LAKE ONTARIO FISHERIES UNIT

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TABLE OF CONTENTS

Section

Lake Ontario Fisheries Unit 1991 Program Summary . . . . 1 - 1

Bay of Quinte Angling Surveys, 1991 . . . . 2 - 1

Outboard Trawling in Eastern Lake Ontario and the Bay of Quinte, 1991 . . . . 3 - 1

Smelt Abundance and Growth in Western Lake Ontario . . . . 4 - 1

Lake Whitefish Early Life History Studies in the Bay of Quinte and Eastern Lake Ontario, 1991 . . . . 5 - 1

Zebra Mussel Monitoring Program on Lake Ontario, 1991 . . . . 6 - 1

Diving Study to Determine Densities of Zebra Mussel in Western Lake Ontario in 1991 . . . . 7 - 1

Potential to Avoid Zebra Mussels . . . . 8 - 1

Radio Biotelemetry Survey of Lake Trout Spawning Sites on Lake Ontario - A Feasibility Study . . . . 9 - 1

Lake Trout Rehabilitation in Lake Ontario, 1991 . . . . 10 - 1

Assessment of the Boat Fishery for Salmonids in Western Lake Ontario . . . . 11 - 1

Hydroacoustics Surveys of Lake Ontario, 1991. A Progress Report . . . . 12 - 1

Alewife and Smelt Abundance Estimates from Midwater Beam Trawl and Hydroacoustic Surveys in Canadian Waters of Lake Ontario, 1991 . . . . 13 - 1

Status of Selected Fish Populations of Eastern Lake Ontario . . . . 14 - 1

Lake Ontario Stocking and Marking Program for 1991 . . . . 15 - 1

Preliminary Report of the Lake Ontario Fall Shore Angler Survey, 1991 . . . . 16 - 1

Trends in Size, Condition and Spawning Time of Coho Salmon in the Credit River, 1977-1991 . . . . 17 - 1

Research Project: Fish Community Dynamics of the Outlet Basin of Lake Ontario . . . . 18 - 1

Research Project: Fish Community Studies of the Bay of Quinte . . . . 19 - 1

Research Project: Variability Associated with Gill Net and Trawl Sampling the Fish Community of the Outlet Basin of Lake Ontario . . . . 20 - 1

Research Project: Development Criteria for Discriminating Among Lake Whitefish Stocks in Eastern Lake Ontario . . . . 21 - 1

Lake Ontario Fisheries Unit
1991 Program Summary

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Introduction

Since 1984, Lake Ontario Fisheries Unit (LOFU) staff have prepared an annual report summarizing work undertaken by Assessment and Research groups during the previous fiscal year (12 month period between April 1 and March 31). The annual report is intended to inform Lake Ontario fisheries managers and scientists of LOFU activities, and to promote cooperation and interaction among these groups. Sections in the annual report are written to highlight information of interest to Lake Ontario fisheries managers; they are not intended to be substitutes for refereed, journal publications. Some projects do not produce immediate results, and it is not possible to report on all our work. The purpose of this introduction is to tie up any loose ends by summarizing tasks and information not presented elsewhere and includes:

1. A summary of Assessment and Research projects, project leaders, and other ongoing activities;
2. A summary of research papers published by LOFU staff during 1991;
3. A report on commercial fishery landings in eastern Lake Ontario; and
4. A list of LOFU staff.

Summary of Assessment Activities During 1991/92.

Six programs involving 17 projects were conducted during 1991/92. A list of project names and associated project leaders is included in Appendix 1. The following summarizes all programs and special projects and, where applicable, refers to appropriate sections in the 1991 Annual Report that provide project details.

Fish Community Indexing

The highest priority for LOFU Assessment is to develop and maintain indices of fish population abundance to detect long-term fish community changes. In 1991, there were six fish community indexing projects. The outboard trawling project (Section 3), designed to index the abundance of small fish in The Bay of Quinte and nearshore habitats of eastern Lake Ontario, was continued in 1991. Smelt bottom trawling, in the western basin of Lake Ontario (Section 4), was again completed successfully in cooperation with the U.S. Fish and Wildlife Service (USFWS), and provides our only long-term index of smelt abundance in western Lake Ontario.

We continue to work towards the development of a lakewide pelagic community indexing program, and successfully completed two important programs in this regard. The first was the midwater beam trawl program, run in conjunction with a hydroacoustic survey, in cooperation with Dr. Steve Brandt of the University of Maryland and graduate students, Andrew Goyke and Doran Mason. Preliminary analysis of these data provides lakewide, regionally specific, estimates of smelt and alewife biomass and examines species-specific selectivity of the beam trawl (Section 13). A second program, in cooperation with the New York Department of Environmental Conservation (NYDEC), completed a lakewide hydroacoustic and trawling survey in each of three seasons; spring, summer and fall (Section 12). Analyses of these data continue as we work to make whole lake pelagic fish community indexing a routine part of our work.

Angler surveys (Section 11), lake trout index gillnetting program (Section 10), and spawning river monitoring programs (Section 17) remain our principal means of indexing salmonine communities in Lake Ontario.

Index gillnetting in eastern Lake Ontario was continued in 1991 and was used, in conjunction with Research trawling and gillnetting projects, to update the status of fish species of particular management interest (Section 14).

Lake Trout Rehabilitation

Lake trout assessment continues to be guided by the "Joint Plan for the Rehabilitation of Lake Trout in Lake Ontario". An updated version of the plan, prepared by OMNR, NYDEC and the USFWS, is currently under review. These agencies participate in a cooperative annual sampling program, collecting data on abundance, survival, and population structure of lake trout and determining sea lamprey impacts (Section 10).

Lake trout sport harvests were monitored during angler surveys in western Lake Ontario (Section 11).

A radio biotelemetry pilot study demonstrated the effectiveness of this technology for learning more about spawning site selection, intensity of use, and timing of egg deposition (Section 9).

During April and May of 1991, emergence traps were placed at Yorkshire Bar in an attempt to catch lake trout fry emerging from this shoal. Despite placement of the traps in specific areas of egg deposition, we failed to capture any emerging lake trout. Further work on Yorkshire Bar by the Assessment group is not planned for 1992.

Salmonid Assessment

Fish stocking statistics for 1991 were compiled and reported (Section 15). The salmonid angling surveys were continued in 1991 (Section 11), including a fall shore fishery survey (Section 16). Bob Lewies and Ann Yagi, of the Niagara District Office, kindly provided historical creel survey data to incorporate into an analysis of angler activity in the lower Niagara River and District shorelines (not reported). With the completion of a lakewide spring shore survey planned for 1992, we can more accurately assess the salmonid stocking program, and quantify the relative magnitude of component fisheries. We continued to monitor biological attributes of coho, chinook, and rainbow trout returning to spawn in the Credit and Ganaraska rivers. Support was provided for Trent University graduate student candidate, Janice Clarkson under the supervision of Dr. Mike Jones, to begin an analysis of the rainbow trout time series. Trends in size of returning coho were also examined (Section 17). Calcified tissue samples collected during angling surveys and monitoring programs will be used to develop techniques to distinguish between fish of native and hatchery origin (see Research summary below).

Lake Whitefish Assessment

The status of lake whitefish populations in eastern Lake Ontario was updated using information from a variety of projects (Section 14). Work on discriminating Lake Ontario and Bay of Quinte whitefish stocks, based on morphological characteristics of calcified structures, continued in 1991 (see Research summary below), and will enhance our ability to manage whitefish stocks. In response to anticipated zebra mussel colonization, a program to monitor growth and feeding of larval whitefish was established in the Bay of Quinte (Section 5). A mark-recapture population assessment program for whitefish was completed in 1991 but has not yet been analyzed.

Walleye Assessment

Trends in walleye abundance in eastern Lake Ontario index gillnets were examined (Section 14), and angling statistics for the Bay of Quinte were summarized (Section 2). A mark-recapture population assessment program for walleye was completed in 1991 but analysis is not complete.

Zebra Mussel Monitoring

We continued to track the colonization of Lake Ontario by the zebra mussel (Section 6). Murray Charlton (Environment Canada, Lakes Research Branch, Burlington) provided additional administrative and technical assistance to this program and completed a complimentary study on zebra mussel depth distribution (Section 8). Samples of zooplankton were also collected to supplement Dr. Ora Johannsson (Department of Fisheries and Oceans, Burlington) biomonitoring program. To allow us to better understand long-term ecological impacts of the zebra mussel, we initiated a program to document their natural densities and distribution (Section 7). This work was a cooperative program with Dr. Norm Rukavina (Environment Canada, Lakes Research Branch, Burlington) and Dr. Robert Bailey (University of Western Ontario, London). LOFU staff have assisted with the development of a provincial zebra mussel monitoring program and hosted a workshop to train other OMNR staff in zebra mussel monitoring and identification techniques.

Other Work Involving LOFU Staff

Periodically, the results from LOFU are published in scientific journals. A list of recent publications of Research and Assessment staff is presented in Appendix 2.

A major accomplishment this year was completion of plans to integrate several index gillnet and trawl programs, formerly designed and administered independently by both the Research and Assessment groups, into one common program (Section 14). Jim Hoyle, Tom Stewart, John Casselman and Dawn Walsh worked together to develop the final design, designated as the "Eastern Lake Ontario Fish Community Index Netting Program". This program is now the sole responsibility of the Assessment group. The new design has resulted in improvements to experimental designs, gear standardization, and eliminated sampling redundancies, while maintaining the continuity and integrity of the historic data series.

The Assessment group also reviewed and updated biological sampling protocols as part of the same process. A major component of biological sampling is the collection and processing of calcified structures to determine fish age. Alastair Mathers led the development of a fish age interpretation plan that identified issues, developed priorities, and should facilitate more timely processing of these materials.

On occasion, LOFU staff are called upon to serve on committees or conduct work outside our normal programs such as fish stocking, collection of fish for contaminant analysis, attending workshops, technical exchanges, or presenting conference papers. Some prominent initiatives in 1991/92 included the following: (1) hosting the Provincial Zebra Mussel Monitoring Workshop, (2) participating in the International Zebra Mussel Conference, and (3) coordinating fish stocking throughout Lake Ontario. A list of all 1992 LOFU staff, and colleagues working at the Glenora station, is presented in Appendix 3.

Commercial Fishing Landings in Lake Ontario, Napanee District

Commercial fish landing statistics are included in this report for reference. During the 1991 calendar year, commercial fishermen reported harvesting a total of 1,212,268 lbs (round weight) of fish with a landed value of $1,003,908.84. A more detailed summary is provided in Appendix 4.

Summary of Research Activities During 1991/92

Research Projects

During 1991-92, four primary research projects were conducted. Three are presented in separate sections of this report: (1) the fish community dynamics of the Outlet Basin (Section 18); (2) the fish community of the Bay of Quinte (Section 19); and (3) sampling variability associated with gill netting and trawling (Section 20 and parts of 19). The fourth project is a study of the factors affecting recruitment of lake trout and the rehabilitation program. The results of this study are not presented in a separate section in this report as in other years, but subsequently in this summary, some of the salient observations will be provided.

Three secondary research studies are under way. One, reported in Section 21, is a study of lake whitefish stocks in eastern Lake Ontario and the development of criteria for discriminating among them. David Brown, a biologist who recently graduated from Trent University, was hired in November to assist in this study. The research was funded through the Zebra Mussel Initiative. Zebra mussel may have a differential impact on the punitive "bay" and "lake" lake whitefish stocks. Only if the stocks can be recognized can any potential differential impact be evaluated.

Another research project, which was partially funded during 1991, involved the development of methods for discriminating among hatchery and native rainbow trout from the natural environment. Lucian Marcogliese, currently a master's student at Trent University, worked for 3 months during the summer on this project. Scale and otolith characteristics are being examined, and characteristics and criteria are being developed and validated. The project, being continued at Trent University for a course credit, is expected to be completed by the end of April 1992.

In recent years, Dr. Don Hurley's research into the diets of fish of the Bay of Quinte has showed that there is a direct relationship between phytoplankton biomass and the biomass of certain fish species and that this is mediated by the diet composition of the fish species. Additional studies on the diet of alewife and white perch were completed in 1991, and two papers were submitted and accepted for publication: (1) "Interactions between alewife (*Alosa pseudoharengus*), their food, and the phytoplankton biomass in the Bay of Quinte, Lake Ontario", accepted by the Journal of Great Lakes Research and authored by R. H. Strus and D. A. Hurley, and (2) "Feeding and trophic interactions of white perch (*Morone* *americana*) in the Bay of Quinte, Lake Ontario" accepted by the Canadian Journal of Fisheries and Aquatic Sciences, authored by D. A. Hurley.

In 1990, COA funds were provided to start collecting data on the scale growth history of white perch, walleye, and lake whitefish by using CSAGES scale growth data collection system and software. Although the primary data collection for white perch was completed, no COA funds were provided for research on Lake Ontario in 1991, so no progress was made in this project. A subsample of scales from 50 to 60 individuals collected during each of the past 30 years has been interpreted in detail. Age determinations will be validated, age-length keys will be constructed, and age will be assigned to length-frequency distributions prepared from combined gill netting and trawl sampling, making it possible to examine changes in growth and relative year-class strength over the years.

Research Personnel, Associations, and Activities

Dr. Mike Jones and the Great Lakes Salmonid Research Unit transferred from the Central Research Station at Maple, Ontario, to the Glenora Fisheries Station in 1991. Les Stanfield and Mike Stoneman also work with the unit, which studies the re-introduction of Atlantic salmon in Lake Ontario and uses Wilmot Creek as a specific study site. A two-way weir is used on the creek to monitor the movement and activity of migrant salmonids. Studies are also being conducted on salmonid ecology and production throughout Wilmot Creek. Mike Jones is also actively involved in modeling predator-prey interactions in the Great Lakes. This work specifically addresses the concern of maintaining an appropriate balance between numbers of stocked predators and natural production of prey species. With Dr. Joe Koonce, he publishes a newsletter on the Sustainability of Intensively Managed Populations in Lake Ecosystems (SIMPLE)--a Task Area of the Board of Technical Experts of the Great Lakes Fishery Commission.

Dr. Steve Campana of the Bedford Institute, Fisheries and Oceans Canada, spent a week in July with John Casselman, working on the final analysis of research they have been conducting jointly on differentiating northern cod stocks of the North Atlantic. The study uses shape analysis of calcified tissue developed over the years by John Casselman and recently converted to an IBM-compatible microcomputer form by Ken Scott. A publication is being prepared describing stock discreteness of North Atlantic cod based on the quantification of otolith shape.

Don Hurley has been active in the development of all phases of the Quinte Remedial Action Plan (RAP). The Stage I document, which outlines the environmental setting and the problems associated with degraded habitat in the Bay of Quinte, is complete and has been accepted by the International Joint Committee. The Stage II document, which will propose the remedial actions to be undertaken, is still in preparation. Several meetings were held in 1991 with the coordinating committee of the Quinte RAP to assist in plans for the Stage II document.

In September, John Casselman was invited to present an overview of his research on age and growth science and technology to the statewide multidiscipline research meeting held every two years by the State of Wisconsin. The meeting was held at Cable, Wisconsin, and the presentation was entitled "Age and Growth Determination of Fish--the Age-Old Problem".

In 1991, John Casselman completed a manuscript on the study he has been conducting for several years with John Gunn, OMNR Cooperative Fisheries Unit, Laurentian University, Sudbury. It was submitted to the Canadian Journal of Fisheries and Aquatic Sciences for inclusion in a special publication documenting the Sudbury Environmental Study. The paper is entitled "Response of a native lake trout population to whole-lake neutralization--changes in year-class strength, growth, and calcified-structure size" and examines the dynamics of the lake trout population of Nelson Lake over a 16-year period and relative strength of year-classes over a 21-year period.

John Casselman was asked to participate on the steering committee of an international symposium on fish otolith research and applications that will be held in January 1993 in South Carolina. The convenors, Drs. Steve Campana and John Dean, with the 10-member steering committee representing five countries, are organizing this 4-day symposium along several major themes: otolith growth, morphology and the estimation of fish growth; otoliths in studies of population biology; and otolith composition as an index of environmental history.

In 1991-92, John Casselman and Don Hurley reviewed and refereed 14 manuscripts for primary journals. Eight of these manuscripts pertained to age-growth research. Additional research proposals were reviewed for major granting agencies; two came from the National Science Foundation in the United States and were studies of calcified tissue associated with age-growth research.

Research Involvement With College and University Studies and Graduate Programs

John Casselman continued in his capacity as a research associate at the Royal Ontario Museum and as a conjunct professor at Trent University, where he presides on graduate committees and supervises one graduate student, Lucian Marcogliese, who is working on a research project on fish communities in oligotrophic lakes of the Haliburton Highlands.

Paul Anderson, a master's degree candidate at Trent University who used the aquatic facilities at the Glenora Fisheries Station in 1990, is completing his dissertation for submission. John Casselman is on his graduate student advisory committee; Dr. Tom Whillans is supervisor. Behaviour of juvenile northern pike in relation to type and density of vegetative habitat was studied at the station. Fish were collected from tributaries and marshes in eastern Lake Ontario. The study is entitled "Adaptation of a habitat suitability model for prioritizing habitat rehabilitation needs of northern pike (*Esox lucius*)".

Mike Mallette, a graduate student in a master's program supervised by Dr. John Gunn at Laurentian University, Sudbury, spent several months at the Glenora Fisheries Station preparing and interpreting otolith samples from brook trout from the Sutton River in northern Ontario. This study examines the movements of brook trout in the Sutton River to determine whether certain fish migrate and spend part of their life in James Bay. John Casselman is an advisor on this master's program and has assisted by obtaining brook trout data from the Quebec government and fish otoliths collected from the east side of Hudson Bay. Otolith techniques are being applied to develop methods for recognizing whether sea-run brook trout can be recognized and their migratory chronology verified and recognized. Chemical analyses will also be included.

John Casselman presided on the examining committee of Scott Finucan's defence of his master's thesis. The thesis, which was accepted, was a study of drift of larval walleye at one of the major spawning grounds in the Trent-Severn Waterway. John Casselman also was asked to be on the examining committee of Paul Kaseloo's defence of his master's thesis at Scarborough College, University of Toronto. He successfully defended his thesis, "Development and application of a new radiotelemetry system monitoring activity by means of axial muscle electromyograms". This system has direct applications for quantifying activity of fish in the natural environment.

Andrea Brown, fourth-year student, Department of Zoology, University of Toronto, completed her course project for Zoology 498Y. John Casselman acted as project advisor. The undergraduate thesis was entitled "Age composition, and growth and mortality rates for a northern population of lake trout *Salvelinus namaycush* from Alaska". John Casselman has been asked to advise on Robert Neumann's Ph.D. program at South Dakota State University. The thesis problem involves seasonal variations in growth, movement, activity, and habitat use by northern pike.

John Casselman presented the age-growth lecture and a laboratory on the science, technology, and fisheries applications of age and growth studies to the undergraduate and graduate Ichthyology courses (ZOO 498Y, Department of Zoology, University of Toronto).

Age-Growth and Environmental Studies Research Program

Although some age-growth research is conducted specifically on problems associated with Lake Ontario (see preliminary report, Section 21), several studies are being conducted with data and samples from other locations. However, in 1991-92, only a very limited amount of provincial age-growth research was conducted because only two months of technical support was dedicated to this work through the Lake Ontario Fisheries Unit.

Jim Johnson and John Webber, of the Michigan State Department of Natural Resources at the Alpena Great Lakes Fisheries Research Station, have consulted with John Casselman concerning the development of otolith marking techniques for differentiating between indigenous walleye and those of hatchery origin. This involves using criteria for recognizing "stocking checks" in the otolith microstructure as well as using direct marking with stable strontium chloride. These methods are routinely used in the walleye stocking assessment program conducted by Eastern Region, OMNR. The Michigan researchers also spent time at the Glenora Fisheries Station in consultation with John Casselman as well as Joe Dibbits, who is specially trained in this type of interpretative technology. They plan to use this otolith technology to assess the intensive walleye stocking and rehabilitation program that is being conducted on Saginaw Bay, Michigan.

