) Lamprey control in 1956–57.
   (b) Lamprey research in 1956–57.
   (c) Progress of Great Lakes Bibliography.
7. Consideration of lamprey control programs:
   (a) Review of program and estimates for fiscal year 1958–59.
   (b) Tentative program and estimates proposed by Scientific Advisory Committee for 1959–60.
   (c) Tentative program and estimates proposed by Scientific Advisory Committee for 1960–61.
8. Lake trout rehabilitation program recommended by Scientific Advisory Committee.
9. A report by the Scientific Advisory Committee on general research being conducted on the Great Lakes with recommendations.
10. Consideration of organizational matters:
    (a) Report of Chairman.
    (b) Report of Executive Secretary on discharge of Commission's duties.
    (c) Annual report.
    (d) Report of Executive Secretary on status of accounts.
    (e) Preparation of supplement to the Report of the International Board of Inquiry for Great Lakes Fisheries to cover period 1941–1960.
    (f) Commission staff.
    (g) Amendments or additions to Rules of Procedure and Financial Regulations.
11. Date and place of next meeting.
12. Resolutions.
13. Other business.
14. Adjournment.

ANNUAL MEETING

PROCEEDINGS

The Second Annual Meeting of the Great Lakes Fishery Commission was held in Toronto, Ontario, on December 2 and 3. Two plenary sessions, one executive session and several brief meetings of the Scientific Advisory Committee took place. The two national sections also met with their advisors.

Call to order and introduction of advisors. The Chairman of the Commission, Mr. L. P. Voigt, after calling the meeting to order and welcoming advisors and guests, called on Dr. A. L. Pritchard and Mr. Claude Ver Duin to introduce advisors to the two national sections. A list of participants appears at the end of the report of the Annual Meeting.

Adoption of agenda. The proposed agenda was adopted.

Approval of past minutes. The minutes of the meeting held in Rogers City, Michigan, on September 20, 1957, were approved.

Press relations. A committee consisting of Dr. Pritchard, Mr. Ver Duin, Mr. Patrick Whalen, public relations officer with the Ontario Department of Lands and Forests, and Mr. Baldwin of the Secretariat, was approved by the Chairman to meet the press and make an appropriate news release regarding the meeting. Several representatives of the press, invited by the Commission, attended the first plenary session.

Presentation of reports on lamprey control and research. A progress report on the lamprey control program carried out in the United States under a contract with the Commission by the Bureau of Commercial Fisheries (page 35), drew discussion on several points, notably the increasing cost of operating electrical barriers and the cost of the control program as compared with the value of the fishery. It was pointed out that the electrical barrier operations were being improved and that the use of chemicals might reduce the cost of control appreciably. In view of these developments such a comparison would be premature at this time. There was also good evidence that sea lamprey, having destroyed lake trout in two of the Great Lakes, were adversely affecting other species, such as whitefish, suckers and deep-water ciscoes, or chubs. Lamprey may also have caused the decline of walleye in Saginaw Bay on Lake Huron. The possible loss in production of species other than lake trout should therefore be considered. The capital value of the lake trout fisheries alone, which prior to the lamprey invasions yielded about $5,000,000 annually, was at least $50,000,000. It would be worth even more to future generations.

The use of chemicals to destroy young sea lamprey in streams drew questions regarding harmful effects on other fish and its persistence in natural waters. The Commission was advised that some trout were killed in the first field treatment but that they were only a small proportion of those present. Freshwater shrimp, *Gammarus*, were seriously affected but the stream was rapidly repopulated by migrations from the lake. Accumulations of the chemical in large bodies of water would not be significant.

The possibility of duplication of effort, particularly in the development of electrical control devices, was discussed by the Commission, following a report on the lamprey control activities in Canada by the Fisheries Research Board of Canada (page 28). It was explained that the use of direct current had been investigated by the Bureau of Commercial Fisheries and a device developed which would guide fish and lampreys into a trap. This device was used in conjunction with alternating-current barriers on some streams in order to prevent the destruction of valuable fish. The direct-current guiding device did not block all sea lamprey and could not therefore be used alone. The Fisheries Research Board of Canada believed that an effective barrier could be developed, using direct current, and that all lamprey and fish could be guided into traps. The Commission agreed that this work should continue but recommended that its agents achieve even closer liaison by the exchange of personnel.

In answer to questions on the commercial catch of lake trout the Bureau of Commercial Fisheries presented a statistical report (page 63). The Chairman stated that development of the Commission's program should be guided by the rather critical situation in Lake Superior, where the only sizable stock of lake trout in the Great Lakes remained.

Great Lakes Bibliography. In 1957 the Commission contracted with the University of Toronto for the preparation of a bibliography of scientific literature relating to the fisheries of the Great Lakes at a cost of $12,000 for the first year. In the first three months the University had prepared a subject key and cards covering 300 references. It had also found it possible to increase the number of copies supplied from 10 to 20 without additional cost.

Distribution of the completed portions of the bibliography had begun as follows:

University of Toronto (2 copies).
Fisheries Research Board of Canada, London.
Fisheries Research Board of Canada, Ottawa.
Ontario Department of Lands and Forests.
Dr. C. Davis, Western Reserve University, Cleveland.
Great Lakes Fishery Commission, Ann Arbor.

Bureau of Commercial Fisheries, United States Fish and Wildlife Service, Ann Arbor.
Research Division, Bureau of Commercial Fisheries, United States Fish and Wildlife Service, Washington, D. C.
State Conservation Departments (8 copies).

The Commission instructed the Secretariat to hold the remaining three copies in reserve and arrange with the University of Toronto to have any additional copies required by these agencies supplied at cost.

Lamprey control program in 1958–59. The Commission reviewed the 1958–59 program and was advised that an estimated 90 barriers would be ready on Lake Superior and 78 on Lake Michigan at the close of fiscal year 1957–58. When plans were being prepared in 1956, it was expected that 74 barriers would be completed on Lake Michigan by 1957 and a total of 107 by the end of fiscal year 1957–58. The construction schedule had not been met in fiscal year 1956–57 because of the need to replace electrical barriers on Lake Superior and an unanticipated rise in the cost of construction and maintenance.

The Commission considered a recommendation that electrical barriers on seven Canadian streams of Lake Superior be placed on standby. These streams were not being used by sea lamprey at the present time, although spawning conditions in them appeared to be ideal. The Commission, having received assurance that these streams would be kept under surveillance, recommended that the seven barriers be placed on standby.

The Commission was asked to consider the treatment of six streams in Georgian Bay with a non-selective poison, such as rotenone or toxaphene. It might be possible to preserve the small remaining stock of lake trout in Georgian Bay if immediate action were taken to reduce young lamprey in the streams. About six Georgian Bay streams supported lamprey spawning and the destruction of a large proportion of the young lamprey could be carried out inexpensively and at a time when there would be little harm to fish.

Although the treatment of Georgian Bay streams with a general poison would be relatively inexpensive, the Commission agreed that its use was not justified when a selectively toxic chemical would soon be in general use. It recommended that methods of destroying young sea lamprey with selectively toxic chemicals be developed as rapidly as possible and put to use first in Lake Superior, then, possibly in Georgian Bay if circumstances at the time favored such action.

The Scientific Advisory Committee was asked to reconsider the current and future programs in the light of reports heard and opinions expressed and recommend:

1. Means of accelerating the experimental use of lampricides in the fiscal year 1957–58.
2. Means of increasing the use of lampricides on Lake Superior and Georgian Bay in 1958–59.
3. Revisions in the 1959–60 program made necessary by changes in the program for the preceding years.

Changes in 1957–58 program. The Scientific Advisory Committee, after reconsidering the 1957–58 program, drew the attention of the Commission to the following:

> The execution of the current program on lampricides was dependent on technological hurdles and weather conditions. In view of these limitations, the allocation of funds from Lake Michigan operations would not contribute materially to the lampricide program. About $40,000 could be diverted by terminating construction on Lake Michigan, but materials were already purchased and easements on property had been obtained.
>
> Technological obstacles to an accelerated larvicide program in the current fiscal year included the purchase of proportioning pumps and the construction of proportioning units and the slow process of purchasing large amounts of the chemicals. In order to allow an interested firm time to make sensible cost estimates, 90 days must be allowed prospective suppliers.
>
> Present plans called for the treatment of one Superior stream in January and five others before June 30th. It was not known which streams would be treated. Although some streams producing large numbers of lamprey would be selected, they would not all be major producers.
>
> The goal of six streams represented the maximum effort in the current fiscal year. The most effective acceleration of the program would be achieved by training of crews and surveying of streams for larvae prior to treatment.

Plans for training key personnel in both countries were discussed. The Fisheries Research Board was prepared to shift one scientist to larvicide work and was willing to have several people work directly with staff of the Bureau of Commercial Fisheries in order to become familiar with the use of selectively toxic chemicals or larvicides. The Bureau of Commercial Fisheries would have one or two key personnel from each of their regions participate in the field tests.

Pre-application surveys to determine distribution of lamprey larvae were required, to supplement those carried out by the State of Michigan. Mid-winter conditions do not permit efficient surveys and this activity would be limited during the balance of the year.

The Commission accepted the recommendations of the Scientific Advisory Committee for action in fiscal year 1957–58, and directed its agents to proceed as quickly as possible with the development of the chemical technique.

Changes in 1958–59 program. The Scientific Advisory Committee recommended that:

> The experimental larvicide effort in 1958–59 be accelerated to the extent permissible in fund savings made by adjusting barrier construction and maintenance costs to the irreducible minimum considered feasible by the responsible agencies. The purpose of this adjustment would be to conduct exhaustive tests of the larvicide in Lake Superior streams with such additional effort in Georgian Bay as funds and available personnel permit.

The Committee was strongly of the opinion that the exact nature of the reduction should be determined by the agencies responsible for the control program. In this same connection, should changes in programs be necessary as a result of limitation of funds, adjustments should be made within a single activity or lake, rather than on a proportional basis which would affect all activities and weaken the entire program.

The Commission was advised by the Bureau of Commercial Fisheries that it might be possible to divert $125,000 to the lampricide development by eliminating some or all of the electrical barriers to be constructed on Lake Michigan streams in 1958–59. This amount might allow the Bureau to treat the major lamprey producing streams on the United States shore of Lake Superior. The Fisheries Research Board reported that a small amount might be provided for this purpose by adjusting the program in Canada.

The Commission adopted the recommendations of the Scientific Advisory Committee regarding the change in the 1958–59 program and asked the Bureau to consult with the Executive Secretary and prepare a program eliminating some or all of the new construction proposed for Lake Michigan and increasing the chemical treatment of Lake Superior streams.

Changes in the 1959–60 program. The Scientific Advisory Committee reported that it had reconsidered the 1959–60 program prepared for the preliminary consideration of the Commission at this meeting. This program was based largely on the use of electrical barriers as the main method of control. The Committee thought that this was still the best program that could be developed on the basis of present information. A reconsideration of the program would be advisable in June when some experience with larvicides in the field had been gained.

The Commission agreed to defer consideration of the 1959–60 program until the next meeting to be held in March.

Lake trout rehabilitation. The Scientific Advisory Committee reported that it had discussed problems of lake trout rehabilitation at two earlier meetings and recommended that:

1. The Commission communicate with all agencies in the upper Great Lakes area with trout hatching and rearing facilities, informing them of the seriousness of the situation and, further, that it establish a special

committee including fish culturists from these agencies to arrange for the securing and holding of specific strains of Great Lakes trout, particularly the siscowet, and for the disposition of present and future hatchery stocks and, further, that this special committee prepare recommendations, no later than January 30, for the disposition of stocks presently held in hatcheries.

2. The chairmanship of this special committee be given to a member of the Commission's secretariat and that the promotion and assessment of the lake trout rehabilitation program be his major initial responsibility.
3. The Province of Ontario be encouraged to continue its program of selective breeding of trout for introduction into the Great Lakes.
4. In order to make the most efficient use of the fish stocks that can be raised in hatcheries, the following actions on the part of both countries are desirable:
   (a) Continue spring plantings of lake trout fingerlings in the Apostle Islands area and off Marquette in Lake Superior, marking all lake trout released.
   (b) In 1958 make two spring plantings each consisting of approximately 250,000 marked lake trout yearlings from inland stock at two separate locations in Superior. The Rossport area and east shore of Superior are suggested.
   (c) Provide the means in 1958 for the examination of planted fish captured by commercial fishermen and the routine examination of as many fish, both marked and unmarked in the catches, as possible.
   (d) Continue to plant and follow the survival of stocks of trout produced artificially by the crossing and back-crossing of brook and lake trout and planted in South Bay and Lake Huron.
   (e) Continue to compare the survival of lake trout from different inland stocks planted in Lake Ontario.

These recommendations were adopted by the Commission with the addition of a statement that it "considered plantings in the Great Lakes experiments and as such should be provided with the controls necessary to insure objective appraisal of results."

Report on general research. The Scientific Advisory Committee reported that it had studied those research programs underway on the Great Lakes not related to sea lamprey control, but was not in a position to make specific recommendations to the Commission at this time. The Committee was asked to give the matter further consideration and report at the next meeting of the Commission.

Organizational matters. The Commission met briefly in executive session and in the following plenary session reported that it had received for scrutiny the Administrative Report of the Executive Secretary and the Auditor's Report on Commission accounts (page 25), and a draft of the 1956 Annual Report. Staff matters had been discussed and the Commission had decided to employ a biologist with experience in fish culture as an assistant to the Executive Secretary. The position would be advertised early in 1958.

No amendments or additions to the Rules of Procedure and Financial Regulations had been proposed.

Mr. L. P. Voigt, who had been appointed in 1957 to succeed Mr. John L. Farley as chairman, had been persuaded to continue in that office until the 1958 Annual Meeting. It had been agreed that, in view of the fact that a member of the United States Section had held the chair for only 15 months, Rule 11 of the Commission's Rules of Procedure was not violated by this action.

The Commission commended its agents in Canada and the United States for the splendid co-operation which had existed between them, and recommended that this continue by exchange of personnel or any other means.

Date and place of next meeting. The Commission announced that it planned to hold a spring meeting in Washington, D.C., on or about March 25, 1958, and another meeting in northern Michigan or Ontario some time in June. At the latter meeting the Commissioners expected to spend several days inspecting lamprey control operations.

Resolutions. No resolutions were proposed.

Other Business. The Commission appointed a sub-committee to investigate a report that young lamprey were being sold to anglers for use as bait.

The Commission considered a proposal that it publish a summary of fish production statistics covering the period 1941–60 to supplement one published by the International Board of Inquiry for Great Lakes Fisheries in 1943, and asked its Scientific Advisory Committee to prepare an analytical report on the material that should appear in such a publication. As the report of the Board was out of print much of the statistical material it contained should appear in the proposed publication.

Adjournment. The Commission asked the Chairman to express to the Minister of Lands and Forests for Ontario the Commission's gratitude for his hospitality and for the help rendered by his staff in arranging the meeting. The Chairman thanked all who had participated and adjourned the Second Annual Meeting of the Commission.

ANNUAL MEETING

PARTICIPANTS

OFFICERS OF THE MEETING

Chairman: L. P. Voigt, United States
Vice-Chairman: A. L. Pritchard, Canada

MEMBER GOVERNMENTS

Canada

Commissioners:

A. O. Blackhurst
Port Dover, Ontario
W. J. K. Harkness
Toronto, Ontario
A. L. Pritchard
Ottawa, Ontario

Advisors:

G. R. Clark
J. R. Dymond
F. E. J. Fry
R. N. Johnston
J. L. Kask
W. A. Kennedy
K. H. Loftus
H. H. MacKay
J. M. Speirs
W. H. R. Werner

United States

Commissioners:

D. L. McKernan
Washington, D. C.
Claude Ver Duin
Grand Haven, Michigan
L. P. Voigt
Madison, Wisconsin

Advisors:

V. C. Applegate
W. F. Carbine
C. F. Clark
G. P. Cooper
R. Cummins, Jr.
C. A. Dambach
Isla V. Davies
L. F. Erkkila
P. Eschmeyer
A. L. Hazzard
Ralph Hile
W. M. Lawrence
J. W. Moffett

Executive Secretary
Norman S. Baldwin

ADMINISTRATIVE REPORT FOR 1957

Officers and staff. Since the previous Annual Meeting there have been several changes in the officers and staff of the Commission. Following the resignation of Mr. John L. Farley, Dr. A. L. Pritchard, Vice-Chairman of the Commission, acted as Chairman. On June 5, Commissioner L. P. Voigt was elected to succeed Mr. Farley as Chairman. Mr. Donald L. McKernan, Director of the Bureau of Commercial Fisheries, U. S. Fish and Wildlife Service, was appointed to the Commission to fill the vacancy in the United States Section created by Mr. Farley's resignation.

Following the Annual Meeting, three persons were hired to fill the position of clerk-stenographer in the Commission's office. Two individuals stayed only a short time; the third, Mrs. Edith McPherson, has continued in that position.

The Commission selected Mr. Norman S. Baldwin as Executive Secretary on June 5. He assumed his duties on August 23, relieving Dr. James W. Moffett of the U. S. Fish and Wildlife Service, who had served in an acting capacity since the Organizational Meeting on April 23, 1956.

Accounts and audit. The accounts of the Commission for the fiscal year ending June 30, 1957, were submitted for audit to the firm of Icerman, Johnson, and Hoffman, 203 State Savings Bank Building, Ann Arbor. The accounts were found to be in good order and no changes in procedure were recommended. The financial statement and auditors' report are appended to the administrative report. Copies of the auditors' report were sent to the governments of Canada and the United States.

At the close of fiscal year 1956-57, there was a balance in the Commission account for Administration and General Research of approximately $14,600, which, in accordance with Financial Regulation V (b)iii was applied to fiscal year 1957-58. This action reduced the amount requested for the operations of the Secretariat from $50,000 to $35,400.

In establishing its office, the Commission acquired a station wagon, duplicating machine, automatic printing calculator, a tape recorder, tables, and additional storage and filing cabinets. Adequate insurance was obtained for the Commission's vehicle and the contents of its office.

The Executive Secretary was bonded for $30,000, in accordance with Financial Regulation XII (a), and further instructions given at the meeting in Sault Ste. Marie, July 30, 1956.

Pension plan. The two members of the Secretariat were enrolled in the Pension Plan for Employees of International Fisheries Com-

missions and contributions commenced in October. The participation of the Commission in the plan necessitated a minor internal revision of the budget estimate for 1958–59 to provide for the Commission's share of the contributions. This revision was approved at the meeting in Rogers City on September 24, 1957.

Contributions from Contracting Parties and distribution to Agents. On January 16, the Commission received a check for $300,000 from the United States as its final contribution to the Commission's 1956–57 program. A check for $300,000 was immediately sent to the U. S. Fish and Wildlife Service to cover the costs of its execution of the Commission's control program in the United States for the last half of the fiscal year. The Commission had previously agreed at its Organizational Meeting in Ottawa on April 23, 1956, to accept Canada's contribution in goods and services estimated at $269,000.

On September 17, 1956, the Commission requested the United States and Canada to provide $968,365.93 and $448,831.07 respectively for its program in 1957–58. On June 25, the Commission requested that the first installments of these funds be transmitted in accordance with an amendment to Financial Regulation, which required that receipt of contributions and payment of contract obligations be made on the basis of three-quarters of the totals on July 1 and one-quarter of the totals on January 1.

The United States subsequently advised the Commission that it had appropriated $914,300 to cover her share of the 1957–58 program, and on July 18, transmitted a check for $469,650. A supplementary check for $216,075 was sent on October 5, thus completing payment of the first installment, adjusted to the restricted vote. The United States also advised the Commission that it had provided an additional amount of $800 to cover half the cost of the Commission's Pension Plan.

Canada, in making payment of its first installment in United States funds, transmitted a check for $331,148.30 on July 23, supplying the amount originally requested. There was, therefore, an overpayment of $18,218.30 by Canada which will be credited against the second installment payment due January 1, 1958. The United States transmitted checks totaling $673,225 in July and October and an overpayment of $6,250 on this first installment will be credited against the second due January 1, 1958.

The funds assured for lamprey research and control total $1,288,840, and contracts total $1,269,610. Currency exchange charges on payments to the Commission's agent in Canada now total $20,089.45 and may reach $23,100 after payment of the second installment. Some adjustments in programs and contracts are anticipated and the estimated deficit will probably be covered by unexpended funds.

ADMINISTRATION AND GENERAL RESEARCH

	United States	Canada	Total
Funds requested	$25,000	$25,000	$50,000
Funds provided*	17,700	17,700	35,400
First installment			
Due	13,275	13,275	
Received	12,500	13,275	
Underpayment	775	-0-	
Second installment			
Due	5,200	4,425	
Pension plan	504	504	
	5,704	4,929	

* Reduced by a credit of $14,600 from fiscal year 1956–57.

Contracts. The first contract for lamprey control between the U. S. Fish and Wildlife Service and the United States Section of the Commission terminated on June 30, 1957. A preliminary report on expenditures and work done has been made and copies supplied to the Secretariat.

Two contracts for lamprey control in 1957–58 were entered into with the United States Fish and Wildlife Service, Bureau of Commercial Fisheries, and the Fisheries Research Board of Canada, for amounts of $776,450 and $493,160 respectively.

A contract was also entered into with the University of Toronto for the preparation of a Great Lakes Bibliography. The cost of the project for the first year is $12,000. This amount may be reviewed and varied by mutual consent in subsequent years.

Meetings. The Executive Secretary participated as chairman at meetings of the Scientific Advisory Committee on September 18 and 30, and on October 1 and 9; prepared summaries of the discussions and arranged distribution to participants and Commissioners.

A visit was made to the Put-in-Bay Laboratory of Ohio State University, and reports of the work carried out at that establishment were heard during an informal meeting between fisheries scientists in

Ohio and personnel of the United Fish and Wildlife Service.

Papers on Great Lakes problems and the Commission's activities were presented at meetings of the Mid-West Fish and Game Commissioners, Northern Great Lakes Council and the Great Lakes Commission.

The Executive Secretary attended the annual meeting of the International North Pacific Fisheries Commission as an observer, and while on the west coast, visited the Pacific Biological Station of the Fisheries Research Board, the School of Fisheries of the University of Washington, and the headquarters of the International Pacific Salmon Fisheries Commission and the International Pacific Halibut Commission.

APPENDIX

Auditor's Report to Commission

ICERMAN, JOHNSON AND HOFFMAN

Certified Public Accountants
200 State Savings Bank Bldg.
Ann Arbor, Michigan

October 7, 1957

Great Lakes Fishery Commission
1319 N. University Avenue
Ann Arbor, Michigan

Gentlemen:

We have examined the Administrative and General Fund and the Lamprey Control Operation Fund of the Great Lakes Fishery Commission for the year ended June 30, 1957.

Our examination included tracing of receipts to the depository, verification of the bank balance by direct confirmation, tracing of expenditures to supporting vouchers and such other tests of the accounting records as were considered necessary in the circumstances.

In our opinion the attached statements of receipts and disbursements present fairly the cash transactions of the indicated funds of the Great Lakes Fishery Commission for the year ended June 30, 1957, and the results of operations for the year then ended.

Very truly yours,
Icerman, Johnson and Hoffman

Exhibit A

Great Lakes Fishery Commission
Administration and General Research Fund
Statement of Receipts and Disbursements
Year Ended June 30, 1957

	Actual	*Budget*	*Under or (over)*
Receipts			
Canadian Government	$15,000.00	$15,000.00	-0-
United States Government	15,000.00	15,000.00	-0-
	30,000.00	30,000.00	-0-
Disbursements			
Communications	233.26	300.00	66.74
Equipment (Schedule A-1)	5,774.93	5,900.00	125.07
Insurance and bonding	236.26	-0-	(236.26)
Rent and utilities	60.00	90.00	30.00
Salaries	1,268.02	15,500.00	14,331.98
Social Security	29.64	-0-	(29.64)
Supplies and equipment maintenance	690.91	700.00	9.09
Transportation	5.96	10.00	4.04
Travel	733.10	800.00	66.90
University of Toronto—Bibliography	6,313.50	6,600.00	286.50
Total	$15,345.58	$30,000.00	$14,654.42
Excess of receipts over disbursements		$14,654.42	
Cash in bank July 1, 1956		-0-	
Cash in bank June 30, 1957		14,654.42	
Note A: Balance, Ann Arbor Bank, June 30, 1957			$14,654.42

Schedule A-1

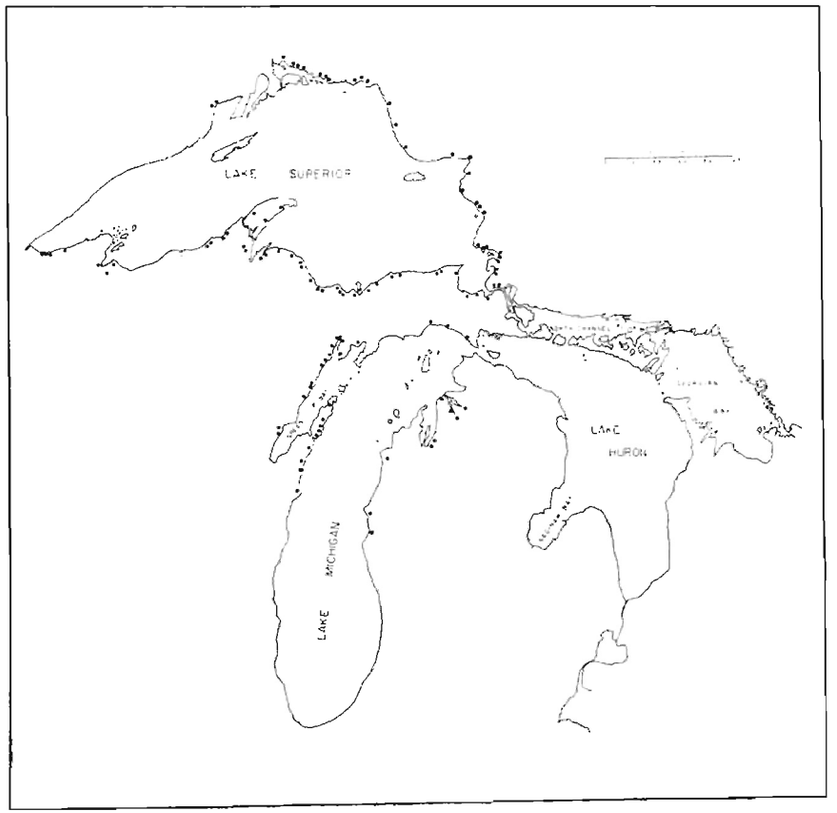
Equipment Purchased

Duplicator	$1,326.59
Tape Recorder	286.00
Electric Typewriter	450.50
Office Furniture	1,181.84
Station Wagon—Chevrolet	2,530.00
Total	$5,774.98

Exhibit B

Lamprey Control Operations
Statement of Receipts and Disbursements

Receipts		
United States Government		$600,000.00
Disbursements		
U. S. Fish and Wildlife Service	$300,000.00	
U. S. Fish and Wildlife Service	300,000.00	600,000.00
		-0-



Electrical barriers on Lakes Superior and Michigan in 1957. Operating barriers shown as solid circles and standby barriers as open circles.

LAMPREY CONTROL AND RESEARCH IN CANADA

by the Fisheries Research Board of Canada

Lake Superior barrier construction and engineering

The lamprey barriers now in use on the Canadian side of Lake Superior were built entirely by employees under the direction of an engineer. Now that the urgency for initiating control measures on all of Lake Superior tributaries is over, an effort is being made to so design future barriers that they can be built by contract. The year 1957 was one of transition from arrangements under which a large staff was retained to build barriers to an arrangement where only a small engineering staff is retained to plan and supervise the construction of barriers under contract.