Smelt collected from the Outlet Basin during June 1991 were supplied to Dr. Eric Taylor of the Pacific Biological Station at Nanaimo. He is studying the geographic origins of smelt in eastern North America by using mitochondrial DNA and is specifically interested in tracing the genetic links of Lake Ontario smelt.

In 1991, several age-growth problems that were of concern to others were examined in some detail. For example, Northeast Region, OMNR, had problems with age interpretation of rainbow trout by the scale method. Lucian Marcogliese examined the photographs that were supplied and provided reliable age and growth interpretations through CSAGES software. Kirkland Lake District, OMNR, had samples of walleye collected from lakes that had been stocked through CFIP programs and needed assistance in applying stock discrimination by using otolith methods. Joe Dibbits examined samples, resolved the interpretation problems, and assigned origin for a sample of fish from several different lakes. Personnel with the Fisheries Section of Renewable Resources Branch of the Yukon government in Whitehorse requested assistance with age determination of humpback whitefish. They sent otolith samples, and David Brown, who has been studying lake whitefish otoliths from Lake Ontario, examined the samples and confirmed, using methods that have been developed for age interpretation of very old fish, that individual humpback whitefish are from 30 to 40 years old.

Ken Scott has worked on refining and improving the software package that has been developed to extract data from age and growth interpretations of calcified tissue. The development of the basic system, which is called the Calcified Structure Age and Growth data Extraction System, is near completion. A technical manual still needs to be prepared to support the software. The system interfaces a computer and a digitizer and permits the interpretation of checks and zones in fish calcified tissue to be fully recorded and quantified so that age determination problems can be easily and systematically recognized and solved. The basic data collection package is used routinely at the Glenora Fisheries Station, and now that it is possible to store the details of age interpretations by computer and to recall them for subsequent examination, much of the ambiguity and imprecision have been removed from this very basic technology. Therefore, the interpretation of fish calcified tissue can now be performed by private contract because all the appropriate details of the interpretation are stored and can be recalled and reviewed. Several copies of the software have been disseminated to those who routinely conduct age interpretations. This has been done to test the system, its software, and hardware installation. Several graduate students are currently using the package to collect data, and Susan Mann, who conducts and supervises routine age and growth interpretation for Northwestern Region, OMNR, is collecting routine data with the system.

A study of age determination, growth, and stock discreteness for sculpin in Lake Ontario has been initiated in collaboration with Randall Owens of the U.S. Fish and Wildlife Service, Oswego, New York. However, progress has been slow because dedicated technical assistance has not been available or able to be applied to this particular study.

Lake Trout Rehabilitation Research Studies Conducted in 1991/92

In the spring of 1991, the incubators that had been installed with lake trout eggs the previous fall on Yorkshire Bar and were also held in the laboratory at Glenora were removed, opened, and examined in detail as in previous years. Most of the preliminary observations associated with this incubation study were in the 1991 report. Analysis of the spring results is currently being conducted and will not be presented at this time. Lake trout rehabilitation research also continued to examine nursery habitat southeast of Main Duck Island. However, only gill netting of this habitat was conducted. Trawling was not done because sampling had to be deferred until September and weather conditions did not permit the work until temperatures were too low, making sampling of the habitat incomparable with other years, and during a time when yearlings would no longer be restricted to this deepwater nursery habitat.

An *in situ* incubation study was again planned for Yorkshire Bar but with a change in design so that the eggs could be installed earlier and later in the spawning season. Control samples from Lake Manitou were also included, and some of these controls were to be held at the Glenora Fisheries Station, and some were to be exchanged with eggs and incubators on the bar over a period that would encompass the entire spawning period. However, because of unpredictable weather conditions, Operations were able to visit the bar only twice during the spawning period--once relatively early and once late. During the early visit, eggs from Lake Manitou lake trout, which were in incubators, were installed in the rubble at the standard incubation location and egg deposition traps were installed in the rubble. During the late visit, there was just enough time to exchange incubators with those held at the Glenora Fisheries Station and to remove the egg deposition traps. There was not enough time to attempt to collect a sample of Lake Ontario lake trout to provide eggs and sperm for parallel incubation of Lake Ontario and Lake Manitou eggs. This was the first time since 1987, when the fall lake trout study on Yorkshire Bar was resumed that lake trout eggs were not obtained. This meant that the *in situ* incubation study on Yorkshire Bar and at the Glenora Fisheries Station, which is still under way, has only eggs from Lake Manitou lake trout. Since this study is not complete, the results will not be reported at this time.

In the fall, newly fertilized samples of eggs collected from lake trout caught at spawning time inshore near the upper gap were shipped to Dr. Patrick Guiney and Dr. Richard Peterson of the University of Wisconsin to study the effect of dioxins, furans, and coplanar PCBs on the survival and development of eggs and fry of Lake Ontario lake trout.

It is apparent from the logistical problems in 1991 that Yorkshire Bar is an inappropriate location for studying *in situ* incubation, of lake trout eggs, especially when it involves exchange of incubators several times during the spawning season. Weather conditions are simply too unpredictable; this interferes with sampling design. For this reason, in 1991 a contract was issued to Integrated Explorations of Guelph, Ontario, to examine other potential inshore spawning sites in eastern Lake Ontario. These sites were historic spawning areas of native lake trout before their demise in the mid-1940s.

The study was completed and involved the following: (1) six potential spawning sites were visited near shore in the Outlet Basin; (2) the spawning habitat was generally described; (3) short-term gill net sets were made, and ripe and running female and male lake trout were collected at five of the six sites; (4) eggs were fertilized from 17 different females and were transported to Glenora Fisheries Station, where they are being held to study hatch, survival, and development; (5) biological data were collected on a subsample of up to 40 lake trout from each site; (6) dives were conducted at each of the five sites where ripe and running adults were collected; and (7) egg surveys were conducted. Some important observations are apparent. These will be used in a revaluation of current sampling design and study site location. Naturally deposited lake trout eggs were discovered at Salmon Island. This was reassuring, since this site had already been considered to be the best possible inshore study site to replace Yorkshire Bar; it was considered one of the best historic inshore spawning sites. The survey proved that lake trout eggs are being widely deposited in the inshore waters of the Eastern Basin of Lake Ontario because in every sample, from 6 to 13% of the fish taken at these locations had eggs in their stomachs.

In recent years, it has been routine to set aside unmarked lake trout from gill netting and trawling and to study them in detail to determine whether they were hatchery fish that had been inadvertently released unmarked, whether the mark had become obscured by growth, or whether they were truly indigenous, indicating that rehabilitation was being realized. During routine sampling conducted by the Lake Ontario Fisheries Unit in 1991, 40 lake trout appeared to be unclipped or unmarked. A detailed examination was conducted of the fins, scales, and otoliths of these fish for characteristics that have been shown to differentiate between indigenous fish and those of hatchery origin. All were shown to have more than a 20% chance of being of hatchery origin, so none were classified as indigenous (Fig. 1). Although a few indigenous lake trout were collected in former years (three in 1990 and four in 1989), none were found in the 1991 sample.

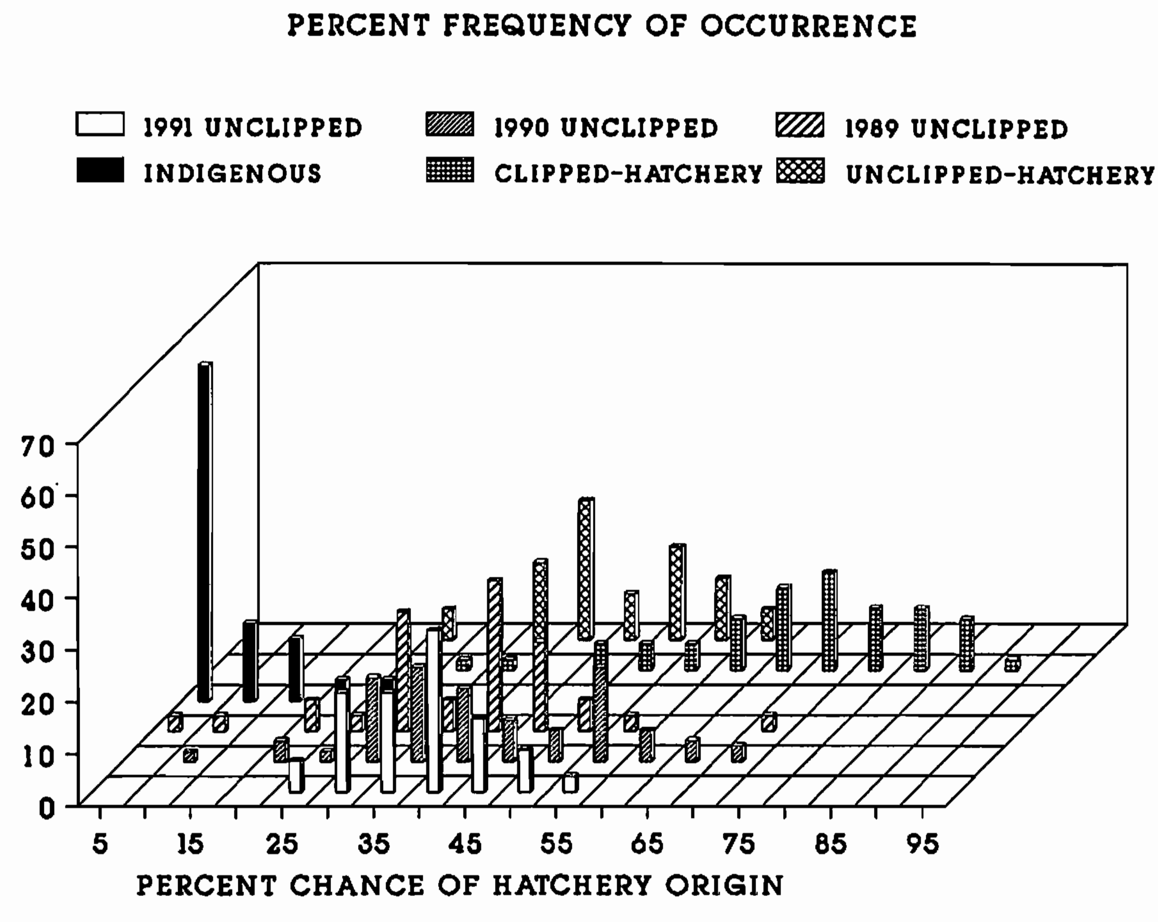

FIG. 1. Percent frequency of occurrence of the distribution of the percent chance of hatchery origin for samples of unclipped lake trout that were caught in OMNR Research and Assessment and NYDEC sampling programs during 1991 (N = 40), 1990 (N = 49), and 1989 (N = 35). These distributions are illustrated, along with the distributions of three sets of control samples: (1) 26 lake trout from an inland lake that were known to be indigenous; (2) 33 unmarked lake trout from an inland lake that were known to be of hatchery origin; and (3) 58 lake trout from Lake Ontario that were fin clipped and of hatchery origin.

Criteria used for determining percent chance of hatchery origin involved three sets of diagnostic characteristics: (1) relative size and shape of the fins and number of rays; (2) degree of optical contrast and abnormal morphology of the otolith; and (3) type and spacing of circuli and relative location and conspicuousness of checks associated with the first annulus and the stocking check on the scales. If a fish was assigned as having less than a 20% chance of being of hatchery origin, it was considered to be indigenous since no unmarked or clipped hatchery fish fell in this category. When using the 20% level of separation, it is possible that some lake trout in the 20 to 25% chance range might be indigenous and might be inadvertently overlooked, since a few indigeous fish (4%) in the test group were classified in this range. More particulars on this diagnostic technique are found in: Casselman, J. M. 1991. Lake trout rehabilitation studies. *In* Lake Ontario Fisheries Unit, 1990 Annual Report, LOR 91.1, (Chapter 24). Ontario Ministry of Natural Resources, Picton, Ontario.

Research Role and Future Direction

Traditionally, Research on Lake Ontario has maintained long-term sampling programs and through these has studied the fish community of the Bay of Quinte and the deep waters of the Outlet Basin of Lake Ontario. These community index programs have run for 31 years in the case of gill netting and 20 years for trawling. It is inappropriate for Research to continue such an extensive "index sampling program" given the implementation of the Assessment Unit concept in the Strategic Plan for Ontario Fisheries. The continuation and maintenance of such indexing programs fall within the mandate and responsibility of Fisheries Assessment Units and furthermore, in recent years almost the entire Research budget has been used to continue the index sampling effort. During 1991, numerous meetings were held among the OMNR Research, Assessment, and Management groups involved with Lake Ontario concerning the transfer of this responsibility and the design of an overall index sampling program for the fish communities of eastern Lake Ontario. It was agreed that the responsibility for routinely sampling the Bay of Quinte and the deep waters of the Outlet Basin would be officially transferred to Assessment in 1992. There was much mutual agreement in the entire process, including the final design of the overall index program, which will provide appropriate continuity for the long and historic research data series that has been accumulated over the past three decades. The integrated sampling program, which uses many of the same Research sampling locations and designs, will bring together the best of the past so that it can be related to and used in the future in a broad indexing program that is more extensive and meets everyone's general needs, yet is adequately quantitative and addresses community sampling objectives. Research continues to have interest in these indexing programs and will continue to analyze the historic along with present (Sections 18 and 19) and future data because by virtue of their relative consistency and rigour, they will permit tests and provide broader explanations of more specific results obtained from future research studies, which will be shorter-term, more precise, and focused on specific problems and processes. Particulars concerning alterations in the Research sampling series in the new overall indexing program are not provided here but are available in various documentation and will be apparent in the future. One reference document dealing specifically with the transfer is:

Casselman, J. M., and D. A. Hurley. 1991. Lake Ontario Fisheries Research long-term fish sampling programs: Bay of Quinte and the deep waters of the Outlet Basin. Review of these programs as index sampling series and a plan for transfer of the responsibilities for continued sampling for these two long-term 30-year Research series to the Lake Ontario Fisheries Assessment Unit and the Lake Ontario Indexing Program. Unpublished OMNR Research report, 16 p.

The new indexing program will incorporate monofilament gill nets. For this reason, Research is conducting a study on differences between the catches of monofilament and multifilament gill nets in sampling the Outlet Basin and the Bay of Quinte in midsummer. Various aspects of this study are reported in Sections 18 and 19, and some additional sampling will be conducted in 1992 to complete the data requirement of the study.

Research that will be initiated in 1992 will follow the recommendations of the review of fisheries research needs for Lake Ontario that was conducted in 1990. The two most important research problems were determining and quantifying the factors that (1) affect and limit rehabilitation of lake trout stocks in Lake Ontario and (2) affect year-class strength of the most important sport and commercial species in the Bay of Quinte and the Outlet Basin of Lake Ontario. The first will continue to be addressed in 1992 through studies of spawning and early life history of lake trout, while the second will involve two new studies concerning the seasonal movement of fish between the Outlet Basin and the Bay of Quinte and will incorporate trawling and hydroacoustics.

Acknowledgments

Thanks to Linda Balsillie and Carol Ward for copy editing and production of this report. Additional administrative and clerical assistance was provided by Herta Jorens and Marilyn Beatty of the Aurora Office.

APPENDIX 1. Programs conducted by the Lake Ontario Fisheries Unit between April 1, 1991 and April 1, 1992.

ASSESSMENT PROGRAMS

Fish Community Indexing

Outboard trawling
Project Leader: Jim Hoyle

Alewife/smelt midwater beam trawl survey
Project Leader: Alastair Mathers

Western basin smelt bottom trawling (USFWS/OMNR)
Project Leader: Jim Bowlby

Hydroacoustics and trawling survey (NYDEC/OMNR)
Project Leader: Ted Schaner

Eastern Lake Ontario assessment index gillnetting
Project Leader: Jim Hoyle

Lake Trout Rehabilitation

Radio biotelemetry pilot study
Project Leader: Tom Stewart

Yorkshire emergence traps
Project Leader: Tom Stewart

Cooperative lake trout gillnetting (NYDEC/OMNR/USFWS)
Project Leader: Ted Schaner

Salmonid Assessment

Salmonid boat angler survey
Project Leader: Jim Bowlby

Fall shore angler survey
Project Leader: Paul Savoie

Lake Ontario, Lower Niagara River
Shore Angler Survey Analysis
Project Leader: Paul Savoie

Charter boat survey
Project Leader: Jim Bowlby

Credit River coho/chinook monitoring
Project Leader: Jim Bowlby

Ganaraska River rainbow trout monitoring
Project Leader: Jim Bowlby

Lake Whitefish Assessment

Lake whitefish early life history monitoring
Project Leader: Jim Hoyle

Lake whitefish mark-recapture
Project Leader: Alastair Mathers

Walleye Assessment

Bay of Quinte creel surveys
Project Leader: Alastair Mathers

Walleye mark-recapture
Project Leader: Alastair Mathers

Zebra Mussel Monitoring

Zebra mussel invasion monitoring
Project Leader: Ted Schaner

Zebra mussel density survey
Project Leader: Ted Schaner

Special Projects

Integration of the eastern Lake Ontario fish community index netting programs
Project Leader: Jim Hoyle

Fish age interpretation plan
Project Leader: Alastair Mathers

RESEARCH PROGRAMS

Fish community dynamics of the Outlet Basin of Lake Ontario
Project Leader: Dr John Casselman

Fish community studies of the Bay of Quinte
Project leader: Dr. Don Hurley

Sampling variability of the fish community of the Outlet Basin
Project Leader: Dr. John Casselman

Lake trout rehabilitation studies
Project Leader: Dr. John Casselman

Diet studies of fish of the Bay of Quinte
Project Leader: Dr. Don Hurley

Lake whitefish stock discrimination studies
Project Leader: Dr. John Casselman

Discrimination between hatchery and native rainbow trout
Project Leader: Dr. John Casselman

Development of a calcified structure age and growth data extraction system (CSAGES)
Project Leader: Dr. John Casselman

APPENDIX 2. Research papers published by LOFU staff during 1991.

CASSELMAN, J. M., T. C. L. PENCZAK, R. H. K. MANN, J. HOLCIK, AND W. A. WOITOWICH. 1990. An evaluation of sampling methodologies for large river systems. Polskie Archiwum Hyrdobioligii 37(4):523-553 (Published 1991).

JONES, M. L., C. K. MINNS, D. R. MARMOREK, AND K. J. HELTCHER. 1991. Assessing the potential extent of damage to inland lakes in eastern Canada due to acidic deposition. IV. Uncertainty analysis of a regional model. Can. J. Fish. Aquat. Sci. 48:599-606.

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STRIDE, F., M. GERMAN, D. HURLEY, S. MILLARD, K. MINNS, K. NICHOLLS, G. OWEN, D. POULTON, AND N. DE GEUS. 1992. An overview of the modeling and public consultation processes used to develop the Bay of Quinte Remedial Action Plan. *In* Under RAPs., J.H. Hartig and M.A. Zarull (ed.), Chapter 8, p. 161-183, University of Michigan Press, Ann Arbor.

APPENDIX 3. LOFU staff in 1991.

Operations staff at Glenora

Dave Jeffrey, Operations Supervisor
John Kinney, Administrative Clerk
Carol Ward, Secretary/Administrative Support/Library
Linda Balsillie, Secretary/Reception/Administrative Support
Ken Scott, Computer Systems and Database Manager
Kelly Sarley, Data Entry
Dawn Walsh, Senior Technician-Field Operations
Chuck Wood, Senior Technician-Marine Service
Wayne Miller, Senior Technician-Base Operations
Jeff Church, Age Determination Technician
Dale Dewey, Technician
Steve Lawrence, Technician
Tim Shannon, Technician
Joe Dibbits, Technician
Steve Welham, Technician
Terry Cronin, Technician
Randy Gurnsey, Technician
Ambrose McCambridge, Technician
Tom Lawrence, Technician
Alan McIntosh, Boat Captain
Marianne Schwartz, Technician
Andy Cook, Technician
Elaine Sheriff, Technician
Jeff Farrington, Technician
Brian Hache, Technician
Shane Lockwood, Technician
Vaughan Jamieson, Maintenance Technician

Fisheries Research Staff at Glenora

Dr. John Casselman, Senior Research Scientist
Dr. Don Hurley, Research Scientist
David Brown, Research Project Biologist
Lucian Marcogliese, Research Project Biologist
Dr. Mike Jones, Research Scientist (Salmonid Unit)
Les Stanfield, Senior Research Technician (Salmonid Unit)
Mike Stoneman, Research Technician (Salmonid Unit)

Fisheries Policy Branch Staff at Glenora

Cheryl Lewis, Warmwater Fisheries Specialist

Assessment Staff at Glenora

Tom Stewart, Assessment Supervisor
Jim Hoyle, Assessment Biologist
Alastair Mathers, Assessment Biologist
Ted Schaner, Assessment Biologist

Assessment Staff at Aurora

Jim Bowlby, Assessment Biologist
Paul Savoie, Assessment Biologist
Pat Dimond, Assessment Biologist
Sandra Michaelsen, Technician
Kimby Barton, Technician
Keith Symington, Technician
Tim Cooey, Technician
Carson Jones, Technician
Mary McKay, Technician
David Briggs, Technician

Other

Significant clerical support was provided by Central Region, Aurora, Fish and Wildlife clerical staff Marilyn Beatty, Ann Ciniglio, and Herta Jorens.