In 1957 the engineering group built one new barrier, finished construction of nine, and made major improvements on eight. Considerable difficulty was encountered because the barriers constructed in 1957 were on that stretch of Lake Superior shoreline which can be reached only by boat and the breakup of lake ice was extremely late. Many improvements have been made to barrier components, particularly to electrodes, and the improvements have been incorporated in existing barriers as opportunity permitted.

Lake Superior barrier operation

In 1957 for the first time electrical barriers were maintained by a separate group called the Lamprey Barrier Operation Unit. The Unit is responsible for placing the electrodes in the water at each barrier as early in the spring as is practicable and for putting the barriers into operation by a specific date. Once the barriers are turned on, the Unit is responsible for insuring that they operate without fail for 24 hours a day every day until the Unit is directed to terminate operation for the year. During operation, the electrical components must be inspected frequently, the motors used as main or auxiliary sources of power must be maintained, the fish inadvertently killed by the barriers must be removed daily, the nets used to minimize the kill of fish at the barriers must be maintained in spite of debris carried by the river, and barbed wire and warning signals which keep the general public away from the very dangerous electrical field must be maintained. The streams above the barriers must be searched for signs of lamprey as a check on barrier efficiency. At the end of the lamprey spawning season, the electrodes must be removed, all equipment laid up, and each barrier winterized. A staff is retained throughout the off season to repair and maintain equipment and to carry

on routine examinations of other streams in the area to see whether new lamprey runs are developing.

In 1957, 32 electrical barriers were operated in Canada: 11 of them were within 100 miles of Sault Ste. Marie, 9 were between Agawa and Marathon, where with one exception they could be reached only by boat, and 12 were between Fort William and Marathon. The numbers of sea lamprey killed at electrical barriers in 1957 and preceding years are given in Table 1.

The barriers killed a total of 3,377 lamprey in 1957, of which 80 percent were killed in four of the rivers, the Goulais, Chippewa, Batchawana and Pancake, which have always been the heaviest lamprey producers on the Canadian side of Lake Superior. Eleven percent of the total were taken in the Michipicoten River and three percent in the Big Gravel River. Apart from the rivers mentioned, no stream had very large lamprey runs. Seven of the eight barriers which can be reached only by boat, killed no lamprey at all, and subsequent investigations showed no signs that lamprey had been using these streams at any time. As a result of these findings, the seven barriers were put on inactive status.

The increase in the kill of sea lamprey reported for most of the electrical barriers is probably the result of an improvement in operating efficiency and the recovery of a higher proportion of the lamprey killed than in 1956. The increase in the Goulais River can be attributed to the installation of "rack-type" electrodes. The decrease in the Chippewa River cannot be explained.

Examination of streams above the barriers disclosed lamprey nests on six, but there is considerable doubt that all of the nests seen were those of sea lamprey. An adult sea lamprey was found above the barrier on the Pancake River and on this river ten nests were located which could be confidently identified as those of sea lamprey. Two of these nests were discovered in the estuary. Skin divers investigated gravel areas in the estuaries of six other rivers but failed to find any sign of lamprey spawning.

A series of experiments have been made on the physiology of sea lamprey with respect to electrical fields. They confirmed early observations that lamprey are stopped by the electrical barriers because their swimming muscles are paralyzed when they enter the electrical fields. Because of paralysis, some of the lamprey fall to the stream bottom within the electrical field and eventually die because they are held in paralysis long enough to interfere with vital functions. Others are carried downstream by water current, recover from paralysis and try again to move upstream, but in an efficient barrier they are always paralyzed before they can completely penetrate the electrical field. The experiments have also shown that the ability of an electrical barrier to paralyze lamprey depends on the voltage gradient

TABLE 1.—Sea lamprey taken at barriers on Canadian tributaries of Lake Superior, 1954–1957

Stream	1954	1955	1956	1957
Stokeley	64	11	58	5
Harmony	28	29	29	16
Sable [1]	46	43	65	76
East Davignon		1	3	..
West Davignon	..	0	0	..
Little Carp	..	20	24	26
Big Carp	..	5	27	28
Cranberry	..	6	11	18
Goulais	..	46	62	820
Haviland	.	0	3	..
Jones	..	0	0	..
Downey	..	0	0	..
Chippewa	..	807	839	359
Batchawana	..	608	421	427
Pancake	..	555	717	1,073
Agawa [2]	..	..	0	26
Michipicoten	.	..	53	372
Little Pic [2]	.	..	0	0
Prairie	..	..	0	13
Steel	.	..	1	0
Hewitson	.	..	0	1
McLean's	..	..	0	0
Pays Plat	.	..	6	3
Gravel	..	..	5	99
Little Gravel	..	..	0	2
Cypress	..	..	1	3
Jackfish [2]	..	..	0	0
McIntyre	..	..	..	0
Neebing	..	..	..	1
Dog [3]	..	..	..	9
Coldwater	.	..	..	0
Baldhead	..	..	..	0
Gargantua	..	..	..	0
Old Woman	..	..	..	0
Swallow	..	..	..	0
White Gravel	.	..	..	0
Willow		..	..	0
Totals	138	2,131	2,325	3,377

[1] Not operated in May 1954.
[2] Intermittant in 1956.
[3] Operated for part of run only.

in the water and on the conductivity of the water. If voltage and conductivity are known, then it is possible to predict accurately from the results of the physiological experiments whether or not a given electrical array will paralyze lamprey sufficiently to prevent them from proceeding upstream.

Numerous voltage readings were taken within the field at each of the barriers operated on Canadian tributaries to Lake Superior in 1957 and the conductivity of the water was determined at each. The graphs obtained from physiological experiments then made it possible to assess, on theoretical grounds, whether each barrier was completely impenetrable to lamprey. It was found that in many of the barriers pathways existed through the electrical field which lamprey could theoretically penetrate. The situation may not have been quite as serious as would appear on theoretical grounds, because it is not possible to take fully into account the effect of water current in preventing lamprey from swimming upstream when only partially paralyzed by a field weaker than that established as a criterion in the physiological experiments. Actual penetration was not observed even where penetration was theoretically possible but, of course, none of the barriers were kept under continuous observation. This assessment of barrier efficiency serves as a guide for further improving the barriers.

There are many tributaries to Lake Superior on which no lamprey barriers have been built because no evidence that lamprey spawn successfully in them has been found to date. Such streams are kept under surveillance to insure that no lamprey runs that develop in them go undetected. After trying many methods, it has finally been decided that the best method of determining whether sea lamprey are using any given stream is to make a thorough search for their ammocoetes (larval lamprey) in that stream. In 1957, 135 streams were re-assessed, of which 65 were examined in detail for the presence of sea lamprey ammocoetes. Only in the Kaministikwia River were these ammocoetes detected in any stream where they were unknown before.

Lake Huron stream surveys

It will probably be necessary eventually to build lamprey barriers on tributaries to Lake Huron, and perhaps to use toxicants in some of them. In order to plan for barriers, it is necessary to know which streams the lamprey use and, in order to plan for toxicants, it is necessary to know where the ammocoetes occur in the stream. The survey technique therefore consists of a thorough search for ammocoetes in all streams suspected of producing lamprey. For this purpose, a portable electrical shocking device powered by a 12-volt battery and converter is used. A good deal of effort has gone into the

development of a suitable shocking device and the one now available is considered efficient enough that where sea lamprey ammocoetes cannot be found by persistent use of it, the stream is regarded as unsuitable for sea lamprey production.

Through the use of the shocking device, a number of tributaries to Lake Huron have been shown to have no sea lamprey ammocoete populations, although originally they were assumed to be lamprey producers. The 1957 surveys indicate that in Lake Huron proper there are only two lamprey producing streams, the Bayfield and the Saugeen Rivers. There appear to be only seven tributaries to Georgian Bay which produce lamprey, namely, Silver Creek and Nottawasaga, Sturgeon, Boyne, Naiscoot, Magnetawan and Still Rivers. The remaining 24 tributaries which are known to have lamprey populations are all on the North Channel, along which almost every sizable tributary is a lamprey producer. Through the use of the electrical shocker, ammocoetes have been found in the open lake in the vicinity of five tributaries to the North Channel off the mouths of the streams in which they presumably originated.

Field observations at Pancake River

The reaction of spawning lamprey to electrical barriers was studied in detail at the Pancake River barrier. Four nets designed to capture lamprey were installed at intervals along the stream and the movements of the lamprey were studied by tagging and recapturing. Unfortunately, it proved very difficult to make the traps lamprey-proof and they took only about 16 percent of the possible catch of lamprey. In spite of this difficulty, it was apparent that some lamprey move downstream after they encounter a lamprey barrier, and that at least some of them leave the stream altogether. There was a great difference in the speed with which sea lamprey move upstream. The time taken for individuals to move over a specific distance varied from 36 minutes to 23 days.

Lamprey in the Sault Ste. Marie Locks

Skin divers continued to examine the hulls of vessels in the Canadian lock at Sault Ste. Marie for attached sea lamprey. No lamprey were found on ships, although a single individual was found unattached in the lock. These observations confirm 1956 findings that migrants through the locks make only a negligible contribution to the sea lamprey population of Lake Superior.

Direct-current lamprey barrier

The lamprey barriers used on Lake Superior are all powered by alternating current. On the United States side some alternating-current barriers also have a direct-current device to help prevent fish from being killed. Direct current has these desirable characteristics: it tends to attract fish and lamprey to the positive electrodes; unlike alternating current, it stuns fish without causing the violent muscular contractions which frequently break their bones and kill them.

Early in 1957 an experiment was started to develop a device in which direct current would be used, both to create a field impassable to lamprey and to lead them into suitable traps where they could be easily handled. The advantages expected from such a device as opposed to the presently used devices are: all lamprey would be caught and none would have the opportunity to swim back downstream again; fish which approach the barrier from downstream would be attracted into the device from which they could be released upstream with less damage and more economically than with any device now in existence; downbound fish would be stunned as they passed through the field and would recover and swim away rather than being killed as in existing devices. Unfortunately, the device was not in operation until the 1957 sea lamprey run was over. However, such tests as could be performed indicated that the direct-current barrier might be a suitable alternative means of controlling sea lamprey.

Ammocoete studies

Information on the distribution and movements of young lamprey has become of increasing importance in planning control measures. A detailed study was undertaken in Big Creek, a tributary to Lake Erie.

In Big Creek, ammocoetes are found only in streams more than three feet wide and generally where the current is slow. The smaller ammocoetes prefer a soft bottom, but as they get bigger they become less selective. When disturbed slightly, the ammocoetes retract into their burrows, but if the disturbance is strong, they leave their burrows and swim downstream to a new location, where they bury themselves again. During a freshet ammocoetes are carried along by the current in the same way as any inanimate object and after a freshet they are found to be distributed differently than when they have had a chance to distribute themselves undisturbed.

Lamprey spawning requirements

In order to assess whether sea lamprey are likely to spawn in certain tributaries to the Great Lakes, it is necessary to know in more detail the exact conditions under which they can spawn successfully. An investigation was initiated in 1956 to determine the range in conditions under which lamprey will spawn and it was continued in 1957. Lamprey spawning was observed in nature in Big Creek. Obser-

vations there confirmed what was already known, but did not materially increase existing knowledge of lamprey spawning. An unsuccessful attempt was made to have the lamprey spawn in an artificial stream in the laboratory. Failure was attributed to insufficient water current in the experimental tanks. The experiment has suggested a better design for the apparatus.

Physiology of sea lamprey

A knowledge of the physiology of sea lamprey is required for improving control methods so many laboratory experiments have been performed on sea lamprey. Some of the results have been included in foregoing sections because they are already being applied to sea lamprey control. Other results follow.

In order to have a stock of lamprey for experimental purposes, it is necessary to hold them in the laboratory for considerable lengths of time. Sea lamprey, which normally would have died many months earlier, were held successfully in the laboratory, simply by keeping the temperature low. In the holding tanks they proved to be resistant to sudden increases and decreases in temperature. They were very susceptible to low oxygen tensions in the water.

The cruising speed of lamprey was determined at two different temperatures, and at each temperature was found to be much the same as goldfish under the same conditions. They were able to swim about twice as fast at a temperature typical of tributaries to Lake Superior as at a temperature comparable to the open lake.

Under a research contract between the Board and McMaster University, research was done which indicates that lamprey produce electrical impulses rhythmically in time with their respiration. Dr. H. Kleerekoper, who conducted the experiments, has indicated the possibility that the resulting electrical field is used by the lamprey for location of prey.

Feeding behavior of sea lamprey

It is obviously important to know exactly how a sea lamprey feeds in order to assess the meaning of scars on lake trout and other fish, and in order to better learn the effect that any given lamprey population will have on the valuable fish. In 1957 an investigation of sea lamprey feeding behavior began but has not proceeded far enough to produce definite conclusions. However, it appears that the presence of a fish or of scrapings from a fish acts as an olfactory stimulus and releases a search behavior reaction in the lamprey. Visual stimuli appear not to be important. The exact behavior mechanism by which the lamprey completes its attack after being stimulated to search for its prey is not known.

LAMPREY CONTROL AND RESEARCH IN UNITED STATES

by the Bureau of Commercial Fisheries
U. S. Fish and Wildlife Service

Sea lamprey control in 1957 was confined to Lakes Superior and Michigan with the exception of a single experimental barrier in the Ocqueoc River on Lake Huron. A field base was established at Ashland, Wisconsin, to accelerate the control program in western Lake Superior. In support of the expansion of the control program on Lake Michigan, new field stations were established at Oconto, Wisconsin and Ludington, Michigan.

Lake Superior barrier construction

The discovery of large runs of sea lamprey in 5 Wisconsin streams required the installation of 4 alternating-current and 1 direct-current control devices. A sixth control installation was erected on the Little Two Hearted River in the State of Michigan. Major improvements on 6 existing alternating-current structures and the addition of 5 more direct-current diversion devices improved the efficiency of the control system.

Preparations for next season's operation on Lake Superior include the installation of 4 new alternating-current barriers in streams of northern Wisconsin and the completion of an alternating-current device on the Brule River. Relocation of the Sucker River structure and the placing of electrical check weirs on the Nemadji and Ontonagon Rivers are also planned. Other construction will be limited to improvements on existing barriers and the installation of 3 additional direct-current diversion devices.

Lake Superior barrier operations

A total of 39 sea lamprey control barriers were operated on streams along the south shore of Lake Superior and 15 others were held in standby status in the event lamprey runs developed. Except for 6 streams, the barriers were activated between March 25 and April 23. The entire network was in operation with the completion of the Brule River direct-current barrier on May 18. Thirty-two were alternating-current barriers and the others were combination alternating-direct-current control weirs. Termination of seasonal control began July 26 and was completed September 13.

The total number of sea lampreys trapped and killed was 57,820. Of this number, 23,042 were from streams of northern Wisconsin and 34,778 were from Michigan streams. The 1957 catches, given in Table 1, exceeded those of preceding years in most streams.

TABLE 1.—Sea lamprey taken at barriers on United States tributaries of Lake Superior, 1953–1957

Stream	1953	1954	1955	1956	1957
Waiska		32	47	71	55
Pendills	23	40	45	42	47
Halfaday		12	3	14	4
Betsy	221	567	569	1,577	786
Little Two Hearted					739
Two Hearted	371	638	600	1,766	7,899
Sucker	750	1,309	1,713	4,400	3,597
Hurricane		8	25	99	188
Beaver Lake	8	19	19	20	49
Miners	64	53	148	96	427
Furnace	18	47	66	209	274
Au Train (Joel's)	204	350	486	613	739
Rock			1,633	3,407	3,102
Laughing Whitefish	9	25	16	19	37
Chocolay		1,227	3,350	6,888	8,096
Carp		0	2	1	4
Harlow		1	1	0	3
Big Garlic		54	89	154	270
Iron		67	206	335	737
Pine		10	12	18	34
Huron		147	472	1,628	2,868
Ravine		1	4	2	10
Silver		247	786	963	2,810
Sturgeon		1	1	4	31
Otter		0	0	1	0
Traverse		3	4	37	45
Little Gratiot		0	1	4	9
Gratiot		1	0	4	2
Elm		0	7	7	7
Misery			183	571	868
Firesteel		60	150	229	1,039
Flintsteel		2	1	1	2
Bad				685	2,652
White				219	412
Fish (N. Br.)					520
Brule					3,988
Poplar					126
Middle					4,289
Amnicon					11,055
Total	1,668	4,921	10,639	24,084	57,820

Effectiveness of the control network was determined by periodic inspection of the streams above the barriers. No serious escapement was discovered in any stream under complete control. In the Brule River, it was not possible to block the entire run with the direct current barrier. Light escapement also occurred in the Bad River during a period of high stream runoff.

Surveys of all potential sea lamprey streams not under control disclosed new runs in the Salmon Trout River, Houghton County, Michigan, and the Cranberry River, Bayfield County, Wisconsin. Several other streams may have been used to some extent by sea lampreys. Positive evidence of the parasite in the Tahquamenon River has been known, but another survey of the lower drainage failed to turn up a satisfactory control site. Fortunately, suitable spawning area is limited in this large stream.

As in the preceding years of operation, a record was kept, by species, of the fish trapped successfully and those killed in the electrical fields. This mortality is being reduced with the installation of more efficient trapping facilities and the addition of direct-current diversion devices.

Lake Michigan barrier construction

The extensive shoreline of Lake Michigan and the large number of streams with sea lamprey runs required establishment of two field stations for handling the control project. Eight electro-mechanical barriers were added to the existing 19 barriers along the west and north shore of Lake Michigan by the staff at Oconto, Wisconsin. Initial control of east shore tributaries was begun on 10 streams by the staff at Ludington, Michigan.

The proposed installation of 55 control barriers was not realized. Plans to continue construction during the operating season were curtailed in order to have sufficient funds to operate the control network. Procurement of land easements was continued and agreements were in process for 24 sites. The equipment and supplies for the remaining 37 control devices were purchased. Failure to meet the construction schedule can be traced to the need to replace and improve installations on Lake Superior and to the considerable rise in cost of construction and operation which could not be anticipated when the budget was originally prepared.

Construction of control devices on 37 streams in Lake Michigan is underway; installations are nearing completion. Direct-current diversion units are proposed for 6 major tributaries along the east shore and one on a west shore stream.

Lake Michigan barrier operations

Alternating-current barriers were operated on 37 Lake Michigan streams. All but three were set in operation between March 11 and April 10. One new barrier on Bear Creek was the last to be placed in operation on May 28. Cessation of operations extended from July 3 to August 16.

A total of 64,455 sea lamprey were captured and killed in Lake Michigan streams. These data are presented in Table 2. Of this number, 60,496 were from the west and north shore network of barriers. The remaining 3,959 were taken from 10 east shore streams.

Periodic inspections above the control barriers were made to determine upstream escapement during the operating season. In the west and north shore area, flooding around the control structures of the Millecoquin and Whitefish Rivers allowed some sea lamprey escapement during the spring runoff. This was later verified by the stream surveys. Escapements may have occurred in 6 other streams, but inspection failed to verify it. On several streams favorable spawning conditions have been created below the control barriers by the receding lake level. Sea lamprey have been observed spawning in these areas on the Cedar, Bark, and Walton Rivers. No known escapement occurred in the 10 streams under control along the east shore of Lake Michigan.

Fish mortality at the electrical barriers operated in Lake Michigan was not serious, except in the Pensaukee River near Oconto, Wisconsin. Low stream levels were responsible here for an intense electrical field that led to the death of 158,000 white suckers. The entire mortality should not be charged to the barrier, as sucker mortality was extremely high above it.

Direct-current diversion device

A new type of relaxing-pulse generator was developed to produce electric current that would guide lamprey and fish into traps. It produced suitable current throughout the entire season whereas previous equipment had been subject to breakdown. Its application, described in an article published this year, was tested on a larger scale when installations were placed in 7 Lake Superior tributaries. This equipment was successful in reducing the kill of migratory fish in 3 or 4 streams where mortalities had been excessive when alternating-current barriers were used alone. The season's results for the trout and suckers handled at 6 of the test barriers, given in Table 3, can be understood better if some comments are offered on the records for certain streams.

The operation of the direct-current device on the Big Huron River was disappointing in protecting the migratory fish because of

TABLE 2.—Sea lamprey taken at barriers on Lake Michigan, 1954–1957

Stream	1954	1955	1956	1957
North and west shore				
Brevoort	..	..	..	497
Hog Island	.	..	..	77
Millecoquin	.	.	.	955
Big Fishdam	..	459	500	835
Sturgeon		2,534	1,610	3,503
Squaw	4,113	384	284	179
Whitefish	283	3,408	2,638	5,263
Rapid	1,489	1,377	937	1,396
Tacoosh	574	15	8	31
Days	11	264	192	272
Portage	205	..	.	35
Ford	..		7,946	10,289
Bark	..	2,420	1,712	2,484
Cedar	..	13,324	16,331	12,188
Walton	..	..	..	162
Beattie	..	..	..	39
Little	..	128	412	142
Pensaukee		893	1,099	520
Ephraim	.	13	6	14
Hibbards	7,279	6,389	5,325	6,625
Shivering Sand	..	..	2	325
Lilly Bay	..	66	40	68
Whitefish Bay	..	..		245
Three Mile	.	1,945	1,473	839
Kewaunee	..	5,127	2,286	3,134
East Twin	..	7,558	12,131	10,313
Bear	..	..	..	66
East shore				
Boyne	..	..	..	225
Jordan	..	..	..	579
Monroe	..	..	..	1
McGeach	..	..	..	257
Yuba	..	..	..	214
Mitchell	..	..	..	71
Betsie	..	..	..	1,704
Lincoln	..	..	..	800
S. Br. Pentwater	..	..	..	0
N. Br. Pentwater		..	..	108
Total	14,646	46,268	54,932	64,455

an intense electrical field near the wing of the trap. Examination of this section at the end of the season revealed a length of electrode buried in the stream bed which probably created this lethal field. Abnormally low stream flow also contributed to the poor results by preventing fish from entering the trap easily.

The results from the initial operation on Fish Creek were not as poor as might appear. This mortality occurred in a heavy downstream movement of suckers through an intense alternating-current field; this difficulty was corrected.

TABLE 3.—Mortality of trout and suckers in experimental direct-current diversion devices.

Stream	Number of fish collected	Number trapped alive	Number of dead fish recovered				Percentage killed
			In a. c. field	In d. c. field	Outside electrical fields	Total	
Two Hearted River	5,324	4,735	548	37	4	589	11.1
Chocolay River	7,117	6,532	360	155	70	585	8.2
Big Huron River	9,864	4,722	1,160	3,148	834	5,142	52.1
Silver River	3,523	3,124	289	56	54	399	11.3
Fish Creek	5,128	3,248	247	35	1,598	1,880	36.7
Brule River [1]	3,360	2,967	..	49	344	393	11.6

[1] Barrier operated with direct current only.

The Brule River had a direct-current device only. The fish mortality probably could have been lessened, but the purpose was to block and trap as many sea lamprey as possible. Consequently, power levels were maintained above those most suitable for fish. The effects of excessive power were indicated by the number of suckers with dislocated vertebrae.

On the Bad River, both a direct and an alternating-current barrier were installed without trapping facilities because of the large fluctuation in stream flow. The addition of the direct-current barrier reduced the fish kill to 21 percent of the 1956 mortality which was 22,255 fish, principally white suckers.

On the whole, results were sufficiently good that it is planned to install these barriers in other streams when excessive fish mortalities create difficulties.

Observations on spawning runs

The discouragingly rapid increase in abundance of sea lampreys in Lake Superior continued in 1957 as is shown from the following

record of take of spawing-run individuals on 30 streams that were under control in each of the last 4 years:

1954	4,922
1955	8,823
1956	19,009
1957	30,069

In Lake Michigan, where lampreys have been extremely plentiful for years, the numbers show little tendency to change. The catches in 17 streams under control in the past three years have been:

1955	46,268
1956	46,984
1957	47,706

The sizes of sea lampreys captured at control barriers have decreased irregularly in both Lake Superior and Lake Michigan, but year for year the Superior lampreys have been the larger. The largest lampreys taken in Lake Superior tributaries over the past four years were caught in 1954 (average 18.1 inches, 8.0 ounces) and the smallest in 1957 (17.0 inches, 6.2 ounces), as can be seen in Table 4.

TABLE 4.—Average lengths and weights of sea lampreys captured during the spawning run in tributaries of Lake Superior and Lake Michigan, 1954–1957.

Area and year	Number measured	Average length (inches)	Number weighed	Average weight (ounces)
Lake Superior—south shore				
1954	3,939	18.1	2,174	8.0
1955	6,174	17.2	6,168	6.9
1956	9,593	17.8	9,593	7.2
1957	11,015	17.0	11,015	6.2
Lake Michigan—west, north shores				
1954	572	17.7	500	6.1
1955	4,972	17.2	4,972	6.1
1956	2,222	17.5	2,222	6.0
1957	14,435	16.7	14,435	4.6
Lake Michigan—east shore				
1957	2,647	15.9	2,647	4.1

The largest and smallest lampreys were taken along the west and north shores of Lake Michigan in the same two years (17.7 inches, 6.1 ounces in 1954; 16.7 inches, 4.6 ounces in 1957). Lampreys from

east shore streams of Lake Michigan were extremely small in 1957 (15.9 inches, 4.1 ounces). This was the first year for operations on the east shore and no earlier observations were made.

The early observations on sea lamprey spawning runs gave cause to believe that the relative abundance of males increased with a rise in the number of lampreys. The data for Lake Superior in Table 5 suggest that the relation may not be as close as was at first suspected.

TABLE 5.—Sex ratio of sea lamprey taken during spawning runs in tributaries of Lake Superior and Lake Michigan, 1954–1957.

Year	*Lake Superior*		*Lake Michigan*	
	Number of lampreys examined	Males per 100 females	Number of lampreys examined	Males per 100 females
1954	3,939	140	6,559	219
1955	6,174	113	4,972	151
1956	9,593	135	2,222	145
1957	11,015	136	14,435	224

Despite the rapid increase in numbers of sea lampreys in Lake Superior mentioned earlier, the changes in the sex ratio have been without trend.

The table shows that the sex ratio has varied widely but without trend over the last four years in Lake Michigan tributaries (west and north shores). The sex ratio was 169 per 100 females in 2,647 sea lampreys examined from east shore tributaries of Lake Michigan in 1957.

Development and testing of selective toxicants

The development of selectively toxic chemicals that will destroy larval sea lampreys in streams without injuring fish progressed rapidly during the year. Certain water-soluble forms of the halogen mononitrophenols were evaluated in the Hammond Bay Laboratory. Two of them, 3,4,6-trichloro-2-nitrophenol and 3-trifluormethyl-4-nitrophenol were tested at various concentrations and water temperatures in a raceway where continuous water flow required the metering of the chemicals during the entire treatment period. The encouraging results of these raceway tests indicated that actual pilot treatments of streams with both chemicals should be undertaken.

Acute oral and dermal toxicity and primary skin and eye irritation characteristics were determined by the Wisconsin Alumni Research Foundation for the active ingredient of both materials. Tests were made also of the effects at stream treatment levels of 3, 4, 6-trichloro-2-nitrophenol upon deer and upon the general well-being and milk production of dairy cows. No harmful effects of this compound were detectable by competent veterinarians.

Laboratory development of at least four additional mononitrophenols containing halogens progressed during the year. This work has the particular objective of finding more effective and less expensive materials. Further laboratory testing and initial raceway tests were undertaken with certain formulations of the larvicidal material O-ethyl-S-pentachlorophenyl thiolcarbonate.