APPENDIX 4. Commercial fish landings in Lake Ontario, Napanee District (excludes St. Lawrence River and western Lake Ontario landings). Prepared by Peter Mabee, Napanee District.

	1991 Harvest (lbs)	Price per lb (dollars)	1991 Value (dollars)
Bowfin	3,143	0.24	753.90
Bullhead	221,239	0.35	77,433.65
Carp	70,380	0.33	23,225.40
Catfish	25,668	0.31	7,957.08
Crappie	12,463	1.49	18,554.38
Drum	28,952	0.17	5,020.13
Eels	213,202	1.37	292,709.19
Lake herring	9,126	0.47	4,305.25
Lake whitefish	262,758	0.74	193,595.59
Rock bass	12435	0.29	3,620.15
Sunfish	51,103	0.35	18,118.60
Suckers	2,441	0.12	304.35
White bass	9,032	0.77	6,921.65
White perch	58,152	0.41	23,911.16
Walleye	25,179	1.43	30,559.06
Yellow perch	206,995	1.43	296,919.38
Total	1,212,268		$1,003,908.84

Bay of Quinte Angling Surveys, 1991

A. Mathers

Ontario Ministry of Natural Resources
Lake Ontario Fisheries Unit
R.R.#4, Picton, Ontario - K0K 2T0

Lake Ontario Fisheries Unit, 1991 Annual Report, Section 2

The walleye angling fishery in the Bay of Quinte has never been larger or more productive. Combined ice and open-water angling effort (882,337 rod-hours) and walleye harvest (220,608 fish) are both at all time highs. The open-water fishery is still much larger than the ice fishery; representing 74% of the angling effort and 85% of the walleye harvest. Walleye harvest rates (HUE) for both the ice or the open-water fisheries were the highest observed since the early 1980's.

Recommendations

Maintain current index survey design provided the complete open-water and ice fishing surveys can be conducted during 1993.

Introduction

Angling surveys have been conducted on the Bay of Quinte periodically since 1957 (Hoyle and Mathers 1991). Traditionally, walleye make up the bulk of the angling harvest. Fishing pressure on the Bay of Quinte was minimal when walleye populations were very low in the late 1960's and 1970's and no angling surveys were conducted at that time. With the resurgence of walleye since 1978 (Bowlby et al. 1991), a large sport fishery has once again developed on the Bay of Quinte. This report summarizes the results of the 1991 ice and open-water angling surveys on the Bay of Quinte and provides comparative data from previous years.

The Lake Ontario Fisheries Unit has monitored the Bay of Quinte ice fishery biennially from 1982 to 1988 and annually since 1988, and has monitored the open-water fishery annually since 1979. Survey designs are framed around the walleye open-season. Bay of Quinte angling surveys are designed to estimate angling effort, catch, harvest, and to collect biological data on sport fish populations. Sampling, like the fishery itself, focuses on walleye.

During 1991, the walleye season in the Bay of Quinte was closed from March 1 until May 3, inclusive. There was a four fish daily bag limit with no restrictions on the size of fish harvested. Anglers were allowed to fish with two lines during the ice fishery and one line during the open-water fishery.

Methods

The basic design and analysis of 1991 ice and open-water angling surveys on the Bay of Quinte were conducted using CREESYS (Lester and Trippel 1985). The angling surveys were stratified by day-type (workdays and non-workdays), and season (open-water survey only, see below). Also, the surveys covered the Bay of Quinte from Trenton to Glenora and included 12 geographic areas (Fig. 1).

Ice Fishery Angling Effort

Angling effort was measured using aerial counts. During each flight "on-ice" anglers and fish huts were counted separately for each of the 12 geographic areas. Two flights were scheduled for each week, one weekend day and one weekday. Twenty-four flights were scheduled between December 8, 1990 and February 27, 1991. Very little ice fishing occurred prior to December 25, 1990 because of the poor ice conditions; therefore the five flights scheduled for this time period were cancelled. Three other flights were cancelled due to inclement weather. All angling was assumed to occur between 0700 and 1700 h.

Ice Fishery Angling Catch and Harvest

Angler interviews and hut occupancy counts were conducted on Big Bay only (areas 32 and 33, Fig.1). The "on-ice" surveys were conducted twice each week, one weekend

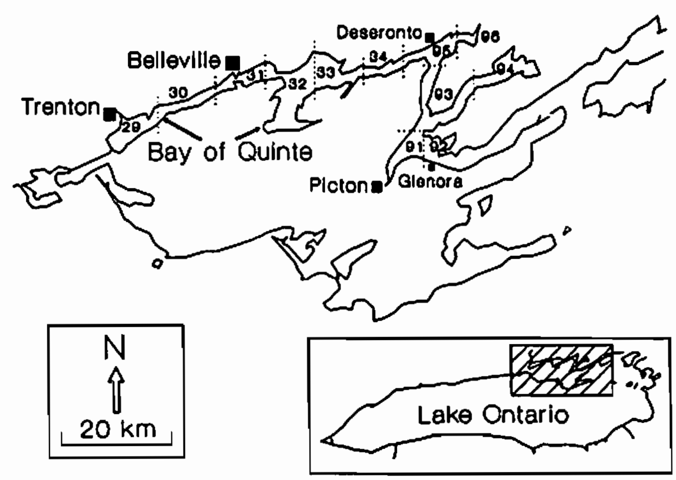

FIG. 1. Twelve geographic areas used in the 1991 Bay of Quinte angling surveys (29-Trenton, 30-Makatewis Island, 31-Belleville, 32-Point Anne, 33-Trident Point, 34-Telegraph Narrows, 95-Deseronto, 96-Napanee River, 93-Long Reach, 94-Hay Bay, 92-Baggot's Bay, 91-Picton Bay.

day and one weekday, between January 3 and February 27, 1991. The estimated catch and harvest of walleye in Big Bay were expanded to determine the walleye catch and harvest for the entire Bay of Quinte based on the geographic pattern of fishing success observed during the 1989 ice fishing survey (Table 1). Fork length and scale samples were collected for all fish observed, weather permitting.

Open-water Fishery Angling Effort

In recent years, an index survey has been used to assess the open-water fishery. Index surveys involve monitoring some seasons of the open-water fishery and expanding the results, based on patterns of fishing observed in years of complete survey coverage.

The 1991 open-water angling survey was conducted from May 4, the opening-day of the walleye season, to June 2 and again from June 24 to July 21. These time periods correspond to three of the six open-water survey seasons defined by Mathers and Bowlby (1990) (Table 2). All angling was assumed to occur between 0700 and 2000 h on the opening weekend and between 0700 and 2100 h for the remainder of the survey.

Angling effort was determined by a combination of aerial and 'on-water' boat counts. Aerial counts were made during the opening weekend (eight flights), each weekend in the May/June season (eight flights), and the July 1 long weekend (two flights). None of the scheduled flights were cancelled due to inclement weather.

On-water boat counts were made during weekdays in the May/June season (2/wk) and for all of the July season (4/wk - two each for weekend days and weekdays) - except for the July long weekend. To facilitate the on-water boat surveys, the 12 sampling areas were divided into two groups (upper bay = areas 29, 30, 31, 32, 33, 34 and lower bay = areas 91, 92, 93, 94, 95, 96) such that one of the two groups was covered during each on-water boat count.

Open-water Angling Catch and Harvest

Angler interviews were conducted on all areas to estimate species-specific catch and harvest rates and to collect biological data on major sport fish populations. During the opening weekend, fork length-tally information was collected for all walleye observed. Thereafter, biological sampling included a fork length and scale sample for age interpretation from a random sample of walleye. Walleye greater than 9-yr-old were grouped into one category because of the difficulty of age interpretation using scales from these older fish. Length-tally information was collected for all other species observed in the anglers harvest. The number and approximate size of all walleye released by anglers was also recorded. Anglers were shown actual size illustrations of 1-, 2- and 3-yr-old walleye and asked to estimate which illustration most closely corresponded to the size of each fish released.

Results and Discussion

Ice Fishery Angling Effort

Angling effort during the 1991 ice fishery (January 2 to February 28, 1991) was estimated at 230,188 rod-hours (Table 3). There has been a relatively consistent increase

TABLE 1. Ratio of walleye CUE and HUE by all 'on-ice' and ice hut anglers in the Big Bay area (areas 32 and 33) vs. those of anglers in all other areas (based on data from the 1989 ice fishery).

Angling mode	Ratio CUE	Ratio HUE
On-ice	0.871	1.027
Ice hut	0.559	0.773

TABLE 2. Description of seasons used in the open-water angling survey. Only the opening weekend, May and July seasons were sampled. The other seasons were extrapolated using expansion factors (shown) based on the seasonal pattern of angling effort (rod-hours), walleye catch and walleye harvest observed in 1988.

Season	Effort	Catch	Harvest
Opening weekend (May 4 to 5)	0.176	0.073	0.100
May = May 6 to June 2 (next four weeks)	0.330	0.452	0.409
June = June 3 to June 23 (remainder of June)	0.073	0.047	0.041
July = June 24 to July 21 (week including July 1 + next three weeks)	0.150	0.262	0.263
Aug. = July 22 to Sept. 2 (remainder of July to Labour Day)	0.196	0.129	0.156
Fall = Sept. 3 to Nov. 31 (remainder of Sept. to end of Nov.)	0.076	0.038	0.031

TABLE 3. The estimated angling effort (rod-hours), walleye catch and walleye harvest for the 1991 angling surveys on the Bay of Quinte.

Season[a]	Angling effort	Walleye catch	Walleye harvest
Ice Fishery	230,188	41,204	32,111
Open-water Fishery			
Opening weekend	99,014	27,530	18,910
May	239,087	201,700	101,565
June[b]	49,341	15,869	7,756
July	82,660	38,781	25,095
August[b]	131,323	43,381	29,385
Fall[b]	50,723	12,658	5,787
Open-water Total	652,149	339,919	188,497
Annual Total	882,337	381,123	220,608

[a]See Table 2 for definition of seasons.
[b]Estimate based on the seasonal pattern observed in 1988.

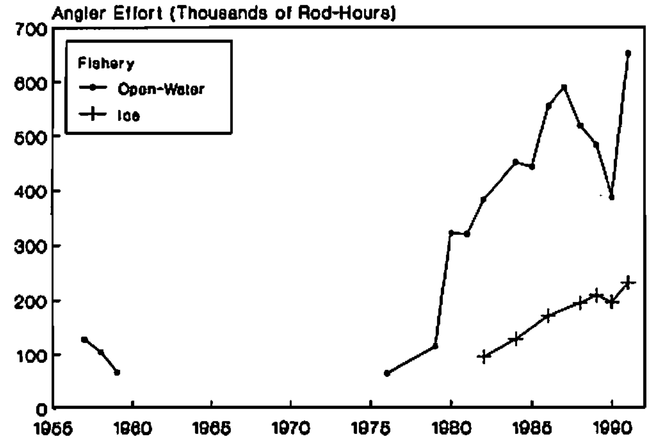

FIG. 2. Angling effort (rod-hours) during the Bay of Quinte ice and open-water fisheries from 1957 to 1991.

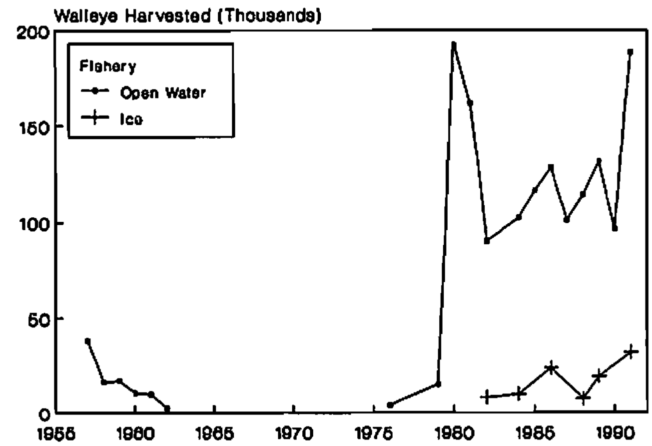

FIG. 3. Walleye harvest during the Bay of Quinte ice and open-water sport fisheries from 1957 to 1991.

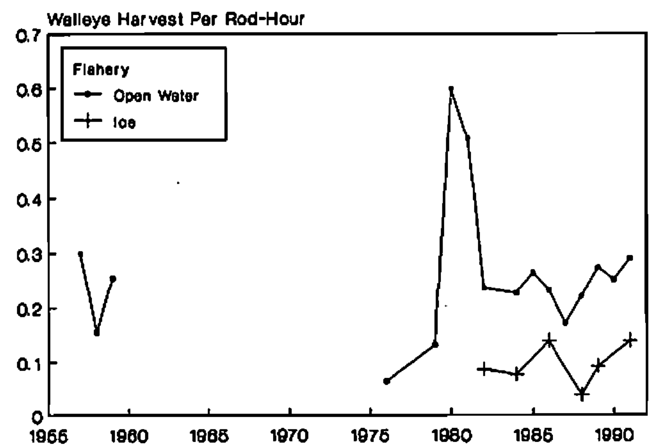

FIG. 4. Walleye harvest per rod-hour of angling effort during the Bay of Quinte ice and open-water fisheries from 1957 to 1991.

in the annual ice fishing pressure since the early 1980's (Fig. 2).

Estimates from most previous years were based on fishing during January and February only, fishing effort in December being considered negligible due to poor ice conditions. During this past winter there was very little fishing until the last week of December. Based on one count December 27 there was probably less than 10,000 rod-hours of fishing effort during December 24 to January 1, which is 4% of the effort observed during January and February.

The highest "on-ice" angling effort occurred in the area including Long Reach, while significant fishing pressure also occurred at Trident Point, Point Anne, Belleville and Deseronto (Fig. 1). As in previous years, the highest numbers of ice huts were in the areas between Trenton and Trident Point. The numbers of ice huts in the Long Reach area increased substantially over previous surveys. Angling effort in our index survey area (Trident Point and Point Anne areas) represented 28% of the total fishing effort in all of the Bay of Quinte. This is similar to the proportions observed in other years. "On-ice" anglers and ice hut anglers accounted for 52 and 48% of the total angling effort, respectively.

Ice Fishery Angling Catch and Harvest

The estimated catch and harvest of walleye for the entire Bay of Quinte were 41,204 and 32,111, respectively, for the January 2 to February 28, 1991, time period (Table 3). The level of harvest is slightly higher than observed in any previous year (Fig. 3). The estimated catch-per-unit-effort (CUE) and harvest-per-unit-effort (HUE - number-per-rod-hour) by walleye fishermen were 0.179 and 0.139, respectively. The harvest rate is high relative to previous surveys (Fig. 4).

Our angling survey did not include walleye catch and harvest estimates for the fishing effort observed in December 1990. Catch rates are generally higher early in the ice fishing season. However, the small quantity of angling effort during December 24 to January 1 probably resulted in a relatively small harvest.

Yellow perch, northern pike, rainbow trout, and lake trout were also present in the catch and harvest of anglers on Big Bay (Table 4). Yellow perch were particularly abundant as in previous years.

Open-water Fishery Angling Effort

Angling effort for the open-water fishing season was 652,149 rod-hours (Table 3). The past three years have shown a decline in the open-water angling effort, however, this year's estimate represents a return to the levels observed during 1986 and 1987 (Fig. 2). Fishing pressure, in all seasons sampled, increased over 1990 estimates.

The low angling effort in 1990 was attributed, in part, to poor weather conditions (Hoyle and Mathers 1991). During the 1990 open-water survey, 38% of the days sampled were judged by survey technicians to have weather conditions that would adversely affect fishing pressure compared to only 16% during the same time period in 1991. The better weather during the 1991 survey no doubt contributed to the increase in fishing effort relative to 1990.

Open-water Fishery Angling Catch and Harvest

Consistent with the increase in angling effort, the catch (339,919) and harvest (188,497) of walleye during the 1991 open-water season were high compared to recent years (Table 3, Fig. 3). Fishing success rates remain very good (number caught and harvested-per-rod-hour were 0.521 and 0.289, respectively) and are slightly higher than any other surveys since the early 1980's (Fig. 4). Our index of walleye year-class strength suggests that large numbers of walleye were produced in 1990 and 1991 (Hoyle 1992). Recruitment of these fish to the angling fisheries should insure continued success for the near future at least.

Biological Attributes of the Walleye Harvest

The mean fork length and weight of walleye harvested during the 1991 open-water fishery were 396 mm (16 in) and 787 g (1.7 lb), slightly larger than the previous summer. The mean age of walleye harvested during the open-water fishery was 3.6 yr (Fig. 5).

The mean fork length of the walleye harvested during the ice fishery was 518 mm (20.4 in) and the mean weight 1.9 kg (4.2 lb). Larger fish are much more commonly caught in the ice fishery than in the open-water fishery (Fig. 6), as observed in previous years (Hoyle and Mathers 1991). The mean age of walleye harvested during the ice fishery was 5.0 yr (Fig. 5).

Survey Design Considerations

This years estimates (and most other recent estimates) of angler harvest and angler effort during the open-water and the ice fisheries rely on extrapolation of index surveys. For example, the 1991 open-water fishing survey was conducted during May and July only. The results were extrapolated based on the seasonal pattern of angler activity and harvest observed during the 1988 survey, which was conducted May to November. Also, the 1991 ice fishing angler interviews were conducted in Big Bay and extrapolated based on the geographic pattern of angler harvest observed in 1989 (conducted on all parts of the Bay).

The use of index creels allows us to survey a portion of the fishery, save money, and still provide an estimate of the whole fishery. However, the patterns of angling activity change with time and the more extensive surveys must be conducted periodically to increase our confidence in expanded estimates of the whole fishery. The next survey which will include all seasons and all locations is scheduled for 1993.

Our estimates of the walleye angling fishery include the boat fishery in the Bay of Quinte only. There are other walleye fisheries in eastern Lake Ontario which need further study. Fall shoreline fisheries in the Bay of Quinte area, which includes the walleye fisheries at Picton Harbour, Belleville Bridge, and Meyer's Pier, were surveyed in 1991 (Savoie and Bowlby 1992). There are also anglers who fish for walleye in the eastern basin (Mathers 1988). We plan to survey this fishery during 1992. The fishery in the Bay of Quinte during December is largely unquantified because of the difficulty in conducting a survey at this time of year. Periodic surveys of these peripheral fisheries confirms their magnitude and allows us to maintain the accuracy of our population models.

TABLE 4. Estimated catch and harvest of fish in Big Bay (areas 32 and 33) by all anglers from Jan. 2 to Feb. 28, 1991. Standard error of the estimate is shown in brackets.