Preparatory to actual field testing of the larvicides, formulation research was carried on cooperatively with the Dow Chemical Company. Negotiations were concluded for delivery of 5,000 pounds of 3, 4, 6-trichloro-2-nitrophenol formulated as a 30 percent stock solution (solvent, "Dowanol 33B") of the compound as a sodium salt (trade name Dowlap 30). A trailer-mounted chemical-feeding unit was constructed to carry a small proportioning device used for raceway tests. A large proportioning device with a capacity of 278 gallons per hour was purchased so that an additional unit could be constructed for treating larger streams. Thirteen streams in Michigan and Wisconsin were selected for test treatment and permission was obtained from the states to perform the tests in these waters. Investigatitons were also carried forward on the causes of deactivation of mononitrophenols at certain seasons and on the pathology of sea lampreys treated with these compounds.

The first stream trial of Dowlap 30 was undertaken on October 29 and 30 in Little Billie's Creek, Cheboygan County, Michigan. The stream, which is about five miles long, had a flow of 4.4 cubic feet per second and a temperature of about 45°F. at the time of the test. Sea lamprey had been observed spawning in the stream since 1949 and and larvae present would number in the tens of thousands.

A qualitative census of fish populations showed brook trout to be common in the test section, along with 14 other species, predominantly forage minnows and the young of coarse fish. In order to determine the effects of the treatment on trout species other than the native brook trout, 100 rainbow and 100 brown trout were planted in the screened test section 24 hours before the chemical was applied. These fish ranged from 4 to 10 inches long.

Six stations were selected for continuous observation and lamprey larvae from another watershed were placed in cages at each to check the effectiveness of the treatment. At each station these cages were placed in midstream, along the banks and in backwaters. They were set into the stream bed so that the imprisoned larvae could burrow

more or less naturally into the bottom within the cages. The 40 cages used contained 1,032 larvae.

The chemical was applied for 24 hours at a concentration of 30 p.p.m. which was slightly in excess of that required. A total of 288 gallons, containing 384 pounds of active ingredient, were used.

Analyses for nitrophenol content of the treated water carried out at regular intervals indicated no significant drop in concentration between the initial feeding point and the mouth even though the stream volume was known to increase by approximately 10 percent. Limitations in the nitrophenol analysis techniques may account for the fact that no drop in concentration was detected. It took almost 6 hours for the treated water to clear the stream after application was stopped. Visual observations of the movement of the mass of treated water were verified by nitrophenol analyses at suitable check points along the test section.

Of the 1,032 larvae confined to the 40 cages, 85.7 percent died during the 24-hour treatment and 10.9 percent died after the body of treated water had passed out of the stream. A total of 96.6 percent died as a result of exposure to the larvicide. Nearly all of these post-treatment deaths occurred within the first 42 hours after exposure to the chemical. Data on the mortality of caged lamprey are presented in Table 6.

TABLE 6.—Mortality of caged lamprey resulting from the treatment of Little Billie's Creek with Dowlap 30.

Station	Number of larvae	Larvae killed				Total mortality	
		During treatment		Following treatment			
		Number	Percentage	Number	Percentage	Number	Percentage
1	135	135	100.0	..		135	100.0
2	130	130	100.0	..	.	130	100.0
3	135	135	100.0			135	100.0
4	201	177	88.1	20	9.9	197	98.0
5	150	125	83.3	21	14.0	146	97.3
6	281	183	65.1	71	25.3	254	90.04
Totals	1,032	885	85.7	112	10.9	997	96.6

The velocity of death among caged control larvae diminished with increasing distance from the point of application. Average time to cause the death of control specimens at Station 1 was 12.5 hours; at Station 6 it was 30.1 hours. This reduction in the effectiveness of the larvicide with increasing distance from the point of introduction

was not consistent with the nominal dilution of the chemical resulting from the slight increase in stream volume. Water analyses conducted on November 4, 1957, at the six stations in the treated area indicated significant changes in certain physical and chemical characteristics of the water over this portion of the stream. Dissolved oxygen increased from 10.3 to 11.5 p.p.m., dissolved CO_2 decreased from 4.2 to 1.7 p.p.m., and pH rose from 7.5 to 7.9. Laboratory studies which have suggested a relationship between the relative amounts of these two dissolved gases and the biological activity of the nitrophenols appear to be confirmed by these findings. Diminishing biological activity of the salt of a nitrophenol with increasing pH is suspected but still must be investigated in the laboratory.

Effect of the treatment upon the larvae in the stream was dramatic. After about 10 hours of exposure, thousands of dead, dying or ill larvae were seen drifting downstream or rolling along the stream bed. While the treatment was still in progress, numerous predators began to feed upon the dead and dying individuals. Sea gulls, several species of shore birds, and crayfish, seemingly undisturbed by the chemical in the water, consumed enormous numbers. Shifting sands in the lower watershed rapidly covered carcasses and hindered any accurate counts. An estimate of the numbers of larvae killed could not, therefore, be obtained.

It is believed that relatively few larvae escaped a lethal exposure to the chemical. Many of the larvae trapped at the lowermost check weir, while obviously affected by the chemical, were still capable of swimming. Most, if not all, of these individuals originated in the lowermost reaches of the stream. The proportion of these larvae which would have been swept into larvicide-free water and survived is not known.

A reconnaissance of the entire treated area of the stream was made shortly after the application was concluded and 19 dead brook trout and 11 dead rainbow trout were discovered. No dead brown trout were found. Observations made during the treatment, during the immediate post-treatment reconnaissance of the stream, and during an electric shocker survey eight days after the treatment, showed that some mortality occurred among mudminnows, northern redbelly dace, and young white suckers. The remaining smaller species seem to have been unharmed by the treatment.

One crustacean *(Gammarus linnaeus)*, which was abundant in the stream, was severely affected by the chemical; large numbers were seen dead or dying during the treatment. Re-population of the stream by this organism, presumably from the shoals of Duncan Bay, was well underway, however, eight days after treatment.

Selected areas, aggregating 16,000 square feet, were examined with electric shocking equipment eight days after treatment to

measure survival of fishes and lamprey larvae. Brook, brown and rainbow trout were present in the treated portion of the stream. In the entire area of stream bed examined only 10 live larval lampreys were found.

LAMPREY CONTROL AND RESEARCH

by Co-operating State and Provincial Agencies

The states bordering the Great Lakes and the Province of Ontario played a major role in early efforts to control the spread of sea lamprey. In 1957 they continued to co-operate closely with the Commission's agents in surveying streams, servicing electrical barriers and conducting studies of the sea lamprey in their waters.

In 1957, Minnesota continued its routine examination of the commercial catch landed in Duluth during the latter part of October in order to record the incidence of lamprey scarring on lake trout. A re-examination was made of nine streams surveyed in 1955 to see if sea lamprey spawning was occurring in them.

Wisconsin operated 7 electrical barriers on Lake Superior and 11 on Lake Michigan in co-operation with the Bureau of Commercial Fisheries. Its personnel assisted in the construction of two new barriers and surveyed streams in the state in order to detect new spawning runs. Spawn-taking crews continued to note incidence of lamprey scarring on lake trout in the Apostle Islands area.

Michigan's contribution to the sea lamprey program in 1957 was directed principally toward studies of the distribution and abundance of lamprey ammocoetes in streams entering Lakes Superior and Michigan; duration of the ammocoete stage; extent and direction of ammocoete migration in streams; and the distribution of ammocoetes in the offshore waters of northern Lake Michigan.

Two field crews continued examination of streams in Michigan's Upper Peninsula to determine occurrence, distribution and ecological requirements of sea lamprey ammocoetes. The survey of streams tributary to Lake Superior was completed in 1957. Sea lamprey ammocoetes were present in 60 stream systems examined. The largest populations were found in the Chocolay, Two Hearted and Sucker Rivers. The survey of Upper Peninsula streams tributary to Lake Michigan was continued and a total of 80 stations were sampled on 14 streams. Sea lamprey were abundant in most of them.

Further observations on the duration of the ammocoete stage of the sea lamprey were made in the Carp and Black Rivers. An "inclined-plane" trap has been operated near the mouth of the Carp River since the winter of 1950-51. It has taken on the average of 6,458 recently transformed sea lamprey and 9,022 larvae annually.

Although there is no proof that lamprey spawning has occurred above the trap, there is still a substantial population of ammocoetes in this section. The catch of lamprey moving downstream was relatively low in 1956-57, but it has fluctuated widely from year to year and no decreasing trend is apparent in the data. There has been an increase of 0.8 inches in the average length of ammocoetes above the barrier and the number of sea lamprey collected per hour indicates a somewhat smaller population in 1957 than in former years. As there is still a larval population above the barrier and no evidence of spawning above it since its installation seven years ago, it is probable that the length of the larval stage exceeds the four to five years commonly assigned to it.

The direction of movement of ammocoetes was studied by marking individuals with cadmium sulphide, releasing them at two points and subsequently sampling an intervening area with a direct-current shocker. All individuals recovered had moved downstream. Migration was independent of size.

Michigan survey crews have sampled the bottom of some 11 bays or deltas of Lake Michigan, at depths up to 32 feet. Sea lamprey ammocoetes were found at 3 to 15 feet in protected areas where the bottom was composed of silty-sand and where aquatic plants were present.

Sea lampreys occur in Lake Erie, but rarely become abundant and never appear to reach levels noted in the deeper cooler lakes. Ohio carried out a limited search for spawning sea lamprey in Conneaut Creek where they had been sighted, but could not find spawning adults. A small number of lamprey were tagged in this same area in co-operation with Ontario biologists studying migrations and growth. Questionnaires to fishermen were distributed to obtain information on the incidence of lamprey scars on fish.

Pennsylvania surveyed its potential lamprey spawning streams but located no spawning adults or larvae. Commercial catches examined contained no lamprey-scarred fish.

New York did not carry out any special investigation of the sea lamprey in Lake Ontario or Lake Erie.

Ontario operated one electrical barrier and two mechanical weirs on Lake Huron and one weir on Lake Ontario in 1957. Field staff assisted in surveys of Lake Huron streams conducted by the Fisheries Research Board of Canada.

The practice of sending monthly questionnaires to Canadian commerical fishermen for a record of lamprey scarring on fish taken on or immediately following a target date was continued. Some distribution, migration and growth studies of sea lamprey in Lake Erie were completed.

SUMMARY REPORTS

GENERAL FISHERY RESEARCH ON THE GREAT LAKES

Fishery research by government agencies on the Great Lakes is devoted to control of the sea lamprey, re-establishment of the lake trout and studies of fish and the conditions that affect their abundance. Research on control of the sea lamprey is supported largely by the Great Lakes Fishery Commission and has already been described. Other studies of the fisheries not related to sea lamprey control have been carried out by a number of government agencies who have reported on the progress of their work at meetings of the Commission's Scientific Advisory Committee and several informal committees. These reports, particularly those submitted at the annual meeting of the Upper Great Lakes Fishery Committee, and which appear in its minutes, have been drawn on extensively in preparing the following summary of general research activities.

Basic researches in aquatic biology, hydrography and geology are also being carried out by a number of universities. These researches are not directly applicable to local fishery problems but are of fundamental significance. A list of these projects without detailed description is given.

Research by the Bureau of Commercial Fisheries United States Fish and Wildlife Service

For the first time in several years a modest but significant expansion of the Bureau's fishery research program has been possible. New field stations have been established at Ashland, Wisconsin, on Lake Superior and at Sandusky, Ohio, on Lake Erie, and vessels have been refitted or rebuilt to make them suitable for work at the two stations. At the same time some additions have been made to the scientific staff in the central offices in Ann Arbor.

Lake trout investigations

Research on lake trout ceased to be a special investigation in May 1956. Two major lines of observations, nevertheless, have been continued: tabulation of returns of marked hatchery-reared fish planted to determine the most suitable size and season for planting; collection of biological data and records of lamprey scarring from landings at Marquette, Michigan.

Over the period 1952-1955, 250,000 fin-clipped fingerlings were planted in the fall (1 year old; average length, 3½ inches) and 303,000 in the spring (1½ years old; average length, 4½ inches). Returns indicate conclusively that survival is the better from spring plantings. Of the 129 returns to date 115 or 89 percent had been stocked in the spring.

The advantage of spring over fall for the planting of yearling lake trout did not extend to older, larger fish. Rate of recapture of the 13,384 larger fish tagged and planted was practically the same (5.1 per cent) for fall and spring releases.

Records of movement and recaptures of tagged native lake trout were reviewed in a 1953 publication. Some additional tagging has since been done and some further recoveries have been made. The rate of recapture from all taggings has declined so much, however, that few additional recoveries are to be anticipated. Returns from all types of tags were substantial, ranging from 17 percent for fish with cheek tags to 45 percent for fish with Petersen tags.

Lake Superior investigations

The establishment of a fishery research station with headquarters at Ashland, Wisconsin, is making possible an expansion of activities which previously had been limited to observations on landings of lake trout at Marquette, Michigan, and the annual collection of scale samples from spawning runs of lake herring at major production centers. The broadened program includes an extension of lake trout studies, a start of research on population identities, growth, and mortalities of whitefish, and tracing of seasonal movements and distribution of lake herring. The latter two phases of the work have been initiated to find a basis for rational increase of exploitation of whitefish and lake herring to support the fishery as the abundance of lake trout declines.

Operations of the Lake Superior staff will be greatly facilitated by the rebuilding of the research vessel *Siscowet* to be stationed at Ashland. This work which is nearing completion will provide a vessel with living accommodations able to carry out a wide range of limnological and fishery operations.

Green Bay and Saginaw Bay investigations

Investigations of yellow perch of Green Bay, initiated cooperatively with the Wisconsin Conservation Department in 1948, have progressed to the point that analyses have been started on year-class strength and on annual fluctuations and regional differences of growth. A paper establishing methodology in age and growth research appeared this year. Research has been started on fluctuations of the walleye in northern Green Bay. This important species has been

at an exceptionally high level of abundance for some years but the fluctuations have been very wide.

An inquiry into the population structure of yellow perch in Saginaw Bay was completed this spring. Numbers of perch increased enormously but growth rate decreased sharply between the 1929-1930 and 1943-1955 sampling periods. Fish of a size that could be retained in commercial trap nets increased approximately sevenfold but the length of time required to attain legal length (8½ inches) also increased from 3 to more than 5 years. The stock is so obviously underexploited that a relaxation of restrictions on fishing is desirable.

Collection of materials on other important species has continued, but, except for the Saginaw Bay walleye, no analysis of the material is being done at the present time.

Deep-water fisheries of Lakes Michigan and Huron

A paper has been issued describing the changes in the deep-water fish population of Lake Michigan consequent on the invasion of the sea lamprey and commenting on implications for the commercial fishery.

Because of difficulties of identifying the species of chubs at small size an attempt is being made to rear these fish from eggs to the fingerling stage. It is hoped that the availability of the progeny of known parentage may permit the discovery of diagnostic characters in the young fish.

Research continued in the forepart of the year on the natural history of the chubs of Lake Michigan—including studies of age, growth, distribution, abundance and food. This project is now temporarily inactive.

Lake Erie investigations

For many years the Bureau's work on Erie, most productive of the Great Lakes, was limited to an annual fall sampling of the commercial catch of the principal species at major ports of landing. This deficiency was remedied in some measure this year by the establishment of a Lake Erie staff—consisting of a project leader in Ann Arbor and two biologists and a master fisherman at a field station at Sandusky, Ohio. The 54-foot trap-net boat *Musky*, equipped with a new engine and specially refitted for Lake Erie work, has been assigned to the Sandusky station.

Operations of the Lake Erie staff have been exploratory. They are acquainting themselves with the lake, its fish population and the nature and methods of the fishery. They have made extensive samplings of commercial catches and have experimented with methods

of sampling the young of commercial varieties and the small species in shallow water. Special emphasis has been placed on learning of the activities of other research groups on Lake Erie.

Limnological-fishery survey of Lake Erie

The research vessel *Cisco* completed ten 2-week cruises in Lake Erie between April 30 and November 19, 1957. Various types of gill nets and trawls were fished at selected locations in the lake to gather information on the relative abundance and distribution (vertical and horizontal) of the various species in relation to limnological conditions in different seasons. This information will provide a better understanding of effects of environment and serve as a basis for planning by fishery biologists of research on the various species and on interspecies relationships. Limnological studies included collection of data on the temperature and chemistry of water, and on bottom fauna and plankton. The survey has also provided much information on the life history of Lake Erie fish and the capabilities of different types of gear in collecting various life history stages.

Results of species-composition and abundance studies await detailed tabulations, but some comments are now possible on certain fish distributions and movements. An abundance of smelt (excluding young of the year) in the western basin in May diminished with rise of the temperature until they were nearly absent in late July. The smelt concentrated in thermally stratified areas in the central and eastern basins of the lake where they stayed mostly in or below the thermocline. As water temperatures declined, smelt started to return to the western basin but had not reached the May abundance by October. Mortality was high among the few smelt that remained in the warmer water of western Lake Erie during the summer.

Young-of-the-year yellow perch, white bass, and sheepshead were common in catches from deeper areas of the open lake in early September where practically none had been taken earlier in the year. At the same time, a decline in catches of these small fish in Sandusky Bay indicates a general movement from bays and shallow water to the open lake.

Channel catfish and sheepshead were very common in the island region off Sandusky in late summer, but their abundance decreased noticeably by October. A few blue pike were caught in the western basin in May where none were taken later in the operating season.

Research on the basic productivity of Lake Erie and its relationship to the standing crop of net plankton and nannoplankton has been in progress since June, 1957. Data on the horizontal distribution of plankton in Lake Erie were obtained at half-hour intervals on a cruise from Sandusky, Ohio, to Dunkirk, New York. Vertical tows

made from April through November will supply information on the seasonal abundance. Water samples have been preserved for analysis of nannoplankton.

Plankton samples from stations in eastern Lake Erie have been sent to Dr. C. C. Davis, Western Reserve University, for his studies of the life histories of various crustaceans.

Analysis of limnological data from earlier surveys

A report in preparation on the limnological data collected in 1952 and 1953 in Lake Superior by the *Cisco* presents results, without extensive interpretation, in order to make the records available to other agencies. Bathythermograph data collected by the U. S. Lake Survey, Corps of Engineers, on Lake Superior in 1956 and 1957 will be included.

Determinations are being made of the concentrations of Na, Ca, Mg, and SiO_2 in Lake Michigan water samples collected in 1955. Analysis of bottom samples collected from Lakes Superior, Michigan, and Huron and from Green Bay in 1951-1955 has been initiated by the Department of Fisheries and Wildlife, Michigan State University. The study will provide information on the general distribution of bottom organisms.

Chemical analysis has been completed on Saginaw Bay water collected on three synoptic surveys in cooperation with the Michigan Department of Conservation in 1956. The concentrations of Na, Ca, Mg, and K were determined through use of a flamephotometer. Usually the higher concentrations occurred along the southeastern shore. Alkalinity, phosphorus, sulfate, and specific conductance values showed a similar trend.

Preliminary studies of recoveries of drift-bottles show that a counter-clockwise current, usually present within the Bay, causes Saginaw River water to flow along the southeastern shore.

Organisms have been sorted and identified for most of the bottom samples, collected during the synoptic studies. Bottom sediments of Saginaw Bay have been analyzed for median particle size, deviation from the median size, sphericity, roundness, organic and inorganic content, and heavy and light minerals. These data will aid in determining the general pattern of water currents near the bottom. Additional sampling was conducted in critical areas this fall.

A study of the relationship between Secchi disc readings and the light penetration in Saginaw Bay and Lake Huron has established that the average percentage transmission of surface light intensity at the Secchi disc depth was 14.7 percent.

Survey of sources of hydrographic data

A study of sources of hydrographic and meteorological data pertinent to Great Lakes problems was initiated through a contract with the Great Lakes Research Institute of the University of Michigan. The first phase is to locate and determine the nature, extent, and availability of hydrographic and meteorological records. This compilation should be completed and ready for publication in June, 1958. When the sources of data are known, a pilot study will be made in a selected area to determine their usefulness in interpreting past changes, and in predicting future hydrographic conditions.

Research by the Fisheries Research Board of Canada

Lake trout studies

In 1957 the Fisheries Research Board began investigations of the lake trout fisheries of Lake Superior and of Georgian Bay. Fishermen at Mamainse Harbor and Rossport fishing ports were interviewed daily and information on catch per net was recorded. At the same time, samples were taken of their catches to determine average size and scale samples collected for age determination. The number of scars and open wounds resulting from lamprey attacks was also recorded. The trout in the Mamainse Harbor area have been under heavy lamprey attack for some time and it was generally assumed that they were extremely scare in the area. It is therefore interesting that more fish were landed at Mamainse than at Rossport and that the catch per net was noticeably greater. In Mamainse 31 percent of the lake trout bore scars or wounds and at Rossport 21 percent. The frequency of attack varied little throughout the season at Mamainse, but at Rossport the percentages were low between mid-July and mid-September.

The investigations in Lake Huron were based at Killarney and at Wiarton. The catch of a few lake trout at Killarney was incidental to a fishery for other species. Those that were landed were mostly of spawning size. There is a small but persistent fishery for lake trout in southern Georgian Bay where lake trout are landed at Meaford, Thornbury and Collingwood in the spring and throughout the spring and summer at Owen Sound and Johnson Harbor. The trout taken in 1957 were mostly small and immature, presumably because the lamprey are destroying those reaching spawning size. Forty-three percent of the trout landed had been attacked by lamprey. Those taken in August were more frequently scarred than those taken earlier. During the summer of 1957 a lake trout population was found in

Parry Sound, a somewhat isolated part of Georgian Bay. It is subject to lamprey attack but apparently not to the same extent as other populations in Georgian Bay for there are many fish of spawning size.

Research by Minnesota Department of Conservation

Minnesota's research activities on Lake Superior were limited to a study of the life history of smelt, a species which has recently become abundant in the western end of the lake.

Research by Wisconsin Conservation Department

Lake trout studies

Wisconsin has planted a total of 1,008,078 fin-clipped lake trout since April 1952 in the Apostle Islands area of Lake Superior. Some 420,000 of these fish were 9 to 10 months old and the remainder 16 to 17 months old when planted. The younger fish planted in the fall, and the older fish planted in the spring were marked differently in order to compare their survival. Information on recaptures was obtained from commercial fishermen through a voluntary report system.

Since 1955, 3,287 recoveries of fin-clipped fish have been reported from both the commercial and sport fishery. Of this total, 2,967 or 89.5 percent of the recoveries have been spring-planted fish; the remaining 311 or 10.5 percent were fall-planted. All lake trout are now planted in the spring. Some of these fish reach a legal size (17 inches) as early as 2½ years after planting. Commercial operators who fish in the immediate vicinity of the Apostle Islands report a greater number of fin-clipped lake trout than those fishing outside the island area. Scattered observations indicate that the ratio of fin-clipped to native fish entering the fishery although variable is surprisingly high. One gill net fisherman noted a ratio of one hatchery fish to three native fish in the undersized trout taken during a 3-month period.

Whitefish studies

A whitefish tagging program was started in 1955 to study the migration and rate of growth of whitefish in the Apostle Island area. Plastic streamer tags were attached to the body, posterior to the dorsal fin. A total of 1,835 undersized whitefish, ranging from 12.0 to 16.9 inches, were tagged. Forty-three recoveries have been made, all in the tagging area.

Research by Michigan Department of Conservation

Michigan has begun a number of studies on the migratory rainbow trout which spend a portion of their life in the Great Lakes, and two life history studies of the walleye and smallmouth bass in Lake Michigan. An investigation of tag retention and the effect of tags on the growth and survival of lake trout held in a hatchery was carried out in co-operation with the Bureau of Commercial Fisheries. The State also participated in the hydrographic survey of Saginaw Bay described earlier.

Rainbow trout

A life history study of the migratory rainbow trout has been in progress on the Black River, Mackinac County, since 1950. A creel census has been taken each year during the annual spring and fall upstream run of adults. A partial count has also been made each year of the adults in the run. These indices of the population of adult rainbow trout entering the stream show that the runs were largest in 1950 and 1951, somewhat smaller in 1952-1954 and the smallest in 1955-1957. The generally downward trend of the rainbow trout run coincided with increasing predation by sea lampreys as evidenced by the scarring records.

Although the runs of adult rainbow trout have been diminishing, no downward trend has been observed in the population of young in the stream. Populations of young-of-the-year rainbow trout were largest in 1955, large in 1952 and 1956, and smallest in 1953, 1954 and 1957.

Rainbow trout have been planted near the mouths of tributary streams since 1955 and records of recovery made to determine their contribution to the depleted "natural run." In 1957 three strains were planted with the intention of comparing their survival.

Anglers had taken about 3.1 percent of the 1955 plant of 20,168 trout and 2.9 percent of the 1956 plant of 26,916 fish by November 6, 1957. About one-half of the fish recovered showed the extremely fast growth typical of trout which spend a good portion of their life in the lake. Recoveries of rainbow trout which remained in the streams were most numerous shortly after stocking. After the first growing season the majority of recoveries were fish displaying lake growth. These recoveries reached a maximum during the first fall or the second spring after planting and comparatively few fish were caught subsequently.

An evaluation of different tags used on rainbow trout has been carried out at the Thompson hatchery. Mortality of fish tagged with

No. 8 ring tag was 8.7 percent, with No. 10 ring 4.3 percent, No. 3 jaw tag 5.2 percent, while unmarked and fin-clipped fish experienced a 2.4 percent mortality. Growth of the different lots was similar, although the fish without tags showed a slightly greater increase in size. Loss of tags was negligible. Some 15 percent of the fish with pectoral fin-clips and 35 percent of those with pelvic fin-clips had partly regenerated fins.

Walleye in Lake Michigan

A study of Lake Michigan walleye which spawn in the Muskegon River, Michigan, was begun by the Michigan Department of Conservation in 1947. Tagging studies conducted have shown that (1) the run up the Muskegon River amounted to more than 100,000 fish in 1953 and in 1954 (two rather typical years); and (2) when the fish returned to Lake Michigan after spawning they moved northward and southward along a 200-mile section of shoreline from Goodharbor Bay (near Leland, Michigan) to Porter Beach, Indiana.

A joint study with the U. S. Bureau of Commercial Fisheries of the walleye in the Bay de Noc area of northern Lake Michigan was begun in September 1957, to (1) determine relative exploitation rates of walleyes by sport and commercial fishing; (2) learn the migration of walleyes in this area and the geographical limits of the subpopulation; and (3) follow fluctuations in walleye abundance as reflected by year-class strength.

A total of 770 walleyes, ranging in total length from 9.4 to 25.0 inches (average, 13.6) were tagged and scale samples taken. The majority were undersized fish taken in commercial fishermen's nets. Further field work is planned next spring, directed toward tagging larger numbers of walleyes during the spawning season, locating the spawning grounds, and obtaining information on the ages, lengths, and sex ratio of the spawning stock.

Smallmouth bass in Lake Michigan

A study of smallmouth bass off Waugoshance Point in northern Lake Michigan started in 1953 was completed in June 1957. A report entitled "The ecology of the smallmouth bass at Waugoshance Point, Lake Michigan" will be issued as a Miscellaneous Publication of the Institute for Fisheries Research.

A further study of smallmouth bass was initiated in the Bay de Noc area of northern Lake Michigan to determine the geographical limits of the bass population and to obtain an estimate of the growth rate, year-class strength, rate of exploitation by anglers, and the effect of temperature on year-class strength.

Survival and growth of tagged lake trout in a hatchery

A comparison of retention of two tags attached in different ways to 2-year-old lake trout and their effect on growth and survival was begun in 1955 by the Bureau of Commercial Fisheries. The results were assessed by the State of Michigan.