Species	Catch		Harvest	
Rainbow trout	67	(59)	67	(59)
Lake trout	14	(10)	14	(10)
Northern pike	382	(83)	309	(67)
Yellow perch	32,238	(5,144)	21,724	(3,909)
Walleye	8,381	(1,588)	7,869	(1,499)

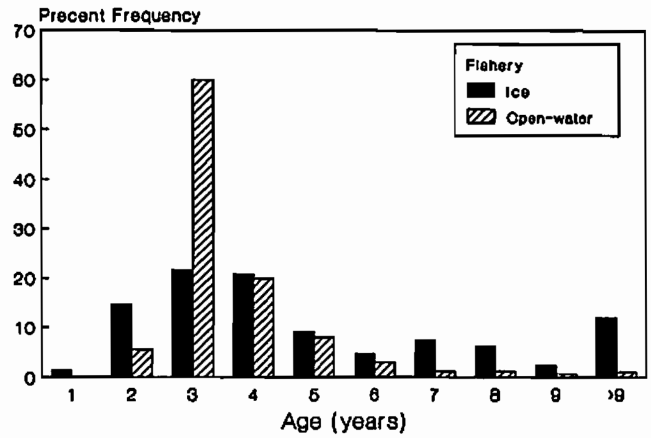

FIG. 5. Percent of walleye harvest by age-class during the Bay of Quinte ice and open-water fisheries in 1991.

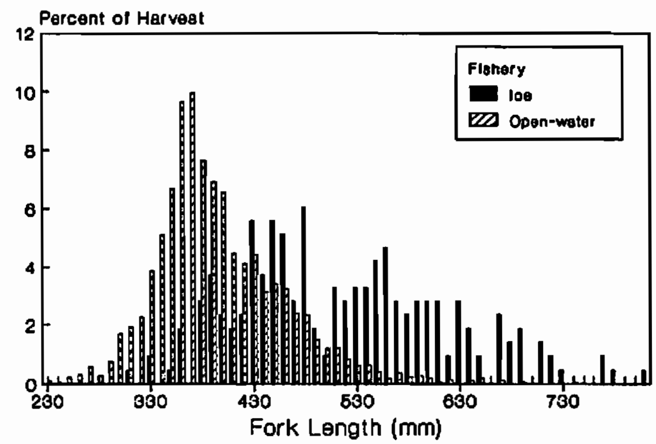

FIG. 6. Percent of walleye harvest contributed by 10 mm fork length-classes during the Bay of Quinte ice and open-water fisheries in 1991.

Acknowledgments

Dawn Walsh, Randy Gurnsey, Leah Smith, Jim Lindsey, Dale Dewey, and Steve Lawrence, of L.O.F.U. Operations staff, conducted the field work for this project.

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Outboard Trawling in Eastern Lake Ontario and the Bay of Quinte, 1991

J. A. Hoyle

Ontario Ministry of Natural Resources
Lake Ontario Fisheries Unit
R.R.#4, Picton, Ontario - K0K 2T0

Lake Ontario Fisheries Unit, 1991 Annual Report, Section 3

The Lake Ontario Fisheries Unit (LOFU) conducted an outboard trawling program at 24 sites representing the Bay of Quinte and nearshore habitats of eastern Lake Ontario in August, 1991. Over 6,000 fish comprising 29 species were caught in 72 trawls. Young-of-the-year (YOY) walleye abundance in the Bay of Quinte outboard trawls was up 30% from 1990; however, this increase was not statistically significant. By contrast, YOY walleye abundance declined by 38% over the same time period in LOFU Research bottom trawls. YOY yellow perch increased in abundance in 1991 compared with 1990. The increase was not significant in Lake Ontario but was significant in the Bay of Quinte. Age interpretation based on length-frequency distributions and scales gave similar results for YOY and yearling yellow perch. Yellow perch length-at-age data were presented. Highlights of a gear comparison study (outboard vs. bottom trawling gear) were also included in this report.

Recommendations

1 Increase the number of outboard trawling sites on Lake Ontario and the embayments of Lake Ontario (Weller's Bay, West Lake, and East Lake) to obtain more precise and representative results. Alternately, outboard trawling should be discontinued in these areas.

2. Outboard trawling on the Bay of Quinte should be discontinued in favor of expanding the traditional LOFU Research bottom trawling program to include six sites.

3. Conduct further gear comparisons using the outboard trawling gear and the LOFU Research bottom trawling gear in 1992 to gain additional insight into differences in the catches of the two gear types.

4. The outboard trawling gear should be used in the future to help determine species composition in other embayments of Lake Ontario as the management need arises, and to re-examine the areas studied during the first four years of this program if major changes in species composition are suspected.

Introduction

The Lake Ontario Fisheries Unit's (LOFU) outboard trawling program, initiated in 1988 (Bowlby 1989), is designed to index the abundance of 'small' fish in the Bay of Quinte and the nearshore habitats of eastern Lake Ontario. Small fish include young-of-the-year (YOY), for species such as walleye, yellow perch and white perch, as well as small-bodied, prey species such as alewife, gizzard shad, trout-perch and spottail shiner.

The indices of abundance provided by the outboard trawling program should prove useful for predicting year-class strength and as early indicators of fish population response to stress from, for example, zebra mussel invasion.

The first two years (1988 and 1989) of the outboard trawling program focused on (1) establishing suitable index trawling sites, (2) examining the influence of factors such as season and site depth on trawling catches, and (3) determining the optimal number of replicate tows at each site (Bowlby 1989). The conclusion reached was that three replicate trawls should be made at each site during August at a depth of 3 to 5 m. This design was adopted for the 1990 field season. Also implemented, in 1990, was the biological sampling of several key species in the catch to document potential early indicators of zebra mussel impacts on resident fish communities.

Analysis of the first three years (1988 to 1990) of outboard trawling data resulted in several recommendations for implementation in future years (Hoyle 1991). Recommendations adopted for the 1991 field season included (1) continued use of three replicate trawls at each sampling site, (2) calculation of a YOY walleye index of abundance based on 12 fixed Bay of Quinte sites, (3) conducting comparative paired trawls using the outboard trawling gear and the much larger, LOFU Research bottom trawling gear to address inconsistencies between YOY walleye indices of abundance as determined by the two gear types, and (4) verifying the use of length-frequency distribution data to determine yellow perch YOY and yearling abundance by comparison to scale-age interpretation.

Methods

Outboard Trawling

Gear

The outboard trawling program utilizes a 6 m long trawl with 13 mm stretched mesh in the codend and with hardwood otter boards which are 0.6 m long and 0.3 m in

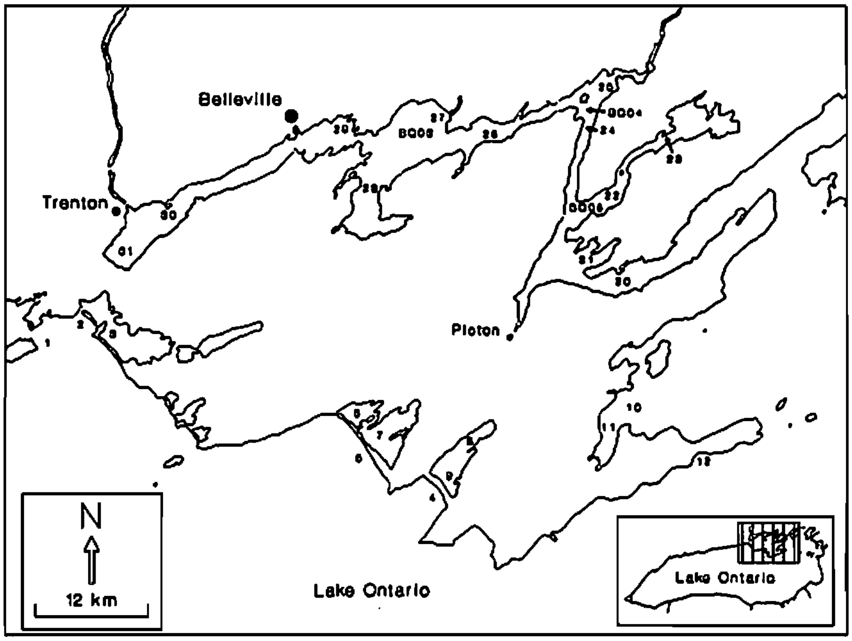

FIG. 1. Eastern Lake Ontario and Bay of Quinte outboard trawling site locations, 1991. Site names are given in Table 1.

height. The trawl is pulled behind a 6.1 m welded aluminum boat equipped with a 70 hp outboard motor and a knotmeter to regulate trawling speed.

Field sampling procedures

Trawling occurred in August across four major geographical areas. Three replicate trawls were made at each of 24 sites which were found suitable for trawling in previous years (Fig. 1, Table 1). All trawls were of 6 min duration at a speed of 4.3 km/hr and covered a distance of 430 m.

All fish were counted by species for each trawl catch. Length-tally information was recorded for at least 30 individuals of each species for each trawl.

A length-stratified sample consisting of 5 yellow perch per 5 mm size-interval was collected in two of the four major geographic areas, Lake Ontario and the Bay of Quinte. Length, weight, sex and age were determined for these perch. Scales were used for the age interpretations reported here but otoliths were also collected for future age and growth studies.

Lengths, weights, scales and otoliths were collected from up to 50 individuals of the following: YOY alewife, spottail shiner, trout-perch, YOY white perch, and YOY walleye, in the Bay of Quinte only. Results of the latter biological sampling are not reported here. Scales and otoliths were archived for future age and growth studies.

Analysis

Two-factor analysis of variance (ANOVA) with unequal replication followed by the Student-Newman-Keuls Multiple Range Test (SNK test) was used to detect significant differences ($p = 0.05$) in mean catch-per-trawl (number per 430 m trawl) among years for YOY walleye in the Bay of Quinte and yellow perch age-classes (see below) in Lake Ontario and the Bay of Quinte. Both factors, year and site, were considered fixed (Model I ANOVA). Only sites where walleye or yellow perch had been captured in at least one year were included in the ANOVA's (see Hoyle

TABLE 1. 1991 Outboard trawling sites within each of the four major areas of Lake Ontario and the Bay of Quinte. Also listed• are the three Bay of Quinte sites where comparative trawling (outboard vs. bottom trawl gear types) was carried out.

Area	Site name	Site number[a]
Lake Ontario	Middle Ground	1
	Barcovan	2
	Athol Bay	4
	Wellington Bay	5
	Big Sand Bay	12
Embayments	Wellers Bay	3
	West Lake (north)	6
	West Lake (south)	7
	East Lake (east)	8
	East Lake (west)	9
Eastern outlet basin	Morrison Point	10
	South Bay	11
Bay of Quinte	Lyons Island	20
	Carnachan Island	21
	Ram Island	22
	Hay Bay	23
	Coles Wharf	24
	Deseronto	25
	Northport	26
	Hungry Bay	27
	Muscote Bay	28
	Belleville Island	29
	Baker Island	30
	Indian Island	31
	Big Bay•	BQ03
	Deseronto•	BQ04
	Hay Bay•	BQ05

[a] Site numbers are consistent with 1990 and 1989 site numbers but not with those of 1988.

TABLE 2. Transformations used on catch data for several common species.

Transformation	Species
Log_{10}(catch + 1)	Alewife, white perch, yellow perch
Square root (catch + 0.5)	Spottail shiner, trout-perch, walleye

1991). Transformations were used on all catch data as shown in Table 2.

Inspection of yellow perch length-frequency distribution data was used to assign ages to YOY and yearling age-classes based on length. A computer program ('MIX', MacDonald and Green 1988) was used to fit normal distributions to length-frequency modes corresponding to mean length-at-age for YOY and yearling age-classes. Proportions of fish in 5 mm length intervals were assigned to each age-class (YOY, yearling, and all older age-classes combined). In this manner, a catch-per-trawl was determined for YOY, yearling, and older yellow perch. This method of yellow perch age-class determination was tested by comparing the results to those of scale-age interpretation for a length-stratified sample (see above) of the perch.

Comparative Trawling

Gear

Paired trawls were made using the outboard trawl and the larger Research bottom trawl. The bottom trawl has measurements as follows: 19 m long with 6 m wings and, like the outboard trawl, 13 mm stretched mesh in the codend (Hurley 1991).

Field sampling procedures

Six paired trawls were made at each of 3 sites (Table 1). All trawls were of 6 min duration at speeds of 4.3 km/hr for the outboard trawl and 4.0 km/hr for the bottom trawl.

All fish were counted by species for each trawl catch. Length-tally information was recorded for at least 30 individuals of each species for each trawl.

Analysis

Catches of the two trawl gears were compared graphically as the mean of the mean catch-per-trawl at three sites for each species (expressed as proportions). Correlation coefficients of the mean catch-per-trawl were compared for some common species in the catch of both gear types.

In addition, the catches of the two gear types during their respective routine community index netting programs on the Bay of Quinte (12 outboard trawl sites and August data for 4 bottom trawl sites (Big Bay, Deseronto, Hay Bay, and Conway) were also compared.

Results and Discussion

Outboard Trawling

Over 6,000 fish comprising 29 species were caught in 72 trawls at 24 sampling sites during the 1991 outboard trawling program. Catches were summarized for each major geographic area as mean catch-per-trawl (Tables 3 and 4).

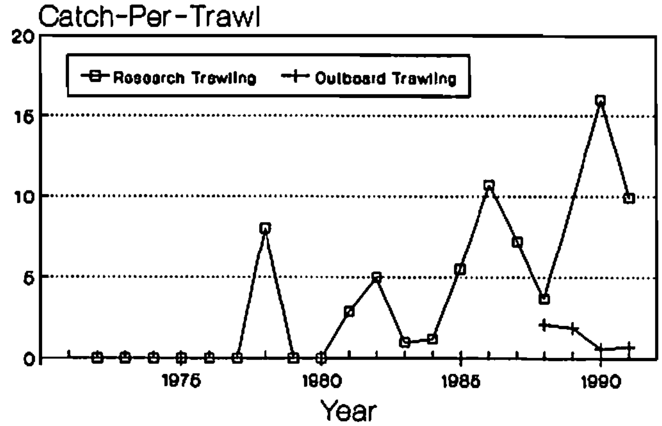

FIG. 2. Mean YOY walleye catch-per-trawl in the Bay of Quinte, 1972 to 1991.

Indices of Abundance

Walleye

Trends in abundance – YOY walleye abundance in the Bay of Quinte (Sites 20 to 31 inclusive, Table 1) was up 30% (based on untransformed means) from 1990 but this increase was not significant (ANOVA, $p > .05$; Table 5).

Comparisons with Bay of Quinte Research bottom trawls – The Research component of LOFU has conducted bottom trawling with much larger trawling gear on the Bay of Quinte since 1972. An index of YOY walleye abundance based on catches at three sites, Conway, Hay Bay and Big Bay, is currently used in the Lake Ontario walleye harvest management model (Bowlby and Mathers 1989). The outboard trawling program provides an alternative index of walleye year-class strength.

Comparison of YOY walleye indices of abundance provided by the two programs for the three years of overlap (1988, 1990, and 1991) show inconsistent results (Fig. 2).

Results of comparative trawling with the two gears are described below.

Yellow Perch

Trends in abundance – YOY yellow perch increased in abundance in 1991 compared with 1990 (Table 6). The increase was not significant in Lake Ontario (Sites 1, 2, 4 and 5) but was significant in the Bay of Quinte (Sites 21 to 31 inclusive, ANOVA $p = 0.05$). Also, large catches (mean catch-per-trawl was 150) of yellow perch were made at Bay of Quinte Site 20, where none had been captured in previous years.

Yearling and adult catches have remained low following comparatively high catches in the first year of outboard trawling, 1988.

Age verification – The length-frequency method of yellow perch ageing, routinely employed in this program, was compared to scale-age interpretation. As illustrated for Bay of Quinte yellow perch (Fig. 3), the results of the two methods were very similar.

Growth – Yellow perch were caught up to 6-yrs-old in the Bay of Quinte; though few were older than 4-yrs-old. Only YOY and yearlings were caught in Lake Ontario.

TABLE 3. Species caught during the 1991 outboard trawling program.

Common name	Scientific name
Alewife	*Alosa pseudoharengus*
Gizzard shad	*Dorosoma cepedianum*
Rainbow smelt	*Osmerus mordax*
Northern pike	*Esox lucius*
White sucker	*Catostomus commersoni*
Common carp	*Cyprinus carpio*
Golden shiner	*Notemigonus crysoleucas*
Spottail shiner	*Notropis hudsonius*
Sand shiner	*Notropis stramineus*
Mimic shiner	*Notropis volucellus*
Bluntnose minnow	*Pimephales notatus*
Brown bullhead	*Ictalurus nebulosus*
American eel	*Anguilla rostrata*
Brook stickleback	*Culaea inconstans*
Threespine stickleback	*Gasteroteus aculeatus*
Trout-perch	*Percopsis omiscomaycus*
White perch	*Morone americana*
White bass	*Morone chrysops*
Rock bass	*Ambloplites rupestris*
Pumpkinseed	*Lepomis gibbosus*
Bluegill	*Lepomis macrochirus*
Smallmouth bass	*Micropterus dolomieui*
Largemouth bass	*Micropterus salmoides*
Black crappie	*Pomoxis nigromaculatus*
Yellow perch	*Perca flavescens*
Walleye	*Stizostedion vitreum vitreum*
Johnny darter	*Etheostoma nigrum*
Logperch	*Percina caprodes*
Freshwater drum	*Aplodinotus grunniens*

TABLE 4. Mean catch-per-trawl for Lake Ontario, Embayments of Lake Ontario, Eastern Outlet Basin, and the Bay of Quinte during the 1991 outboard trawling program.

	Lake Ontario	Embay-ments	Eastern outlet basin	Bay of Quinte
Alewife	6.1	0.0	0.0	0.6
Gizzard shad	0.0	0.0	0.0	0.2
Rainbow smelt	0.0	0.0	0.0	0.1
Northern pike	0.0	0.1	0.0	0.0
White sucker	0.0	0.2	0.0	0.1
Common carp	0.1	0.1	0.0	0.0
Golden shiner	0.0	0.0	0.0	0.1
Spottail shiner	12.5	5.0	0.7	35.5
Sand shiner	2.1	0.0	0.0	0.0
Mimic shiner	0.0	6.8	0.0	0.0
Bluntnose minnow	0.0	11.4	0.0	0.0
Brown bullhead	0.0	0.3	0.0	0.6
American eel	0.0	0.0	0.0	0.1
Brook stickleback	0.0	0.0	0.3	0.0
Threespine stickleback	0.5	0.0	0.0	0.0
Trout-perch	0.0	0.0	0.2	14.5
White perch	0.0	36.8	0.0	18.6
White bass	0.0	0.1	0.0	0.1
Rock bass	0.0	0.1	0.2	0.0
Pumpkinseed	0.0	11.3	0.0	2.1
Bluegill	0.0	3.0	0.0	0.0
Smallmouth bass	0.1	0.6	0.0	0.1
Largemouth bass	0.0	1.9	0.2	0.0
Black crappie	0.0	2.9	0.0	0.2
Yellow perch	43.5	12.8	0.0	35.4
Walleye	0.0	0.3	0.0	1.0
Johnny darter	0.3	0.0	1.2	0.1
Logperch	0.0	0.1	0.0	0.1
Freshwater drum	0.0	0.0	0.0	0.4
Total number captured	977	1405	16	3941
Number of trawls	15	15	6	36
Number of species	8	18	6	19

TABLE 5. Mean catch-per-trawl (transformed data; untransformed means in parentheses) for several common Bay of Quinte species. The SNK test was performed to compare catches among years for each species. Values, for a given species with the same letter are not significantly different (p>.05).

Species	1988		1989		1990		1991	
Walleye (YOY)	1.609 (2.089)	A	1.538 (1.865)	A	1.032 (0.565)	B	1.114 (0.741)	B
Alewife	0.136 (0.370)	A	0.126 (0.337)	A	0.368 (1.336)	B	0.090 (0.231)	A
Spottail shiner	3.047 (8.284)	A	2.369 (4.612)	A	2.572 (5.615)	A	4.903 (23.539)	B
Trout-perch	3.707 (12.742)	A	4.175 (16.431)	AB	1.999 (2.996)	C	3.098 (9.098)	B
White perch (YOY)	1.208 (15.144)	A	0.736 (4.445)	B	1.202 (14.922)	A	0.943 (7.770)	C

TABLE 6. Yellow perch mean catch-per-trawl (log transformed data; untransformed means in parentheses) for YOY, yearling, and older age-classes combined in Lake Ontario and the Bay of Quinte. The SNK test was performed to compare catches among years for each species. Values for a given species with the same letter are not significantly different (p > .05).

Age group	1988		1989		1990		1991	
Lake Ontario sites								
YOY	1.036 (9.864)	A	0.963 (8.183)	A	0.483 (2.041)	A	0.677 (3.753)	A
Yearlings	0.563 (2.656)	A	0.000 (0.000)	B	0.083 (0.211)	B	0.025 (0.059)	B
Older	0.366 (1.323)	A	0.000 (0.000)	B	0.000 (0.000)	B	0.000 (0.000)	B
Bay of Quinte sites								
YOY	0.855 (6.161)	A	0.752 (4.649)	A	0.312 (1.051)	B	0.750 (4.623)	A
Yearlings	1.180 (14.136)	A	0.502 (2.177)	B	0.201 (0.589)	C	0.259 (0.816)	C
Adults	0.848 (6.047)	A	0.533 (2.412)	B	0.137 (0.371)	C	0.297 (0.982)	D

Figure 4 shows the length-at-scale age for yellow perch caught in Lake Ontario and the Bay of Quinte. Yellow perch were of smallest length-at-age in Lake Ontario; they were somewhat larger in the lower Bay of Quinte (Site 20), and the largest were found in the upper/middle Bay of Quinte (Sites 21 to 31 inclusive). The length-at-age data presented here are not back-calculated to the beginning of the growing season, hence, differences in length-at-age among sites may be due in part to seasonal differences in sampling.

Other Species

Comparisons of annual indices of abundance (same Bay of Quinte sites used for the YOY walleye index of abundance) for several common species are shown in Table 5.

Comparative Trawling

Eighteen paired trawls were made at three Bay of Quinte sites (six paired trawls at each site) using outboard and bottom trawling gear. The relatively small outboard trawl caught 809 fish comprised of 13 species, while the larger bottom trawl caught 10,827 fish and 19 species (Table 7, Fig. 5). Among the five most abundant species in both trawling gears, only trout-perch catches-per-trawl were positively correlated (one-tailed t-test, p = .05, Table 8). Some of the other species would have been significantly correlated if the sample size were larger. Future comparative trawling should include additional trawling sites.

Results of comparative paired trawling, presented above, and a further comparison of catches by the two gear types during their respective routine community index trawling programs (Fig. 6) can briefly be highlighted as follows. At a given trawling location, the bottom trawl samples more fish species by virtue of its large size and ability to capture large numbers of individuals (during the comparative trawling study, the six species not captured by the outboard trawl were caught only in very small numbers by the bottom trawl). During both the comparative trawling study and the routine trawling programs, the bottom trawl catches contained much higher proportions of alewife and gizzard shad, probably again reflecting this trawl's larger size, and thus its ability to sample these pelagic species. Some of the differences in the catches of the two gears during routine trawling can be attributed to (1) the bottom trawls ability to sample deep water, and thus capture species such as lake whitefish (*Coregonus clupeaformis*), lake herring (*Coregonus artedii*), and sculpin (*Cottus sp.*) in the lower Bay of Quinte (Conway), and (2) the outboard trawls ability to sample shallow more nearshore areas, and thus catch species such as golden shiner, smallmouth and largemouth bass, and logperch. Carp (*Cyprinus carpio*) and channel catfish (*Ictalurus punctatus*), not caught by the outboard trawl in 1991, have been caught in previous years.

Assessment of the Outboard Trawling Program

Bay of Quinte

By virtue of sampling a large number of sites, including shallower more nearshore sites than the bottom trawl, the outboard trawl provides good indices of abundance for the YOY of several Bay of Quinte species. Nonetheless, given that the outboard trawling program provides little additional information to that of the bottom trawl (with the current Bay of Quinte fish community), and that the bottom trawl program is scheduled to expand to two additional sites in 1992 (Trenton and Belleville; total of six

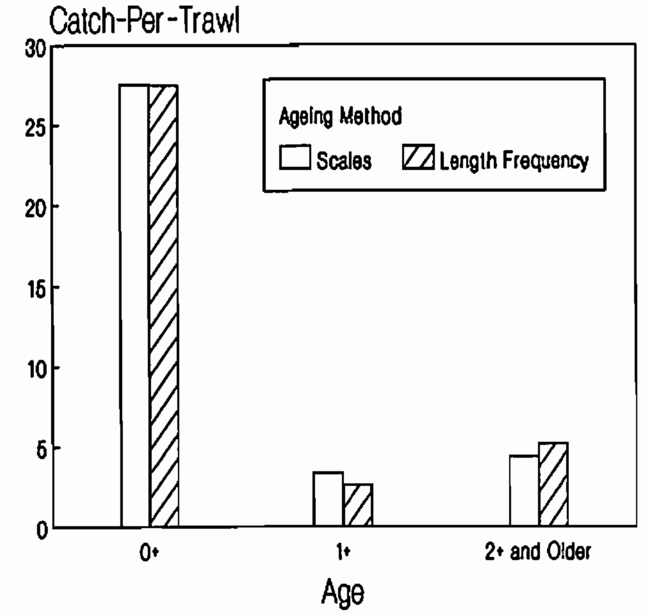

FIG. 3. Comparison of age determination by length distribution vs. scales for Bay of Quinte yellow perch.

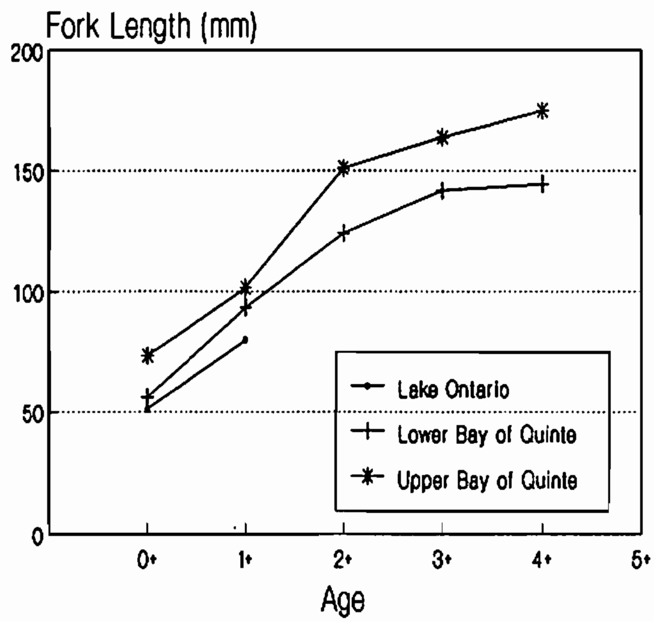

FIG. 4. Yellow perch fork length-at-age for Lake Ontario (Sites 1 to 4 and 12, n = 41), lower (Site 20, n = 92), and upper/middle (Sites 21 to 31, n = 39) Bay of Quinte.

TABLE 7. Mean catch-per-trawl and percent species composition (in brackets) in outboard and bottom trawls during the comparative trawling study at three Bay of Quinte sites.

Species	Trawling gear: Outboard		Trawling gear: Bottom	
Alewife	0.2	(0.5)	99.0	(16.5)
Gizzard shad	0.4	(1.0)	86.6	(14.4)
Rainbow smelt	0.0	(0.0)	0.1	(0.0)
Northern pike	0.0	(0.0)	0.1	(0.0)
White sucker	0.1	(0.6)	3.7	(0.6)
Common carp	0.0	(0.0)	0.4	(0.1)
Spottail shiner	14.8	(33.0)	66.7	(11.1)
Brown bullhead	0.6	(1.2)	20.7	(3.4)
Channel catfish	0.0	(0.0)	0.2	(0.0)
American eel	0.3	(0.7)	1.3	(0.2)
Trout-perch	7.5	(16.7)	71.8	(11.9)
White perch	16.0	(35.6)	185.9	(30.9)
White bass	0.1	(0.2)	1.3	(0.2)
Pumpkinseed	0.1	(0.1)	0.2	(0.0)
Black crappie	0.0	(0.0)	0.1	(0.0)
Yellow perch	3.9	(8.7)	27.9	(4.6)
Walleye	0.8	(1.9)	27.1	(4.5)
Johnny darter	0.0	(0.0)	0.1	(0.0)
Freshwater drum	0.1	(0.2)	8.4	(1.4)
Total number captured	809		10 827	
Number of trawls	18		18	
Number of species	13		19	

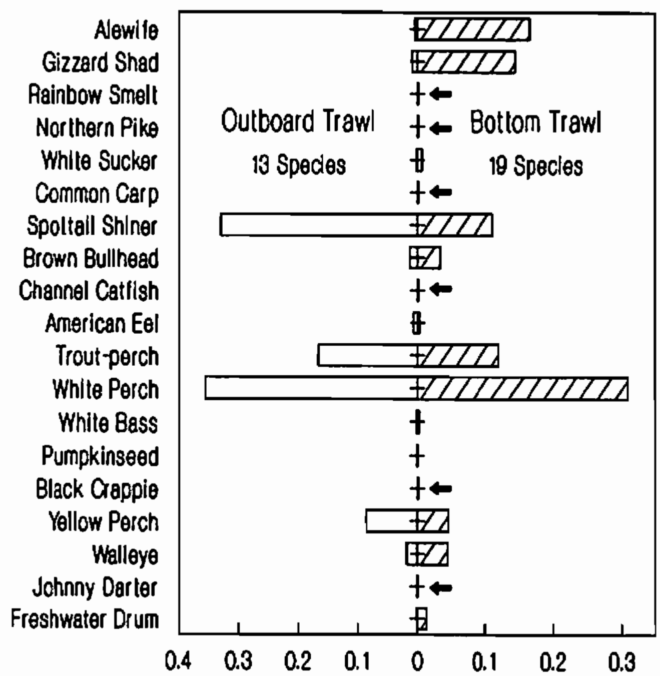

FIG. 5. Species composition of outboard and bottom trawl catches (expressed as proportions of the total catch) during the 1991 comparative netting study (18 paired trawls). Arrows indicate species unique to that gear type.

TABLE 8. Correlation between mean catch-per-trawl in outboard and bottom trawls during the comparative trawling study at three Bay of Quinte sites.

Species	Correlation Coefficient	
Spottail shiner	−.989	n.s.
Trout-perch	+.998	•
White perch	+.911	n.s.
Yellow perch	+.346	n.s.
Walleye	+.839	n.s.

• = significant, one-tailed test (p = .05)
n.s. = non-significant

sites), it is recommended that the routine outboard trawling program be discontinued on the Bay of Quinte. However, further comparative trawling should be conducted in 1992 to gain additional insight into differences in the catches of the two gear types.

Lake Ontario and other embayments

In the first four years of outboard trawling, very few suitable trawling sites have been found on Lake Ontario. Catches at the few sites where trawling is practical, probably do not accurately reflect species composition and abundance of the Lake Ontario nearshore fish community. In any event, differences in species abundance among years is very difficult to detect with the current sampling intensity. For example, though the abundance of YOY yellow perch caught in the outboard trawling program has varied greatly on Lake Ontario during the last four years, the changes have not been statistically significant.

Similarly, though the sites sampled by the current outboard trawl program in embayments of Lake Ontario (Weller's Bay, West Lake, and East Lake) are much more representative of the embayments as a whole, the current sampling intensity, again, is not sufficient to detect even relatively large year-to-year differences in species abundance. Sampling intensities in these embayments would have to be increased to obtain species abundance indices with a degree of precision and statistical power adequate to base management decisions.

Conclusion

I recommend that the outboard trawling program be discontinued except for a gear comparison study in 1992. The outboard trawling gear should be used in the future to help determine species composition in other embayments of Lake Ontario as the management need arises, and to re-examine the areas studied during the first four years of this program if major changes in species composition are suspected.

Acknowledgments

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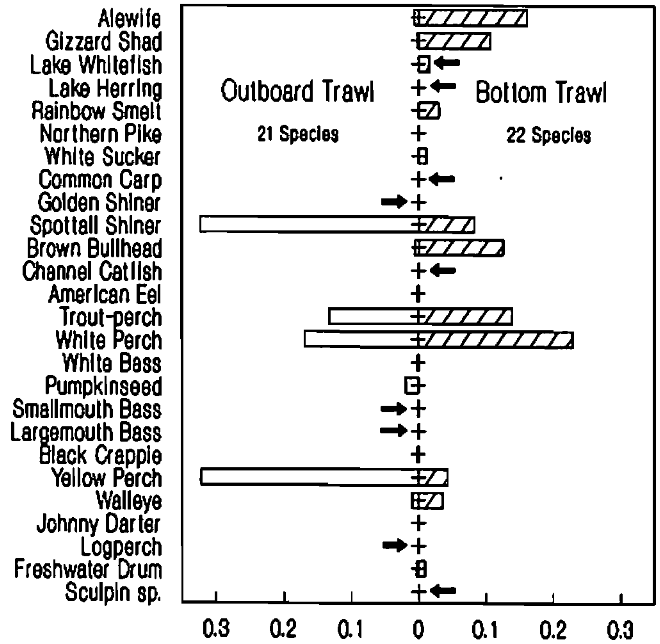

FIG. 6. Species composition of outboard and bottom trawl catches (expressed as proportions of the total catch) during their respective 1991 routine index netting programs. The bottom trawl data is for August only. Arrows indicate species unique to that gear type.

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Smelt Abundance And Growth In Western Lake Ontario

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Smelt population dynamics in western Lake Ontario appear to be changing. During the early and mid-1980's, yearling smelt abundances in both U.S. and Canadian waters of Lake Ontario alternated between high and low abundances with a 2 or 3 yr period. A high yearling abundance has not been observed since 1987, and the wide cycling pattern in abundance, is no longer apparent. Adult abundance has also remained relatively low and steady. Growth of yearling smelt has increased since 1987.

Recommendations:

1. Continue to use bottom trawls to monitor smelt in western Lake Ontario.
2. Continue to develop prey fish stock assessment techniques suitable for all of the Canadian waters of Lake Ontario.
3. Validate an age interpretation method for smelt.

Introduction

Studies of smelt populations provide important information for the management of the pelagic fish community in Lake Ontario. In the spring of 1978, the U.S. Fish and Wildlife Service (USFWS) initiated a bottom trawl sampling program to assess abundance of smelt and alewife in U.S. waters (O'Gorman et al. 1991). Since 1981, smelt were sampled using bottom trawls in Canadian waters between Toronto and Niagara with similar gear and techniques to the U.S. survey. Surveys in Canadian waters were limited to this area because substrate was not suitable for bottom trawling elsewhere. However, alternative techniques to sample smelt and alewife, which can be implemented in all Canadian waters, are being developed (Mathers et al. 1991; Schaner and Mathers 1991).

This report provides an update on the yearling abundance, adult abundance, and growth of smelt in Canadian waters of western Lake Ontario.

Methods for Fish Sampling and Abundance Calculations

In early August of 1981-85, the USFWS Research Vessel Kaho bottom trawled along three principal transects in western Lake Ontario: Niagara, Hamilton, and Toronto (Fig. 1). At each site, trawling was done at 5 m depth intervals starting at 15-20 m to a maximum of 55 m. A severe storm during the western Lake Ontario trawling in 1983 drastically altered local smelt distributions (Stewart and Oliver 1989). Therefore, 1983 western Lake Ontario data were not used in this summary.

From 1986 to 1991, sampling was conducted in June at approximately the same locations with the addition of an 8 m site and several sites deeper than 55 m. To accommodate differences in sampling depths among years, we derived estimates of abundance for bottom areas common to all years surveyed (10-50 m). Catches were stratified into bottom areas of 10-20, 20-30, 30-40 and 40-50 m. Each year's abundance was the summation over all areas of the average catch-per-10 min trawl (CUE) in each depth stratum times the number of hectares in each stratum, divided by the area trawled (0.73 ha/10 min tow). Twenty-seven trawls were completed during 1991.

Methods for Age Composition and Growth of Smelt

A random sample of smelt was measured for length from each sample. Length, weight, sex, and aging material were taken from a length stratified subsample of approximately 200-400 individuals per yr. Length-frequency analysis (MIX - MacDonald and Pitcher 1979) were used on the 1981-91 data to distinguish between yearling fish and the remainder of the catch.

Length-frequency distributions (Fig. 2) were derived for the 1981-91 populations by weighting length data from samples by the CUE. A mean size-specific CUE was then calculated for each depth strata. Size-specific population estimates were derived by expanding the CUE's by the area of the depth strata and the areas trawled. MIX was then used to calculate the proportion of yearlings and the proportion of adult fish in each size-category. Adult age groups could not be distinguished from each other using MIX analysis.

Length frequency analysis to determine growth and age composition of smelt populations has not been applied to these data in the past. Ages were interpreted from scales for samples taken during 1981-85, and from pectoral finray sections for samples taken during 1986-90. Review of these age interpretations suggest that these methods produced inconsistent results. In this study, growth es-

FIG. 1. Map of western Lake Ontario. Bottom trawls were taken within shaded areas at Niagara, Hamilton, and Toronto.

timates derived from length frequency and calcified structures were compared.

Yearling Abundance

The use of MIX analysis resulted in minor changes to the proportions of yearlings in the population relative to previous estimates based on interpretation of calcified structures. Overall trends in the data did not change.

The estimated abundance of yearling smelt in 1991 was 336 million fish (10-50 m depth) which is a moderate number relative to previous years (Fig. 3). In the past, yearling smelt abundances in both U.S. and Canadian waters of Lake Ontario have cycled with a 2 or 3 yr period (O'Gorman et al. 1991; Mathers 1991). In western Lake Ontario, a high yearling abundance has not been observed since 1987, and the cyclical pattern does not appear to be continuing. The abundance of yearling smelt in the U.S. waters has continued to cycle through 1990 (O'Gorman et al. 1991).

Cannibalism by yearling smelt on YOY has been hypothesized to cause the alternating cycle (O'Gorman et al. 1991). Several possible explanations for the loss of the cyclical recruitment pattern exist. Increased predation on yearling smelt could reduce their numbers to the point where cannibalism would not have a strong effect on the year-class which follows them. The Lake Ontario Predator-Prey Model suggests that predator demand has increased throughout the 1980s (M. Jones, O.M.N.R., RR#4, Picton, Ontario K0K 2TO, pers. comm.). Smelt abundance could also be influenced by changes in the alewife population through competition or predation. Also, lower smelt recruitment could be caused by degradation of spawning areas and/or unfavorable climatic conditions. Further surveys will be required to resolve these questions.

Adult Abundance

The abundance of adult smelt (aged 2 yr and older) observed in 1991 was 304 million fish. This estimate is similar to the past 2 yr and is moderate relative to the range observed in previous surveys (Fig. 3). Adult abundance generally peaks when a strong year-class reaches 2-yr-old. Since yearling abundance has remained relatively constant in recent years adult abundances should not change dramatically. There is no strong stock-recruitment relationship (Fig. 4); however, adult abundances similar to the current level have produced both large and small year-classes in the past.

Size of Smelt

Large smelt (total length = 150 mm) were very uncommon in western Lake Ontario during 1991, representing only 1.0% (6.4 million fish) of the population. The abundance of large smelt has not been high since the early 1980's (Fig. 5). This trend, which was also observed in U.S. waters of Lake Ontario, has been attributed to changes in growth of older smelt and an increase in their mortality due to the increased numbers of salmonids in the lake (Mathers and Stewart 1990, O'Gorman et al. 1991).

There was no correlation ($r^2 = 0.21$, df = 3) between the mean lengths of yearling fish (1986-90) determined by MIX and the mean lengths determined by pectoral fin-rays. Also, the MIX results were generally smaller (Fig. 6). The fin-ray and MIX data for 1986 are particularly dif-

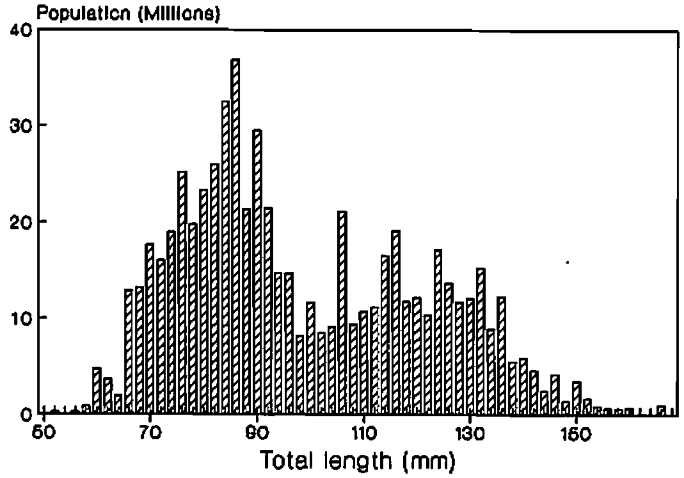

FIG. 2. Total length frequency distribution in 2 mm size-categories (weighted by sampling strata area) for the 1991 smelt population in western Lake Ontario.