Survival, or the retention of tags, was similar for cheek, Petersen, and lower-jaw tags (85, 86, and 91 percent, respectively), but all of the upper-jaw tags and all except one of 200 streamer tags were lost. Ninety-five percent of the fish with clipped adipose fins remained at the close of the experiment. The growth of fish tagged with cheek, Petersen, and lower-jaw tags was nearly identical but the growth of the tagged fish was retarded by about 25 percent in comparison with the control group. The coefficient of condition of tagged fish was not significantly different from that of untagged fish at the end of the year.

Propagation of lake trout

A brood stock of lake trout is being built up at Michigan's Marquette hatchery. The older fish are now contributing significantly to the total number of lake trout eggs available for the artificial propagation of this species in the Great Lakes area. A careful record of the age of maturity, fecundity, and spawning period is being kept. This information should prove useful in estimating the future brood stock requirements of the lake trout restoration program.

Research by Ohio Department of Natural Resources

Ohio continued its routine trawl sampling of fish populations at a number of stations in Lake Erie. The catches per haul have been quite consistent in the same area on the same day, but are highly variable when taken over an extended period of time in different areas. Trawl catches have been composed largely of yellow perch, white bass, alewife, gizzard shad, and channel catfish. Trawling undertaken several years ago gave early indication of the present abundance of white bass. Operations in 1957 have shown a relative scarcity of young perch, although spawning fish were abundant. Ohio also conducted a survey of angling pressure in the island area between Port Clinton and Cedar Point.

Research by Pennsylvania Fish Commission

Pennsylvania is concerned with only a short stretch of shoreline on the Great Lakes, and its research program has been limited to a

study of the survival of rainbow trout planted in several streams tributary to Lake Erie.

Research by New York Conservation Department

New York is studying the survival of rainbow trout planted in a stream tributary to Lake Erie, but has concentrated most of its efforts in the eastern portion of Lake Ontario where it is studying the survival of planted lake trout in co-operation with the Province of Ontario. Some 170,000 fin-clipped trout were planted by the State and the Province during the period 1953-57. New York has contributed 74,000 fingerlings which have been planted in the fall, and 20,000 yearlings which have been planted in the spring. Recoveries of 72 of the planted trout have been made in 4¾-inch gill nets fished for whitefish by a commercial fisherman in New York waters. The growth rate of the trout has been good; a length of 20 inches was reached by the end of the fourth year. Although roughly equal numbers of lake trout have been planted by these two agencies at about the same places and times in the lake, rates of return have been very unequal. New York's plantings of Seneca Lake stock have contributed 90 percent of the recaptures. Their predominance may reflect the relative suitability of this particular strain.

Research by Ontario Department of Lands and Forests

Lake Superior

The rate of occurrence of sea lamprey scars on lake trout and whitefish continued to increase, particularly in the inshore fisheries. In anticipation of effective control of the sea lamprey, 500,000 lake trout yearlings were marked in preparation for their planting in the Rossport and Lizzard Island areas during 1958. Catch sampling and population studies which were abandoned after 1955 because of shortage of scientific staff were not resumed in 1957 for the same reason. Some of this work was again undertaken by the Fisheries Research Board of Canada.

Lake Huron

The fishing operations in South Bay which began as an experimental fishery when the station was established in 1947 were continued in 1957. Fish populations were sampled routinely with the same gear and effort as in previous years. Some 10,000 individual fish were measured, weighed and sexed; scale samples and stomach contents also were obtained. The decline in the total catch from the Bay during 1957 was due mainly to a drop in the smelt catch in streams during the spawning run. Since the gill-net catches of smelt following spawning did not indicate a decline in abundance, the decreased catch of this species was attributed to low water levels at spawning time. The alewife catch of 19,000 pounds, although higher than that made in 1956, showed signs of leveling off for the first time since this species appeared in the fishery five years ago. The fishing operations also took 1,378 lake trout planted during the period 1951-1955. A study of the survival of these planted trout is now complete and a report is in press. The study has shown a remarkably high survival of hatchery-reared yearlings.

Hybrid trout (speckled × lake trout) planted first in 1953 and annually since 1955, continue to appear in the experimental catches. The hybrids survive for about the same length of time as planted lake trout before they are eliminated by sea lamprey. They mature at an earlier age than lake trout and grow more rapidly.

The 10-year accumulation of meteorological and hydrographic records for South Bay is now being examined. The data show a close correlation between the monthly mean temperatures of the epilimnion and the monthly mean air temperatures. This relationship will be most useful in establishing past water temperatures from meteorological records.

Catch sampling in Georgian Bay was considerably expanded. Recaptures of whitefish tagged in 1956 indicated a high rate of exploitation of this species by commercial fishermen and suggested the occurrence of at least two discrete populations of whitefish.

Completed questionnaires from commercial fishermen showed a continued high level of sea lamprey predation on commercial species throughout Lake Huron.

A study of the use of fresh-water fish, particularly smelt, as feed for mink begun in 1951 with the co-operation of the Ontario Veterinary College has continued and a report has been issued.

Lake Erie

Net-run sampling of the commercial catches at the two major Lake Erie fishing ports, Port Dover and Wheatley, was established and continued through December 1957. Preliminary analyses of data allowed predictions of 1958 catches for some species. Smelt studies, including spawning behavior and post-spawning mortality of males, were continued. Tagging studies on walleye were designed to learn the movements of this species in Lake St. Clair and western Lake Erie. The launching of the research vessel *Keenosay* in the fall of 1957 will facilitate the intensive blue pike studies planned.

Lake Ontario

The commercial catch of whitefish was again sampled in 1957. Age determinations from scale samples were completed for the years 1952 through 1956 and a corroboration of readings for the years 1944 to 1951 was largely completed. Young fast-growing whitefish continued to constitute the bulk of the catch. An assessment of the contribution to the fishery of whitefish fry produced by the Glenora hatchery is close to completion.

Marked lake trout planted by New York and by Ontario were recaptured in substantial numbers by experimental gill nets and by commercial fishermen. The New York plantings continued to survive better than the Ontario plantings. Some 4-year-old male trout were mature in 1957 but females will evidently not be mature until next year.

A study of walleye was begun in the Bay of Quinte to determine the size of this population and its relative exploitation by anglers and commercial fishermen. The commercial catches were examined; experimental nets were fished; and a creel census was initiated. Preliminary information is now available on rate of growth, age at maturity, food habits, year-class strength, and movements.

Laboratory studies

Studies of splake, the hybrid between speckled trout and lake trout, were continued at various locations, principally at the Southern Research Station, Maple. The objective of this project is to combine, through selective breeding, the deep-swimming ability of the lake trout with the early-maturing character of the speckled trout. Two means of accomplishing this goal are being tried. Hybrids have been planted in South Bay while the lamprey continues to be abundant. It is expected that the natural selection exerted by the physical environment together with the effect of the lamprey in eliminating the late spawners will result in survival of the desired genetic types. The other approach is to carry on artificial selection of stocks retained in culture. In this program first-generation hybrids are selected for the deep-swimming characteristic during their first year of life. These fish are retained for two or three years until the early-maturing individuals can be selected. Studies of vertebral counts and swim bladder gas retention in F_1 and F_2 hybrids and in certain backcrosses have provided grounds for optimism that a fish with the desired fixed characteristics can be produced.

Facilities for graduate research in fisheries continue to be supplied by the Department to the University of Toronto at the Laboratory of Experimental Limnology, Maple. Numerous projects are going forward as a result of this arrangement.

Physical limnology

Field work during the 1957-58 year was restricted to Lake Simcoe where the research vessel *Plainsville* operated from June 1 till freeze-up. Weekly observations were made on the lake, and other experimental work was conducted on current measurements and bottom coring. This work was undertaken primarily as a pilot project to develop procedures for Great Lakes work. Two experimental surveys by aircraft were made over Lake Simcoe and a third, the length of Lake Ontario, with a Canso aircraft loaned for the trial by the R.C.A.F. A foundation for expansion of research in the Great Lakes was laid during the year by the formation of the Great Lakes Geophysical Research Group. The purpose of the Group is to establish liasion among Canadian agencies and universities concerned with the Great Lakes and to establish cooperatively supported research where necessary. In the latter category, plans were concluded for trial expansion in physical limnology with cooperative financing by a number of provincial agencies. This arrangement will permit the operation in the lakes of a 125-foot, 400-ton R.C.N. vessel *Port Dauphine*, the loan of which is a contribution to the program by the Department of National Defense.

Research by the Great Lakes Research Institute University of Michigan

The Great Lakes Research Institute was established by the University of Michigan in 1945 for the encouragement of studies of the physical, chemical, geological and other aspects of the Great Lakes and related areas. Studies undertaken by the Institute in 1957, which deal largely with the physical limnology, geology and biology of the lakes at lower trophic levels, are as follows:

1. Seiches in Lakes Michigan and Huron.
2. Distribution of benthic fauna in the Straits of Mackinac in relation to the mechanical nature of lake sediments.
3. Evaluation of quantitative methods for measuring biological productivity in the Great Lakes.
4. Sediments and hydrography of Grand Traverse Bay.

Field work was completed and manuscripts are in preparation for the following projects:

1. Preliminary observations on unusual phytoplankters in Lakes Huron and Michigan.
2. Study of the deep-water sediments of northern Lake Huron, including their relationship to the present environment and their indications of the history of the lake.

3. Water transport studies in the Straits of Mackinac.
4. Currents and water masses in Lake Michigan.
5. The standing crop of benthic fauna at three stations in the Straits of Mackinac.
6. Geological interpretations of the Straits of Mackinac based upon bathymetric data and nature of surface sediments.

A paper by Dr. John Ayers, entitled "The hydrography of Grand Traverse Bay," was published by the Institute in 1957.

Research by the Natural Resources Institute
Ohio State University

The Natural Resources Institute was established to coordinate the activities of various departments at Ohio State University concerned with the study of natural resources. The Institute acts also as the University's agent in arranging research services in the field of natural resources to outside organizations. Studies undertaken under the auspices of the Institute in 1957 are as follows:

1. Embryonic development of the northern pike.
2. Mid-seasonal gonadal development of the white bass.
3. The biology of Lake Erie calanoid copepods.
4. Crayfish of the island region of Western Lake Erie.
5. Fish parasites of Lake Erie.
6. Analysis of growth rate and causes of growth differences in the yellow perch.
7. Basic factors in productivity of Lake Erie waters.

Research by the Department of Fisheries and Wildlife
Michigan State University

The Department of Fisheries and Wildlife began its fishery investigations in the Great Lakes in 1948, with a study of whitefish in northern Lake Michigan. The results of these studies, which form the basis for a number of doctorate and master's theses, are summarized in a paper published in 1957 by E. W. Roelofs, entitled "Age and growth of whitefish, *Coregonus clupeaformis* (Mitchell), in Big Bay de Noc and northern Lake Michigan."

LAKE TROUT CATCH STATISTICS

The collection of commercial catch records for the principal species of fish is carried out by the states bordering the Great Lakes and the Province of Ontario. Routine tabulations of catch and catch per unit of effort are made by the Bureau of Commercial Fisheries for the Great Lakes water of New York, Pennsylvania, Michigan, Indiana, Illinois and Wisconsin. Ohio, Minnesota and the Province of Ontario prepare similar tabulations for their fisheries.

Records of lake trout catches from Lake Superior and Georgian Bay are of no particular significance, as these are the only areas in which this species has not been practically eliminated by the sea lamprey. No lake trout have been reported for Lake Michigan or Lake Huron proper in the last two years. Small catches are still reported, however, from Georgian Bay and the extreme eastern portion of the North Channel. The landings made in these two closely associated areas of Lake Huron have therefore been combined and are presented with landings for Lake Superior in Table 1.

TABLE 1.—Commercial landings of lake trout in Lakes Superior and Huron during the period 1950–1957.

Year	Thousands of pounds	
	Lake Superior	Lake Huron (Georgian Bay and North Channel)
1950	4,708	415
1951	4,188	552
1952	4,227	588
1953	3,784	344
1954	3,522	168
1955	3,104	73
1956	2,340	50
1957	1,515	20

The downward trend of production in Lake Superior continued in 1957. The 1957 catch of lake trout was 35 percent of average landings for the base period 1929-1943. Landings in Georgian Bay and the extreme eastern portion of the North Channel continued to decline. Only 229 pounds of trout were taken in the North Channel and these in Manitowaning Bay. Most of the lake trout reported for Georgian Bay were taken in the southern portion. An isolated population, fished only by anglers, continues to persist in Parry Sound on the east shore of Georgian Bay.

Information on availability is at hand for State of Michigan waters where calculations of catch per unit effort have been made annually by the Bureau of Commercial Fisheries, United States Fish and Wildlife Service, beginning in 1929. The abundance indices (1929-1943 mean = 100) for lake trout in the combined statistical districts of the Michigan waters of Lake Superior in 1950-1956 have been:

1950	80	1954	64
1951	76	1955	68
1952	75	1956	63
1953	71		

The above indices are overestimates of availability. The 1929-1943 base period was one in which all gill nets (the principal gear) had cotton or linen webbing. In 1950-1956 nearly all gill nets had the much more efficient nylon webbing. The bias to the 1950-1956 indices cannot be assessed but it was severe. Limited available evidence indicates that nylon twine may be more than twice as efficient as cotton. It appears certain that only the availability of this efficient twine has made fishing possible in recent years.

Fishing pressure on lake trout in State of Michigan waters of Lake Superior has been decreasing. The intensity indices (1929-1943 = 100) for the combined districts have been:

1950	146	1954	122
1951	137	1955	103
1952	133	1956	98
1953	121		

The slow but steady decline of lake trout in Lake Superior resembles closely that in Lake Huron where 10 years were required for the decrease of catch to amount to 90 percent. The stocks of lampreys in both lakes were built up by natural reproduction within the lakes. In Lake Michigan, which obviously suffered mass immigration of lampreys from Lake Huron, the take dropped about 95 percent in only 5 years.