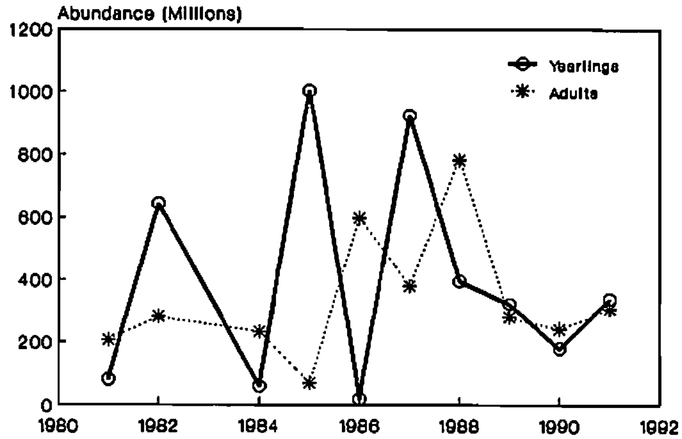

FIG. 3. Abundances of smelt, by age group, available to bottom trawls in western Lake Ontario areas of 10-50 m depth. Note that age specific estimates were derived using MIX and differ slightly from previously published estimates.

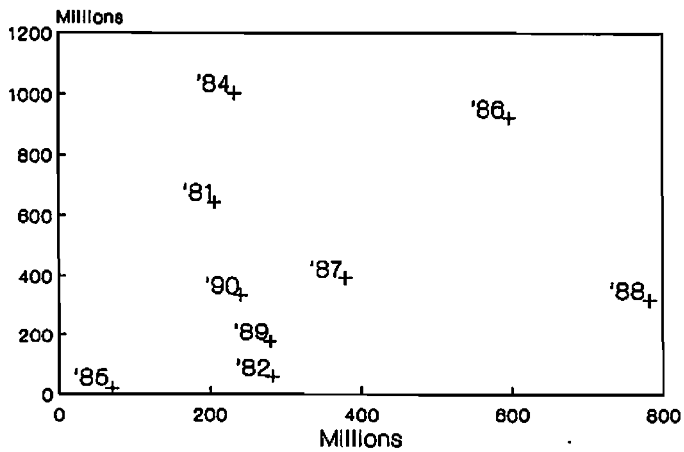

FIG. 4. The relationship between parental stock of smelt (aged 2 yr and older) and recruits (as shown by yearlings in the following year). Data are from trawls (10-50 m water depth) in western Lake Ontario, 1981-89. The year-class is shown beside each observation.

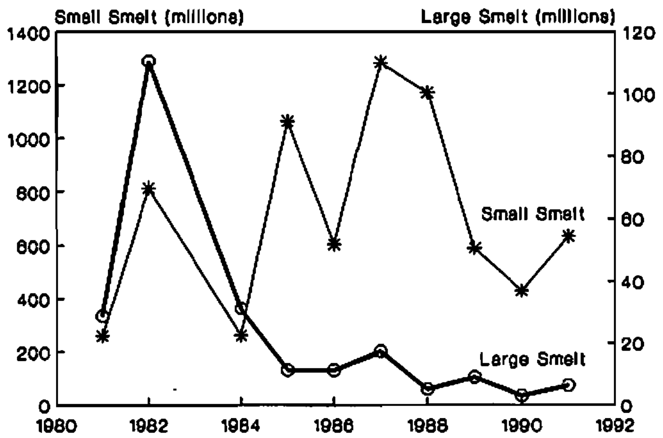

FIG. 5. Estimated abundance (millions of fish) of large smelt (total length > = 150 mm) and small smelt (total length < 150 mm) for the 10-50 m depth strata sampled during the 1990 bottom trawl program in western Lake Ontario.

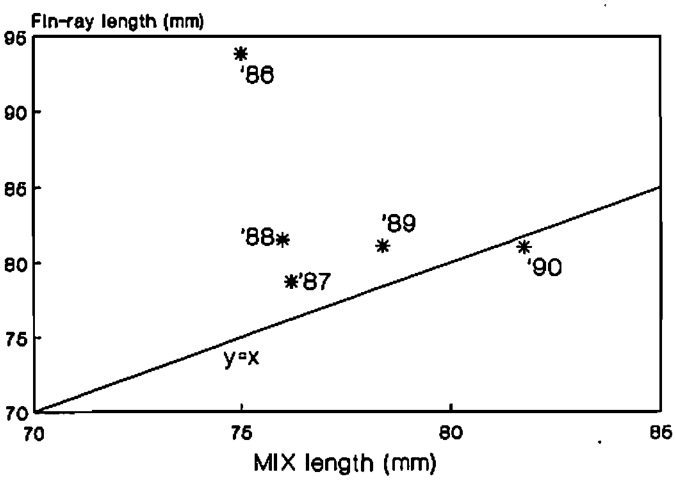

FIG. 6. Mean total length of yearling smelt from 1986 to 1990, as determined by MIX analysis, plotted against the length determined by interpretation of pectoral fin-rays. The y = x line is shown for reference.

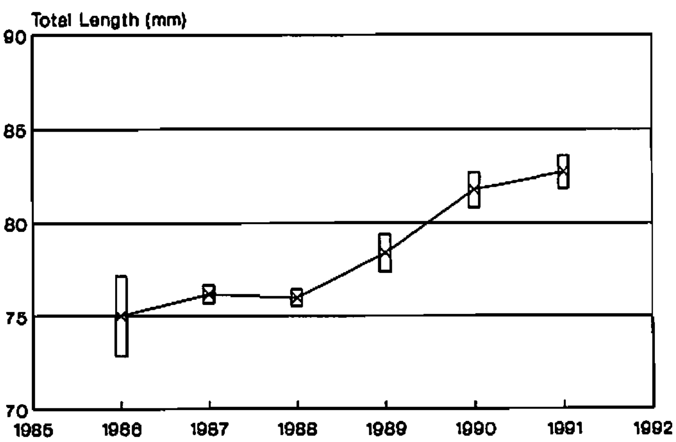

FIG. 7. Mean total length and 95% confidence limits of yearling smelt, caught during bottom trawling conducted from 1986 to 1991 in western Lake Ontario.

ferent. Calcified structures collected during this and future surveys will be archived until an interpretation technique can be validated.

Yearling smelt, during 1991, had an average total length of 82 mm (SD = 9.7, n = 1308) and have increased in size since 1987 (Fig. 7). This increase is coincident with the decline in yearling abundance, suggesting that growth of yearling smelt is density-dependent. Previous reports (Stewart and Oliver 1989) have suggested that the growth of young smelt was higher in Canadian waters than in U.S. waters. The apparent differences may have been due to bias in our fin-ray age interpretation technique. The mean lengths determined by MIX are similar to the range cited by O'Gorman et al. (1991) for U.S. waters of Lake Ontario.

Acknowledgments

Thanks to the USFWS for their assistance with the bottom trawling. Jim Bowlby administered the project. Tom Stewart, and Jim Hoyle reviewed a draft of this report.

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Lake Whitefish Early Life History Studies in the Bay of Quinte and Eastern Lake Ontario, 1991

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Lake Ontario Fisheries Unit, 1991 Annual Report, Section 5

Eastern Lake Ontario lake whitefish emergence trapping and larval fish sampling studies were conducted in the spring of 1991. Emergence trapping in the Bay of Quinte indicated that lake whitefish emerged from the spawning substrate between April 4 and April 12 as water temperatures rose from 4 to 8°C. Free-swimming larval lake whitefish were first captured in a tow net over a known Bay of Quinte spawning shoal (Makatewis Island) on April 9 (mean total length = 14.4 mm, n = 4). Larval lake whitefish dispersed to deeper water about mid-May as the surface temperature rose above 14°C (mean total length = 26.3, n = 44). By counting otolith daily growth rings, I determined that lake whitefish hatch dates corresponded closely to the dates of emergence, suggesting that these fish emerge soon after hatching. Cyclopoid copepodids and two small-bodied cladocerans, *Chydorus sphaericus* and *Bosmina longirostris*, predominated in the larval lake whitefish diet with the larval fish selecting the largest prey individuals available.

Recommendations

1. Future lake whitefish fry trapping studies should use fry traps with a mesh size of 7 bars per cm as per Collins (1975).
2. Abandon attempts to quantify larval lake whitefish abundance; use bottom trawl data to index the abundance of young-of-the-year (YOY) lake whitefish in August.
3. Conduct additional work with otoliths from known aged lake whitefish in order to validate the use of daily growth rings for determining age, hatch date, and growth.
4. Routinely implement lake whitefish stock discrimination techniques as they become available.
5. Further investigate the apparent differences in growth between Lake Ontario and Bay of Quinte stocks of lake whitefish.
6. Examine the spatial distribution of zooplankton abundance as it relates to larval lake whitefish distribution (e.g. back-eddies vs. open water).
7. Continue to assess larval lake whitefish diet and growth relative to zooplankton community structure in order to document the impacts on whitefish population dynamics resulting from zebra mussel (*Dreissena polymorpha*) invasion.

Introduction

Lake Ontario lake whitefish (*Coregonus clupeaformis*) are concentrated in the eastern end of the lake where habitat is most suitable. Here, they provide a locally significant commercial fishery (125,000 kg harvested in 1990). Commercial fishing quotas are established and reviewed on an annual basis to ensure that the abundance of this endemic species is maintained.

Ongoing assessment indicates that the eastern Lake Ontario lake whitefish population is supported by two major spawning stocks, one which migrates into the Bay of Quinte to spawn; and the other which spawns in Lake Ontario, mostly along the south shore of Prince Edward County.

Dive surveys, conducted in November/December, 1990, confirmed the presence of lake whitefish eggs at the two Bay of Quinte sites studied, Makatewis Island and Trident Point (Hoyle and Melkic 1991). Areas of egg deposition have yet to be confirmed for the lake Ontario stock, but commercial fishing activity in November along the south shore of Prince Edward County centers on large congregations of lake whitefish, apparently spawning, near Gull Bar, Petticoat Cove, and areas to the east of Petticoat Point.

Mark-recapture population estimates indicate that the Bay of Quinte spawning stock population size has increased tremendously in recent years (e.g. 3.2 times higher in 1988 than 1987, Bowlby 1990). Neither population estimates or relative abundance indices are available for the Lake Ontario stock (Stewart 1991). However, commercial harvest reports suggest that the Lake Ontario spawning stock has also increased in abundance recently (P. Smith, Ontario Ministry of Natural Resources, R.R. 4, Picton, Ontario, pers. comm.).

Apart from the spawning period in late fall, the two lake whitefish stocks cohabit in the eastern basin of Lake Ontario for the remainder of the year (Christie 1967). The stocks are morphologically as well as behaviorally divergent (Ihssen et al. 1985), and ongoing research, aimed at quantifying the unique morphological features, will soon allow routine discrimination of the two stocks (Casselman 1990).

This report describes the results of lake whitefish emergence trapping and larval fish sampling studies conducted on the Bay of Quinte. The objectives of these studies were to verify lake whitefish egg hatching and emergence, to develop an index of larval lake whitefish abundance, and to examine their diet and growth. Field work consisted of emergence trapping and larval fish sampling using a tow net. The later component included concurrent sampling of the zooplankton community.

Methods

Emergence Trapping

Emergence trapping was conducted immediately after "ice-out" (late-March). Thirty emergence traps (Collins 1975) were set at each of the two confirmed spawning sites, Makatewis Island and Trident Point (Hoyle and Melkic 1991), in the Bay of Quinte (Figs. 1 and 2). Traps were set in a single file along 300 m transects at 10 m intervals (30 traps x 10 m = 300 m) from the shore outwards, at each site. To ensure selection of the most suitable substrate (e.g. gravel/cobble, crevices or pockets with gravel/cobble), the traps were positioned by scuba divers within a short distance of each 10 m interval location.

Traps were checked at approximately weekly intervals (Table 1). All larval fish were removed and preserved (95% ethanol) for subsequent processing. The preserved fish were enumerated and measured for total length (0.1 mm) and weight (0.0001 g).

Continuous water temperature recorders (TempMentors, Ryan Instruments, Redmond, Washington) were installed, on the bottom, at the deep end of each of the two 300 m transects, for the duration of the lake whitefish emergence trapping study.

Larval Fish Sampling

Larval fish sampling involved the use of a tow net (see Loftus 1982; Cucin and Faber 1985 for gear specifications). In an attempt to establish index sampling locations, larval fish sampling was initially concentrated near the two confirmed Bay of Quinte spawning shoals, but expanded to a wider geographic area as larval lake whitefish dispersed. Eventually, samples were taken throughout the Bay of Quinte, from west of Makatewis Island to Indian Point and at two Lake Ontario sites (Big Sand Bay and Petticoat Cove, Figs. 1 and 2).

All larval fish tows were surface tows of 5 min duration. The tow speed was about 0.5 m/s and covered a distance of 150 m. If larval lake whitefish were caught in the first tow at a site, two additional replicate tows were made.

Larval whitefish samples were also obtained using a small (12 cm by 20 cm) aquarium dipnet attached to a 1 m wooden handle. The dipnet was used to "scoop" through schools of larval fish observed by field crews, typically in shallow nearshore areas.

Larval fish were preserved in 5% buffered formalin for subsequent identification using the key provided in Cucin and Faber (1985). Larval lake whitefish were measured for total length (0.1 mm) and weight (0.0001 g). Buffered formalin was used because it proved suitable for preserving both the larval fish and their stomach contents which consisted of zooplankton. Stomach contents of 20 larval whitefish, taken in a single catch, were combined and analyzed in the same fashion as zooplankton samples (see below). Some larval fish were preserved in 95% ethanol for later otolith extraction.

Table 1. Summary of larval lake whitefish field activities, spring 1991. Site locations refer to map insets in Figs. 1 and 2.

Dates	Site locations	Activities
March 26	Makatewis Island	Fry traps and TempMentor set
March 27	Trident Point/Big Island	Fry traps and TempMentor set
April 4	Makatewis Island	Fry traps checked
	Trident Point/Big Island	Fry traps checked
April 9	Makatewis Island	Larval fish towing
		Zooplankton sampling
April 12	Makatewis Island	Fry traps checked
	Trident Point/Big Island	Fry traps checked
April 16	Trident Point/Big Island	Larval fish towing
		Zooplankton sampling
April 17	Makatewis Island	Fry traps checked
	Trident Point/Big Island	Fry traps checked
April 19	Makatewis Island	Larval fish towing
		Zooplankton sampling
April 24	Makatewis Island	Fry traps checked and removed
	Trident Point/Big Island	Fry traps checked and removed
		Larval fish towing
		Zooplankton sampling
May 1	Sherman's Point	Larval fish towing
		Zooplankton sampling
May 3	Trident Point/Big Island	Larval fish towing
		Larval fish dipnetting
		Zooplankton sampling
	Deseronto	Larval fish dipnetting
		Zooplankton sampling
May 10	Sherman's Point	Larval fish towing
		Larval fish dipnetting
		Zooplankton sampling
	Indian Point	Larval fish towing
		Larval fish dipnetting
		Zooplankton sampling
May 16	Lake Ontario	Larval fish towing
		Larval fish dipnetting
		Zooplankton sampling
May 22	Sherman's Point	Larval fish dipnetting
		Zooplankton sampling

Otoliths were used to estimate the age and hatch date of the fish by counting daily growth rings (Powles and Warlen 1988). This method was validated using known age fish (three samples, 24-, 31-, and 38-d-olds) of hatchery origin (White Lake Fish Culture Station, Sharbot Lake, Ontario. Three age interpretations were made on each otolith by each of two individuals. There were no significant differences in the interpretations by the two individuals (ANOVA, $p<.05$), hence the six interpretations for each otolith sample were averaged to give the age in days.

Zooplankton Sampling

Zooplankton sampling was carried out concurrently with larval fish towing using a Wisconsin net (OMNR 1990). Zooplankton tows were of 2 min duration. Two zooplankton tows were taken at all sites where larval lake whitefish were caught. The two zooplankton tows were combined into one integrated sample, representing a total volume of 934 l (assuming 100% flow efficiency), and preserved in buffered formalin.

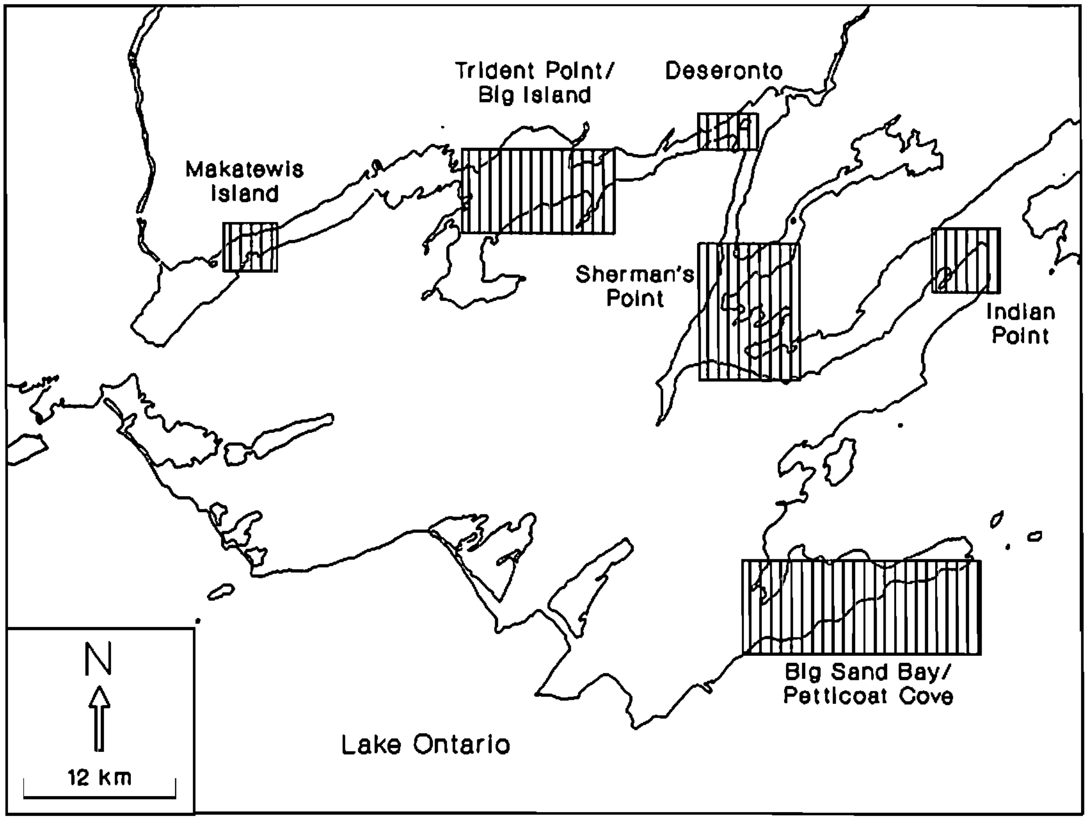

FIG. 1. Map of eastern Lake Ontario and the Bay of Quinte showing the areas of lake whitefish emergence trapping, larval fish collection and zooplankton sampling (see Table 1). Enlargements of the insets are shown in Fig. 2.