INCIDENCE OF LAMPREY SCARRED TROUT IN LAKE SUPERIOR

Information on the incidence of lamprey scarred trout in the commercial catch has been collected by a large number of agencies. Precise interpretation of the data is difficult because information on the relative abundance of trout and sea lamprey is largely lacking. Small trout are comparatively free from attack and therefore changes in the size composition of the catch further hinder interpretation.

The records of scarring still afford a rough measure of the increase in lamprey predation. As the information has been gathered by each agency under somewhat different circumstances, it is not strictly comparable. The series of records collected over the years by each agency is consistent in itself. Information collected by four agencies presented in Table 1, shows increasing lamprey predation over the past nine years. The figure of 79.2 percent in 1957 is not unusual as the incidence of scars fluctuates during the fishing season, reaching a peak in October. An incidence of 68 percent was noted for landings made at Canadian ports and 65 percent at Marquette, Michigan, during the same month.

There was a difference in the percentage of scarred trout landed by Canadian fishermen on the north and east shores of Superior. The Fisheries Research Board of Canada reported a 21-percent incidence at Rossport in northern Superior and 31-percent incidence at Mamainse Harbor on the east shore.

TABLE 1—Lamprey scars on lake trout taken in Lake Superior.

Year	Percentage scarred (by number)			Percentage scarred (by weight)
	Isle Royale 1/ (October)	Ontario waters 2/ (season)	Apostle Is. 3/ (October)	Michigan waters 4/ (season)
1949	0.6	..	..	1.0
1950	3.2	..	..	3.1
1951	3.8	..	.	5.0
1952	3.4	..	10.4	3.7
1953	10.0		8.8	6.9
1954	7.1	13.2	16.4	14.0
1955	20.3	20.9	36.0	20.6
1956	33.4	29.2	56.9	27.0
1957	33.8	29.0	79.2	

1/ Collected by Minnesota Conservation Department.
2/ Collected by Ontario Department of Lands and Forests.
3/ Collected by Wisconsin Conservation Department.
4/ Compiled by Bureau of Commercial Fisheries from commercial fishing reports.

RECOMMENDATIONS FOR REHABILITATION OF LAKE TROUT STOCKS IN THE GREAT LAKES

By the Bureau of Commercial Fisheries
United States Fish and Wildlife Service

Lake trout populations can be replaced in Lakes Huron and Michigan and supported in Lake Superior by artificial propagation and planting or by allowing restoration to occur naturally. The latter approach would be long and tedious and perhaps impossible because lake trout populations are practically extinct in Lakes Huron and Michigan. Hatchery production and planting appear to be the only practical means for rehabilitating the lake trout stocks in a reasonable time.

Experimentation was undertaken by Michigan, Wisconsin, Illinois, Indiana, and the Fish and Wildlife Service in 1944, to learn the survival of hatchery-produced lake trout and their contribution to the catch. Unfortunately, the increased abundance of sea lampreys and the accompanying collapse of the lake trout fishery made impossible the expected study of returns of marked individuals in the 1944 (100,280), 1945 (159,712), and 1946 (151,402) year classes of lake trout planted in Lake Michigan in mid-September as yearlings (3-4 inches in length). By the end of 1951, 1,319 verified recoveries of marked fish had been reported but most of these were under the legal commercial size of 1½ pounds. Recoveries from the three year classes indicated highly variable survival among the lots of fish stocked. The 1944 year class produced very few (43) recoveries, while that of 1945 produced 1,029 recoveries or 78 percent of all marked fish taken. The individuals in the 1946 year class had not been in the lake long enough to yield representative samples before the fishery collapsed, but the 247 recoveries made indicate a survival intermediate to that of the other plantings.

This experimentation was repeated on Lake Superior. Paired lots of marked yearling lake trout, with similar growth history to the time of marking, have been stocked. One lot was planted in the fall over water depths and at locations where the presence of native lake trout of similar size has been demonstrated by experimental fishing from the research vessel *Cisco*. The other lot was held over the following winter and stocked at the same locations in the spring. Three replications of this experiment were made by the spring of 1955. Early returns from the marked lots indicate a distinctly higher survival of fish planted in the spring.

Regardless of the opinions about fish culture, lake trout production records from Lakes Huron and Michigan since 1936 demonstrate, very convincingly, that this once profitable and stable fishery is gone. As there has been no observable recruitment in Lake Michigan and presumably in Lake Huron since 1950, there is little doubt that replacement of lake trout stocks by artificial or natural means is very improbable, if not impossible, as long as the predatory sea lamprey populations remain uncontrolled.

The duration of rehabilitation activities

Lake trout spawning stocks of any size do not exist in Lakes Michigan and Huron. Therefore, once sea lamprey control is in effect, it will be necessary to restore, artificially, at least part of this population. Rehabilitation will have to continue through 8-10 years if an adequate number of year classes is to be assured. Plantings should be made annually for at least 7 or 8 years—about the length of time a lake trout needs to reach sexual maturity. Probably 2 additional years of stocking should be carried out to augment the natural reproduction of virgin spawners which, because of their relatively small size and egg production, would not yield large numbers of eggs.

Timing of the rehabilitation

There is some evidence that lake trout are not subject to heavy sea lamprey predation until they exceed the size range of chubs (*Leucichthys* spp.) with which they live. Once the sea lamprey control network is completed and in operation on Lakes Huron and Michigan, planting of hatchery-reared lake trout can begin although 3 to 5 generations of sea lampreys may remain in the streams. These small lake trout can live in the lakes for 3 or 4 years or more (depending on their rate of growth) before they exceed the size range of chubs. By starting the stocking program concurrently with sea lamprey control, the time required to develop a breeding population of lake trout would be reduced from 11 to perhaps 7 years. Research and development in sea lamprey control methods may provide means for further shortening this waiting period. However, estimates must be based on known and proven control procedures.

The timing of the lake trout rehabilitation, then, depends upon the time of completion of the physical facilities needed for sea lamprey control. Consequently, it is presently without purpose to attempt to schedule exactly fish-cultural operations which would make available a specific number of lake trout at a given time. Fish-cultural operations could begin at the end of the two years required to complete installation of sea lamprey control networks. The first lots of

lake trout produced would be ready for stocking within a year after the start of full-scale sea lamprey control.

Numbers of lake trout needed

There is no good information on which to base estimates of the numbers of lake trout required for planting once the rehabilitation program is activated. Lakes Huron and Michigan will need practically complete replacement of lake trout stocks. The course of experience in the lake trout fishery of Lake Superior will determine the extent to which rehabilitation is carried in that lake.

The safest specification of lake trout required would recommend production of the maximum number possible. But, there are several practical considerations that prohibit such a recommendation, such as: availability of lake trout eggs, capacities of the various existing hatcheries to produce the desired fish, and the present opinion that once the rehabilitation is completed, the need for artificial propagation will cease or be greatly lessened.

Availability of lake trout eggs

Lake trout eggs are becoming increasingly difficult to obtain. The only remaining major domestic source of eggs is Lake Superior. Stocks of Lake Superior lake trout are dwindling each year and if present trends continue, this source of eggs may not be large enough to supply a reasonable demand. Without additional special fishing seasons for eggs, not more than 4 or 5 million eggs can be expected from the United States lake trout fishery on Lake Superior in good years. In poor years, the production of eggs seldom exceeds 3 million. The Province of Ontario collects eggs from its lake trout fishery in rather large numbers.

Fishing for eggs in United States waters of Lake Superior by specially supervised crews could be made much more effective than the inefficient practice of issuing permits to commercial fishermen to "fish for spawn" during closed seasons. Abuses and inefficiencies of this fishery led to the restriction of the practice in Michigan and Wisconsin. Supervised fishing will have to be considered thoroughly and perhaps adopted if egg supplies lessen materially in the next few years.

Imports of lake trout eggs may be possible from Great Slave Lake in Canada and other large lakes which produce this species if the Lake Superior source of eggs disappears. The methods of obtaining eggs from large Canadian and United States lakes must be planned and worked out in detail as insurance against the collapse of Lake Superior supplies.

Existing federal and state hatchery facilities

At present, two Fish and Wildlife Service hatcheries or rearing stations are concerned with lake trout production. The Charlevoix station and the rearing station at Pendill's Creek can produce a maximum of 500,000 yearling lake trout with their present facilities. The possibilities for production at a station at Lake Mills, near Milwaukee, are being explored. Some modernization is planned for the Charlevoix station and further development of Pendill's Creek rearing station is underway. With these changes, the capacity of Service facilities might be increased sufficiently to make possible the production of 1,000,000 yearling lake trout. The Service has several other hatcheries which probably could be used for lake trout production (LaCrosse, Genoa, and Guttenberg) if the need arises.

In response to inquiries by the Bureau several of the Great Lakes states have stated, informally, that they have physical facilities to handle lake trout eggs, fry, and fingerlings in approximately the following quantities:

State	Eggs and fry (until June)	Fingerlings (less than yearlings)	Yearlings or older
Michigan	14,800,000	1,000,000	1,000,000
Wisconsin	5,000,000	500,000	500,000
Indiana	None	None	None
Illinois	Several million	500,000	500,000
Minnesota	5,000,000	1,000,000	None

Hatchery use after rehabilitation

Should current opinions regarding the value of hatchery plantings of lake trout to maintain a commercial fishery be substantiated by the experimentation already described and by future experience, there will be no need for continuation of plantings beyond the initial rehabilitation program. Assuming this to be the case, extensive increases in hatchery facilities for the rehabilitation effort cannot be justified. If it is not the case, the economics of that portion of the lake trout fishery maintainable by hatchery production may not justify much expansion beyond present state, provincial, and federal facilities modernized to operate at high efficiency.

Number and size of lake trout recommended

The Bureau believes that the planting of yearling lake trout in approximately the following numbers annually represents the best

compromise between facilities to do the job, egg availability, and biological needs:

Lake Michigan	3,000,000
Lake Huron	2,500,000
Lake Superior	2,000,000[1]

[1] Required in the event that the fishery collapses.

The lack of any correlation between past hatchery plantings of eyed-eggs and fry of lake trout and later lake trout production furnishes rather convincing indirect evidence that such practices have not contributed significantly to the abundance of lake trout in the Great Lakes. Many persons have contended that the lack of success has been due to the small size of the hatchery fish at planting. The few experiments to determine the proper size of lake trout at planting have been generally inconclusive. However, the fragments of evidence available seem to support the argument for larger size of lake trout at planting. Results of experiments by the Service, the Great Lakes States and Ontario in Lake Superior waters, although incomplete, favor a length range of 3 to 6 inches. A period of initial, high mortality at hatching and at the first establishment of feeding is presumed to apply in the life history of lake trout. Any hatchery practice which holds the young trout beyond this stage is considered beneficial. Fish of this size can be marked for future identification without undue influence on survival. Marking of at least 10 percent of all lake trout planted is essential to the proper evaluation of this rehabilitation attempt.

Time of planting lake trout

Experiments started in 1952 with marked hatchery lake trout planted in Lake Superior by the Service indicate the desirability of spring (May) planting. Results, to date, are inconclusive but of the recoveries on record, a large majority are from spring-planted lots of marked trout. Captures of marked lake trout released by Wisconsin near Bayfield, on Lake Superior, show a majority of spring-released trout. The Service's research vessel *Cisco* caught 35 small trout with trawls and gill nets in that area during two sampling periods: May 29–30 and July 28–30, 1953. Of these trout, 18 were marked and 15 of the 18 were from spring releases.

Perhaps, the indicated advantage of spring planting may not hold for Lakes Huron and Michigan. Until such a difference has been demonstrated, however, the Bureau recommends that as many lake trout as possible be planted in the spring. Enough experimental lots should be planted in the fall to test this recommendation.

Locality of planting lake trout

Various studies have revealed several facts in lake trout life history which should influence the choice of planting sites. Naturally spawned lake trout eggs incubate through most of the winter and hatch in the spring. Young-of-the-year lake trout in Lake Superior occur in water 10–25 fathoms deep, do not disperse widely, feed on plankton, grow 3–5 inches in their first season, and move toward deeper water as they increase in size. Through their first years of life, small trout gradually disperse from their point of origin.

On the basis of these findings, young hatchery trout should be planted: at several localities in a lake for adequate dispersion but close to known spawning reefs; in water 10–25 fathoms deep, and, where possible, with existing trout populations; where plankton is abundant; and in areas affording ready access to water deeper than 25 fathoms.

Summary of recommendations

On the basis of present knowledge, the Bureau recommends as follows:

1. Hatchery production and planting of lake trout in Lakes Huron, Michigan, and Superior must be undertaken as a means of rehabilitating lake trout stocks.
2. Hatchery production should be continued through 10 years. After that time, a decision should be made relative to its future need for maintenance of the lake trout population.
3. Hatchery production should begin in each lake as soon as the sea lamprey control network is completed. The first crop of hatchery fish should be ready for stocking one year afterward.
4. Hatcheries of the Service, the Great Lakes States, and the Province of Ontario should attempt to produce annually: 3,000,000 yearling lake trout for Lake Michigan; 2,500,000 yearling lake trout for Lake Huron; and 2,000,000 yearling lake trout for Lake Superior.
5. Possibilities and methods of importing lake trout eggs from lakes other than the Great Lakes and supervised "spawn fishing" in Lake Superior should be explored thoroughly and applied, if necessary, to insure supplies of eggs.
6. The yearling lake trout should be planted in the spring whenever possible, at several localities in each lake, near known lake trout spawning reefs, in water 10–25 fathoms deep and in areas offering free access to deeper water. If some planting is

done in the fall, water temperatures at the planting site should be below 50°F.

7. At least 10 percent of all lake trout planted should be marked.
8. A comprehensive program of observation and study must be developed to follow the fate of the lake trout after planting.
9. This entire operation must be considered an experiment and must be handled with precision. The program must be flexible to allow changes without disruption should new information call for them.
10. An objective evaluation of established operations must be made at frequent intervals.