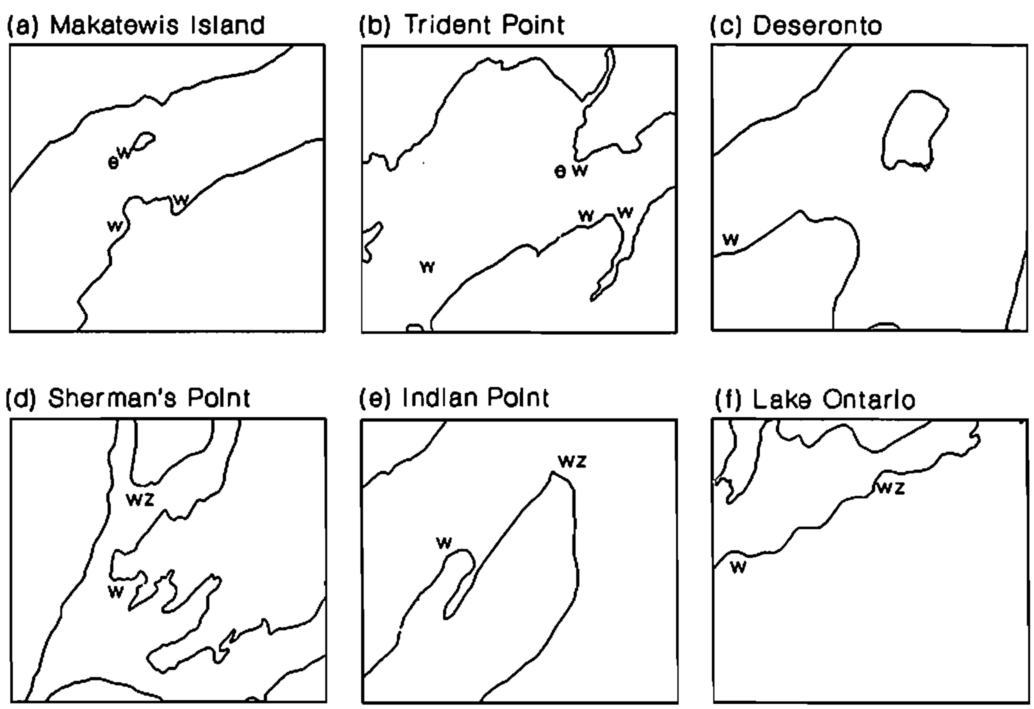

FIG. 2 (a) to (f). Enlargements of Fig. 1 insets showing areas of lake whitefish emergence trapping, larval fish collection and zooplankton sampling (see Table 1). Symbols refer to locations where larval lake whitefish were captured in emergence traps (e), larval fish tows or dipnets (w), and where zooplankton samples were taken for comparison to stomach contents (wz).

Zooplankton samples were identified, enumerated, and measured for size (maximum length measurement not including appendages).

The present report focuses on those zooplankton samples taken at locations where larval lake whitefish were abundant in order to make direct comparisons to stomach contents.

Results and Discussion

Emergence Trapping

Emergence traps were set on March 26 at Makatewis Island and on March 27 at Trident Point (Table 1). Traps were checked at both sites on April 4. A severe storm had resulted in extremely turbid water conditions and the emergence trap containers were partly filled with sediments. Traps were again checked on April 12, and nine lake whitefish were captured, six at Makatewis Island and three at Trident Point. In addition, two of three larval fish observed swimming at Trident Point were captured using a dipnet. The mean length of these fish was 13.3 mm (SE = 0.2, n = 11). All traps were checked again on April 17 and 24 but no larval lake whitefish were caught. Emergence traps were removed on April 24.

The emergence traps used in this study had been used in previous years for lake trout emergence trapping. These traps were a modified version of the trap developed by Collins (1975) for lake whitefish. The modified traps used in the present study were made with a mesh screening material which was probably too large (4 bars per cm vs. 7 bars per cm used by Collins 1975) to capture larval lake whitefish fry efficiently. This may account for the small numbers caught.

Larval Fish Sampling

The original objective of larval fish sampling was to locate larval lake whitefish, establish several fixed sampling site locations, and measure larval lake whitefish abundance. Larval lake whitefish were easily located but measurement of their abundance proved to be difficult in the Bay of Quinte using the gear and methodology employed by others (Loftus 1982; Cucin and Faber 1985).

Catches (in 5 min tows) at or near known and suspected lake whitefish spawning sites, shortly after the larval fish were known to have emerged, were very low. However, field crews readily located (visually) schools of up to several hundred larval whitefish swimming near the surface in shallow water.

The schools of larval lake whitefish were typically found in back-eddies established by currents, wind, and wave action behind points of land (Fig. 2). Further sampling focused on such areas but catches in the tow net were highly variable (mean catch-per-tow = 2.25, n = 68, C.V. = 249%). Thus, the tow net proved to be an inappropriate gear for measuring larval lake whitefish abundance in the Bay of Quinte, given the extreme patchiness of these fish.

Subsequently, attempts to index larval whitefish abundance were abandoned and further efforts were directed at obtaining larger numbers of larval fish for growth and diet studies.

A small aquarium dip net (12 cm by 20 cm) attached to a 1 m wooden handle proved highly efficient at capturing large numbers of larval whitefish from the schools described above. In this manner larval whitefish samples were obtained for follow-up growth and diet studies. Field sampling was discontinued when larval whitefish dispersed from the shallows, as surface temperatures warmed, to deeper water. No larval lake whitefish were observed in the Bay of Quinte after May 12 but the larval fish of several other species began to appear at this time. Though Fig. 2 shows only those locations where larval lake whitefish were observed or caught, most of the shoreline within the major areas (Fig. 1 insets) sampled was visually inspected for larval fish.

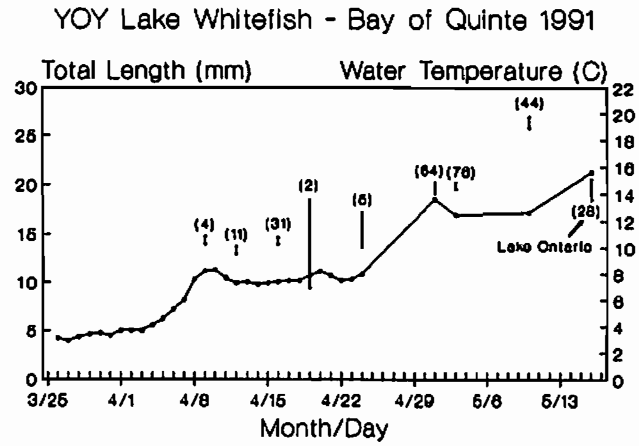

FIG. 3. Changes in larval lake whitefish total length (error bars represent 95% confidence intervals) and water temperature (continuous line) during spring, 1991, in the Bay of Quinte. The mean length for a single sample of Lake Ontario larval lake whitefish is also shown (May 16). Water temperatures were recorded continuously with a TempMentor on spawning shoal substrate from March 26 to April 24 (the figure shows a mean temperature for the two spawning sites, Makatewis Island and Trident Point). Thereafter, surface water temperatures were recorded with a hand-held thermometer on days of larval lake whitefish sampling.

Growth

Larval lake whitefish total length increased over the study period in the Bay of Quinte from 14.4 mm (SE = 0.2, n = 4) on April 9 to 26.3 mm (SE = 0.2, n = 44) on May 10 (Fig. 3). By contrast, a sample of larval whitefish collected from Lake Ontario (Big Sand Bay, 43°55'29"N 76°55'86"W) on May 16 had a mean total length of 19.5 (SE = 0.5, n = 28).

Water Temperatures

Water temperatures, as recorded by the TempMentors placed on spawning substrate near fry traps, were similar at the Makatewis Island and Trident Point spawning sites. Average daily temperatures are plotted in Fig. 3. Water temperatures rose most quickly between April 3 and April 10, from 3 to 4°C to over 8°C. The time period of rapid increase in water temperature corresponded to the first observation of larval whitefish over the spawning grounds (April 9). Water temperatures declined slightly after April 10 then remained relatively steady to the end of the fry trapping study on April 24. After this date, surface water temperatures were recorded during larval fish sampling field work with a hand-held thermometer. Larval lake whitefish disappearance from shallow water (mid-May, see above) occurred as surface temperatures rose above 14°C.

Table 2. Results of the larval lake whitefish otolith studies. Samples from the White Lake Fish Culture Station (FCS) were of known age. Assessed ages (in days) and hatch dates were determined by counting otolith daily growth rings. The Bay of Quinte (Sherman's Point and Indian Point) "known" hatch dates were based on emergence trapping results[a] (see above). Mean lengths are also provided.

Location and date of sample		Age in days		Hatch date		Mean total length (mm)
		Known	Assessed	Known	Assessed	
White Lake FCS	May 2	24	21 (n=10)	Apr. 8	Apr. 11	17.1 (n = 19)
White Lake FCS	May 9	31	30 (n=5)	Apr. 8	Apr. 9	23.9 (n = 20)
White Lake FCS	May 16	38	36 (n=5)	Apr. 8	Apr. 10	26.8 (n = 23)
Sherman's Point	May 10	-	33 (n=10)	Apr. 4 - 12[a]	Apr. 9	25.6 (n = 24)
Indian Point	May 10	-	31 (n=10)	Apr. 4 - 12[a]	Apr. 11	23.2 (n = 25)
Big Sand Bay	May 10	-	31 (n=10)	-	Apr. 17	19.5 (n = 27)

Otolith Study

Analysis of known aged lake whitefish from the White Lake Fish Culture Station indicated that counting otolith daily growth rings could be used to estimate age, in days. Age interpretations based on otoliths were 1 to 3 d less than the known age (Fig. 4, Table 2). Powles and Warlen (1988) found that, for larval yellow perch (*Perca flavescens*), the first microzone was formed 1 to 3 d post-hatch with subsequent rings formed daily. Additional work is planned to investigate the formation of the first post-hatch microzone in lake whitefish.

For the purposes of this report, I assumed that otolith age interpretations were over-estimated by 2 d in order to estimate hatch dates of lake whitefish in the field. Three samples of fish were examined: Bay of Quinte (Sherman's Point), Lake Ontario (Big Sand Bay), and a transition area between the Bay of Quinte and Lake Ontario (Indian Point).

Interestingly, estimated hatch dates for Bay of Quinte lake whitefish (April 9 at Sherman's Point, April 11 at Indian Point) corresponded closely with the hatch date (April 8) in the hatchery. The Bay of Quinte hatch dates also corresponded closely to the date upon which larval whitefish were observed in fry traps (April 12). The fry traps had previously been checked on April 4, therefore, emergence must have occurred some time between April 4 and April 12. These results suggest that lake whitefish emerge from the substrate shortly after hatching. Cucin and Faber (1985) indicated that lake whitefish are able to begin swimming immediately after hatching because of their small yolk reserves.

Larval lake whitefish from Lake Ontario were interpreted as having hatched about one week later (April 17) than the Bay of Quinte fish. Assuming that the total length of lake whitefish after hatching is about 13 mm (see Fig. 3 and the conclusions above regarding hatch and emergence dates), the Lake Ontario fish appeared to grow more slowly (0.22 mm per d) than those from the Bay of Quinte (0.41 mm per d).

However, inspection of length-frequency data for YOY lake whitefish caught in Lake Ontario Fisheries Unit Research bottom trawls show that by August, Lake Ontario stock lake whitefish are larger than the Bay of Quinte fish (Fig. 5). This observation assumes that YOY lake whitefish fish from Bay of Quinte and Lake Ontario stocks are still geographically separated in August. The assumption should be tested by conducting further studies, which include implementation of stock discrimination techniques as they become available.

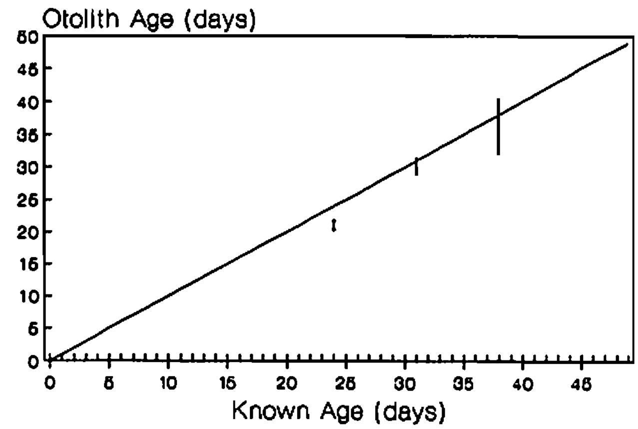

FIG. 4. Correspondence between interpreted otolith age (number of daily growth rings) and known age for three samples (24-, 31- and 38-d-olds) from the White Lake Fish Culture Station. Three age interpretations were made for larval fish examined by each of two individuals. Otoliths from five to ten larval fish from each of the three samples were examined. Points on the graph represent the mean (+/- 95% confidence intervals) for each sample. The one-to-one correspondence line is also shown.

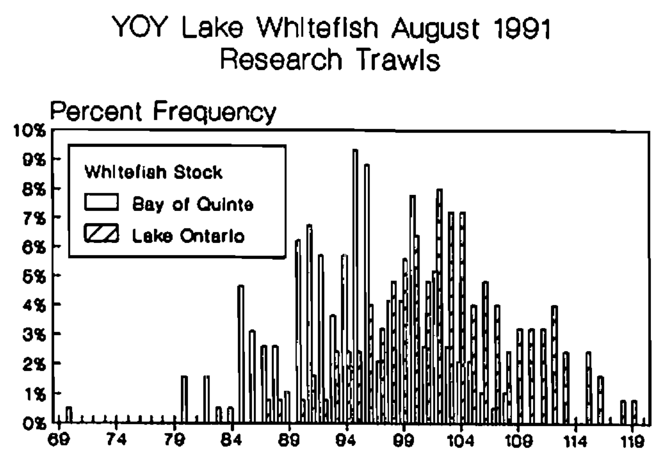

FIG. 5. Length distribution of YOY lake whitefish caught in Lake Ontario Fisheries Unit Research bottom trawls, August 1991.

Differences in water temperature regimes between the Bay of Quinte and Lake Ontario may account for differences in hatch dates as well as growth rates, but comparable water temperature data from Lake Ontario were not collected.

Diet Study/Zooplankton Sampling

A list of zooplankton species found during larval lake whitefish studies on the Bay of Quinte is given in Table 3. Cyclopoid copepodids were the most numerous prey in larval lake whitefish stomach contents, followed by the small-bodied cladocerans, *Chydorus sphaericus* and *Bosmina longirostris* (Fig. 6). These groups, along with cyclopoid nauplii, were also numerically dominant in zooplankton samples taken in shallow areas inhabited by the larval lake whitefish.

Cyclopoid copepodids and *Bosmina longirostris* comprised a greater percentage of the diet (57 and 18% by number, respectively) than in the zooplankton community (38 and 13%, respectively), suggesting a positive selection for these zooplanktors. Though *Chydorus sphaericus* was the second most common zooplankton type in the diet (19%), they were relatively more common in zooplankton samples (31%). Also, though cyclopoid nauplii were abundant in zooplankton samples (13%), they were rarely eaten (1%).

The members of the Bay of Quinte zooplankton community, as found in this study, were similar to those reported by Cooley et al. (1986) with one notable exception. *Eubosmina coregoni*, also a small-bodied cladoceran, was one of the most common zooplankton observed by Cooley et al. (1986) but was rare in the present study. Note, however, that zooplankton density in early spring, at the time larval lake whitefish inhabit nearshore waters (April to mid-May), is extremely low compared with late spring and summer densities (e.g. Fig. 3 in Cooley et al. 1986 for the seasonal pattern of *Bosmina longirostris* densities).

Larval lake whitefish selected the largest zooplankton available (Figs. 7, 8 and 9). Cyclopoid copepodids provided both the largest individuals (mean length = 0.46 mm) and the widest size range (0.3 to 0.7 mm were most common) available to the larval fish. These attributes may account for their prevalence in the diet (mean length = 0.66 mm; sizes of 0.4 to 0.9 mm were most common). By contrast, though cyclopoid nauplii were common in zooplankton samples, their small size (mean length = 0.17 mm) presumably made them a less attractive food source.

Freeberg et al. (1990) found that larval lake whitefish survival in Lake Michigan was positively correlated with the abundance of large copepod zooplankton. Growth and survival was also shown to be positively related to prey density in a laboratory study of Lake Michigan and Lake Huron larval lake whitefish strains (Brown and Taylor 1991).

As observed in the present study, larval lake whitefish were most often found in back-eddies established by currents, wind, and wave action behind points of land. Surface debris and zooplankton were also concentrated in these areas. Future work on larval lake whitefish distribution and feeding ecology should include a study designed to examine the spatial distribution of zooplankton (e.g. back-eddies vs. open water).

Table 3. Macrozooplankton taxa found during larval lake whitefish studies on the Bay of Quinte, April-May, 1991. [1] indicates that the taxon was also found in larval lake whitefish stomach contents.

Cladocerans	Copepods
Alona sp	*Calanoid copepodids*[1]
Bosmina longirostris[1]	*Diaptomis minutis*
Ceriodaphnia lacustris	*Diaptomis sicilis*[1]
Ceriodaphnia sp	Calanoid nauplii
Chydorus sphaericus[1]	
Daphnia galeata mendotae[1]	Cyclopoid copepodids[1]
Daphnia pulicaria[1]	*Cyclops bicuspidatus thomasi*[1]
Eubosmina coregoni[1]	*Cyclops scutifer*
Holopedium gibberum	*Cyclops vernalis*
Polyphemus pediculus	*Eucyclops agilis*
Sida crystallina[1]	*Mesocyclops edax*
Diaphanosoma birgei	Cyclopois sp[1]
Daphnia sp[1]	*Tropocyclops prasinus mexicanus*
Other Cladocera[1]	Cyclopoid nauplii[1]

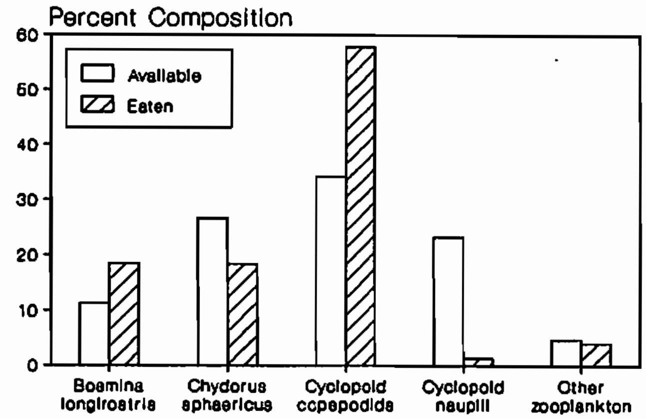

FIG. 6. Percent composition by number of major zooplankton taxa found in stomach contents of larval lake whitefish, and in zooplankton samples taken in the vicinity of the larval fish samples.

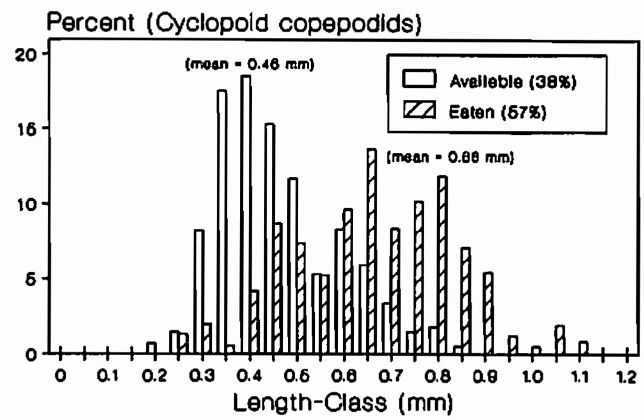

FIG. 7. Percent composition by number of cyclopoid copepodids length-classes in the stomach contents of larval lake whitefish, and in zooplankton samples taken in the vicinity of the larval fish samples. Percentages shown in legend represent the percent composition of this zooplankton taxa in the zooplankton community (available) and in stomach contents (eaten).

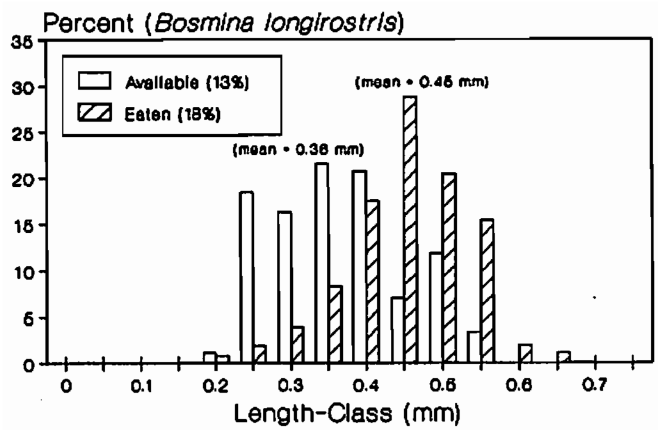

FIG. 8. Percent composition by number of *Bosmina longirostris* length-classes in the stomach contents of larval lake whitefish, and in zooplankton samples taken in the vicinity of the larval fish samples. Percentages shown in legend represent the percent composition of this zooplankton taxa in the zooplankton community (available) and in stomach contents (eaten).

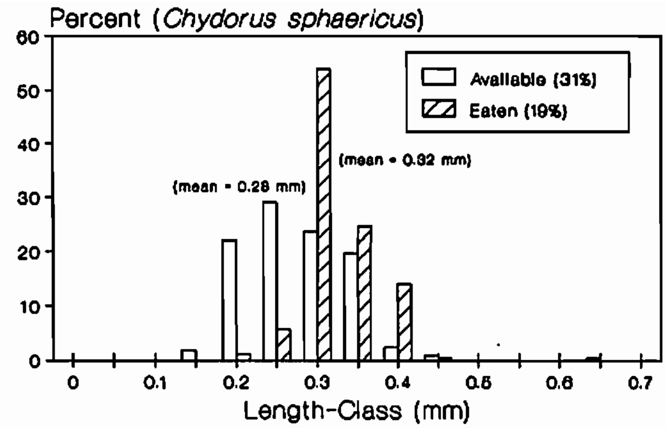

FIG. 9. Percent composition by number of *Chydorus sphaericus* length-classes in the stomach contents of larval lake whitefish, and in zooplankton samples taken in the vicinity of the larval fish samples. Percentages shown in legend represent the percent composition of this zooplankton taxa in the zooplankton community (available) and in stomach contents (eaten).

Management Implications

A potential threat to lake whitefish stocks in eastern Lake Ontario is zebra mussel (*Dreissena polymorpha*). Moderate numbers of zebra mussel were observed along Lake Ontario's west and south shores in the summer of 1990 and isolated individuals have been recorded throughout the lake, including the Bay of Quinte (Schaner 1991). Zebra mussel numbers increased further in 1991 (T. Schaner, Ontario Ministry of Natural Resources, R.R.4 Picton, Ontario, pers. comm.), and colonies are now present throughout Lake Ontario. Zebra mussel are filter feeders, subsisting mainly on algae, and have the potential to change zooplankton community structure in Lake Ontario and the Bay of Quinte via their feeding ecology.

Since zooplankton community structure, during the first seven weeks of lake whitefish life, appears to be a major determinant of year-class strength (Freeberg et al. 1990), continued assessment of: (1) larval lake whitefish diet, growth, and survival, (2) zooplankton community structure, and (3) zebra mussel invasion, is strongly recommended.

Acknowledgments

Thanks to emergence trapping and larval fish sampling field crews including, Dale Dewey, Joe Dibbits, Dave Jeffrey, Steve Lawrence, Tom Lawrence, Ambrose McCambridge, Wayne Miller, and Tim Shannon. Larval lake whitefish otoliths were extracted and prepared by Joe Dibbits and Tim Shannon. Joe Dibbits assisted with otolith age interpretations. Zooplankton and stomach content samples were processed by Bill Geiling. Tom Stewart helped produce the maps shown in Figs. 1 and 2. Al Mathers and Tom Stewart reviewed the manuscript.

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Zebra Mussel Monitoring Program on Lake Ontario, 1991.

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Lake Ontario Fisheries Unit, 1991 Annual Report, Section 6

The progress of zebra mussel invasion in Lake Ontario was monitored for the second year in 1991, using plankton samples to detect veliger larvae, and using artificial substrate samplers to detect settling mussels. Veligers were found in western Lake Ontario in greater abundance and over a greater area than in 1990, and they were for the first time consistently detected in the Kingston basin. Only few veligers were detected along the north central shore, and none in the Bay of Quinte. The artificial substrate samplers failed to collect settling mussels. Experiments with various types of artificial substrate samplers suggest that a semi-enclosed settling surface would be more suitable than the currently used sampler.

Recommendations

1. Continue the veliger survey for at least another year, to monitor the spread of zebra mussel throughout Lake Ontario. The survey can be terminated earlier in the season in September.
2. Switch to pipe or similarly shaped artificial substrate samplers.
3. The artificial substrate survey can be reduced to a single period of collection, such as installation in June and collection in September.

Introduction

Zebra mussel were first sighted in Lake Ontario in the fall of 1989 at Port Weller. In 1990 the Ministry of Natural Resources began a monitoring program, and it was continued essentially unchanged in 1991. The objective of the program is to document the progress of the invasion, and to provide timely information to the public and industry. This report summarizes the 1991 findings.

Program Overview

The two principal projects in the monitoring program were the veliger survey and the artificial substrate survey. They were carried out monthly throughout the summer and fall at 22 locations spanning the entire Canadian coastline of the lake (Fig. 1). Both types of sampling were done at the same times and locations. Additionally, a variety of artificial substrate samplers were deployed to investigate possible replacement for the Plexiglas samplers used in 1990 and 1991. In a cooperative project with Department of Fisheries and Oceans, we also collected biweekly phytoplankton and zooplankton samples at 6 sites. This was part of a long term project to assess zebra mussel's impact on the planktonic community, and the results are not reported here.

Methods

Veliger Survey

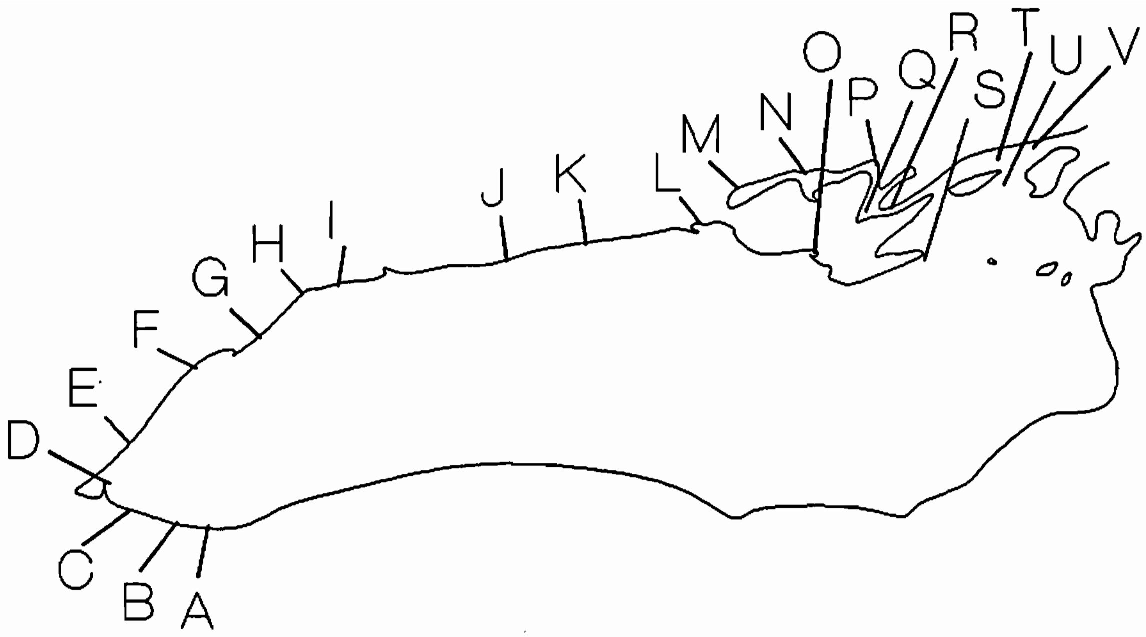
Plankton samples were taken monthly between June and October. Sampling was done at 6-8 m bottom depths. At each location we obtained a composite sample by pumping equal amounts of water from depths between 5 and 0.5 m at 0.5 m intervals, for a total volume of 250-300 l. The pumped water was strained through a 53 µm plankton net and the samples were preserved in 10% buffered formalin.

The volume of the samples was adjusted to 100 ml in the lab. Five 10 ml subsamples were processed through a sugar settling column to isolate the veliger larvae (Schaner 1991). The remaining 50 ml were kept for future plankton counts. The isolated veliger larvae were counted, and measured along a line perpendicular to the axis bisecting the hinge.

Artificial Substrate Survey

Artificial substrate samplers were installed in July, and inspected at monthly intervals between August and October. At most locations we placed single samplers at 5 m bottom depth, but at Niagara, Port Credit and Oshawa, arrays of 9 samplers were placed in a 3 X 3 grid, spaced approximately 500 m apart along the shore, at 3, 5 and 8 m bottom depths.

The samplers were made up of 152 X 152 mm (6 X 6 in) plates of 6 mm (1/4 in) thick sandblasted Plexiglas. Most of the plates had been used in the previous summer, and scrubbed clean without the use of cleaning compounds. A series of four plates were strung together with removable chain links, and suspended 1.5 m below the surface from an anchored buoy. The faces of the plates were hanging vertically. During the first inspection in August the bottom plate was removed and replaced with a clean plate, and during subsequent visits two bottom plates were removed and replaced with a single clean one. The monthly samples therefore consisted of plates that were in the water since the beginning of the survey in July, as well as



A.	Niagara-on-the-Lake		H.	Whitby		O.	Wellington
B.	Port Weller		I.	Oshawa		P.	Deseronto
C.	Grimsby		J.	Port Hope		Q.	Picton
D.	Hamilton		K.	Cobourg		R.	Glenora
E.	Bronte		L.	Presqu'ile		S.	Long Point
F.	Port Credit		M.	Trenton		T.	Millhaven
G.	Scarborough		N.	Big Bay		U.	Amherst Is.
						V.	Kingston

FIG 1. Locations surveyed in the 1991 OMNR zebra mussel monitoring program in Lake Ontario.

plates that were in the water for one month. The plates were examined in the lab under a dissecting microscope.

Experimental Artificial Substrates

The experimental substrate samplers consisted of a number of objects that have been suggested as suitable sampling devices. They were hanging from a horizontal metal pipe and weighted down by another. The following objects were used: (1) a 500 mm length of 13 mm (0.5 in) polypropylene line, (2) a 305 mm (12 in) length of 76 mm (3 in) i.d. PVC pipe, split in half lengthwise and held back together with hose clamps, (3) five microscope slides held horizontally in a plastic slide storage box with sides cut open to expose slides, and (4) three 159 X 159 mm (6 X 6 in) Plexiglas plates: one new sandblasted plate, one sandblasted plate previously used last summer and scrubbed without cleaning compounds, one new plate not sandblasted.

Three such arrays were suspended 1.25 m below the surface from a permanent platform situated approximately 1 km offshore at Hamilton. The entire arrays were removed and replaced on the same schedule as individual plates in the standard artificial substrate survey.

Results

Veliger Survey

During the first two months of the survey, veligers were found only in the western part of the lake, between Niagara and Port Credit (Table 1). Findings in this area persisted until the end of the sampling program in October. Towards the second part of the season, veligers were found in low densities in the Kingston basin (Long Point, Millhaven, Amherst Island and Kingston). The findings in the central portion of the lake were few and sporadic, and no veligers were ever found in the Bay of Quinte.

The June and July samples from the western part of the lake had the highest veliger concentrations. The detailed seasonal pattern of veliger densities is probably not well described by our observations, because the monthly sampling schedule can easily miss periods of peak abundances. It seems clear, however, that abundance of veligers is lower in the fall than in the summer.

The bulk of the captured veligers were under 150 µm long. The maximum size in the June sample was 180 µm, but in subsequent months few larger individuals (up to 29 µm) were found.

TABLE 1. Densities of veliger larvae detected in plankton samples. The density estimates have been corrected for 60% efficiency of isolating veligers by using sugar column. Hyphen indicates that no veligers were found.

Location	Density (m^{-3})				
	June	July	August	Sept.	Oct.
Niagara	985	190	6	160	6
Port Weller	239	1123	98	929	10
Grimsby	3887	4509	186	38	-
Hamilton	1129	149	1542	24	6
Bronte	151	11	116	5	5
Port Credit	40	-	170	-	-
Scarborough	-	-	46	6	-
Whitby	-	-	12	-	-
Oshawa	-	-	-	5	-
Port Hope	-	-	1	-	-
Cobourg	-	-	-	-	-
Presqu'ile	-	-	-	6	-
Trenton	-	-	-	-	-
Big Bay	-	-	-	-	-
Wellington	-	-	-	-	-
Deseronto	-	-	-	-	-
Picton	-	-	-	-	-
Glenora	-	-	-	-	-
Long Point	-	-	10	13	6
Millhaven	-	-	-	6	24
Amherst Island	-	-	-	6	-
Kingston	-	-	-	6	-

Artificial Substrate Survey

A single settled zebra mussel was found on one of the Niagara samplers in June. All other samplers at all times were found empty.

Experimental Artificial Substrates

Settled mussels were found on several of the objects (Table 2). The most successful were the PVC pipe, and the box holding the microscope slides (but no mussels were found on the slides themselves, which were actually the tested substrate). All but one of the mussels here were found on the inside of the object. Furthermore, in the pipe, the mussels were all found on or near the lengthwise cut splitting the pipe in two, or near the rim. The four mussels found on the polypropylene line were not on the exposed part that was intended for testing, but rather on a portion wrapped in electric tape, near the point where the line was attached to the sampler.

Other Observations

In October, while retrieving the samplers used in the standard artificial substrate survey, we cursorily examined the cement blocks used as anchors, as well as the first 0.3 m section of the polypropylene anchor lines at the anchor end. Moderate numbers of mussels (<100) were observed on the cement blocks at locations between Niagara and Bronte, and small numbers (<10) were observed at locations between Port Credit and Oshawa. The anchor lines were free of settled mussels, with the exception of one mussel found at Port Weller.

TABLE 2. Counts of mussels settled on various types of experimental artificial substrate samplers.

Substrate	Period in water			
	July-Sept.	Aug.-Sept.	July-Oct.	Sept.-Oct.
Polypropylene line	4	0	0	0
Plexiglas - old sandblasted	2	0	0	0
- new sandblasted	0	0	0	0
- new clear	0	0	0	0
PVC pipe	8	0	1	0
Microscope slides	1	0	0	0
Box holding microscope slides	6	0	7	0

Discussion

Distribution of Zebra Mussel

The veliger survey indicates that the southwestern portion of the lake, between Niagara and Hamilton has the highest densities of zebra mussel on the Canadian side of the lake. This distribution extends to the east along the north shore as far as the Toronto area. Lower veliger densities around the Kingston basin indicate presence of populations in this vicinity as well. The north-central shoreline (Toronto to Quinte Peninsula) was relatively free of veligers, and no veligers were found in the Bay of Quinte.

The distribution of veligers conforms to the general pattern of observations from other sources. A systematic diving survey in western Lake Ontario (Schaner et al. 1992) showed higher densities of adult mussels on the south shore between Niagara and Hamilton, than on the north shore between Hamilton and Toronto. Few mussels were found at the eastern limit of the diving survey at Whitby. In the Kingston basin area, where veligers began to appear in the fall, there have been other reports of adult zebra mussel in Kingston (D. Montgomery, OMNR, Napanee, pers. comm.), at Main Duck (J. Casselman, OMNR, Glenora, pers. comm.), and at Cape Vincent on the U.S. side (G. LeTendre, NYDEC, C. Vincent, pers. comm.), as well as reports from the previous summer. The remainder of the Canadian shoreline appears to be relatively free of zebra mussel. Veliger larvae were occasionally found in the OMNR survey along the north-central shoreline, and a single adult mussel was found by divers during an unrelated survey at Wellington. There have been no reports of incidental findings by the public along the north-central shore. Being new to this area, the mussels would presumably be noted if they were present. Similarly, there have been no reports of mussels in the inner Bay of Quinte beyond Picton, even though the shoreline is densely populated, and navigational buoys from the bay have been examined at the end of 1991 (mussels were found on a boat hauled out at Trenton in the fall of 1991, but the boat had also been in waters outside of the Bay of Quinte - D. Montgomery, OMNR, Napanee, pers. comm.).

Evaluation of the Sampling Methods

The Plexiglas artificial substrate samplers failed to collect settled mussels. Experience with the same samplers from last year indicated that zebra mussel detach themselves from the plates to migrate either to the lake bottom or to other parts of the sampler assembly. The nearly complete absence of settled mussels this year is discouraging, and the samplers should be modified in the future.

The results obtained with the experimental samplers suggest how the standard samplers may be improved. It appears that the settling mussels prefer sheltered surfaces (inside of the PVC pipe or the inside of the box holding microscope slides). They also prefer structure or discontinuity on the surface (crack in the PVC pipe, mussels settling near inside corners of navigational buoys - R. Dermott, CCIW, Burlington, pers. comm.). Various sources indicate that with few exceptions the substrate material does not matter, though steel has been successfully used in Lake Erie, and would therefore be a safe choice. The position of the sampler in the water column should also be considered, since a structure placed on the lake bottom would more closely approximate the mussel's natural habitat, and also be less prone to wave action, and to tampering by boaters.

The PVC pipes have inadvertently demonstrated another advantage of a semi-enclosed sampler: The inside of the pipe was free of algal growth, other than a narrow band around the rim. This surface was easy to inspect, and counts of settled mussels could be made with confidence. This is in contrast with the Plexiglas plate samplers, which usually became overgrown with *Cladophora*, making inspection time consuming, and possibly even unreliable.

Plankton sampling for veliger larvae proved to be dependable, producing results that agreed with the expected distribution patterns, and with information from other sources. The monthly sampling cycle cannot adequately describe the temporal variation in veliger abundances, but the survey appears to describe well the geographical pattern of mussel populations.

Acknowledgments

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Diving Survey to Determine Densities of Zebra Mussel in Western Lake Ontario in 1991.

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Lake Ontario Fisheries Unit, 1991 Annual Report, Section 7

A diving survey to estimate zebra mussel (*Dreissena polymorpha*) densities was conducted in the Canadian waters of western Lake Ontario in the summer of 1991. The survey was stratified by areas based on existing substrate information, and by depth zones. Divers observed the extent of substrate suitable for mussel colonization, and collected rock samples for later mussel counts and measurements. Density estimates were expressed as numbers of mussels per total area of the collected rocks, and conversion to numbers per bottom area is suggested. The highest densities were found in the area between Niagara and Hamilton (up to 3805 mussels per m^2 of rock surface area or 10805 mussels per m^2 of bottom area), lower densities were found on the north shore west of Toronto (52 or 148 mussels/m^2), and no mussels were collected (though some mussels were seen) in the area immediately east of Toronto.

Recommendations

1. Implement a full scale survey that includes other known areas of infestation (e.g. the Kingston basin), so that whole-lake estimates of zebra mussel populations can be made.
2. Continue using substrate maps to stratify the survey area.
3. Use echo-sounding to estimate extent of unsuitable substrate, and to direct the diving effort.
4. Clarify, through empirical observations, the relationship between rock surface area measured in collected samples, and bottom area.

Introduction

The zebra mussel (*Dreissena polymorpha*) was first detected in Lake Ontario in the fall of 1989, and started to spread through the lake in the summer of 1990. High mussel concentrations in the Canadian waters so far have been restricted to the western portion of the lake between Niagara River and the Toronto area, however, based on the Lake Erie experience documented by Griffiths et al. (1991), we can anticipate that the zebra mussel will be present in all parts of the lake within the next one or two years. Efforts are being made to document the spread by measuring relative abundance indices, such as densities of planktonic veliger larvae, and settlement rates on artificial substrate samplers (Schaner 1992).

The Lake Ontario ecosystem is monitored in considerable detail. Its recreational fisheries, and the related salmonine stocking program, are supported by intensive monitoring of the major components of the fish community. The dynamics of the commercially important predator species, and of their prey, are closely watched (Jones 1990), and attempts are currently being made to extend the study framework to include lower trophic levels. Zebra mussel, through its consumption of phytoplankton, is expected to shift the balance of the system, if it attains high densities. Information on population levels of zebra mussel is therefore central to the quantitative study of its

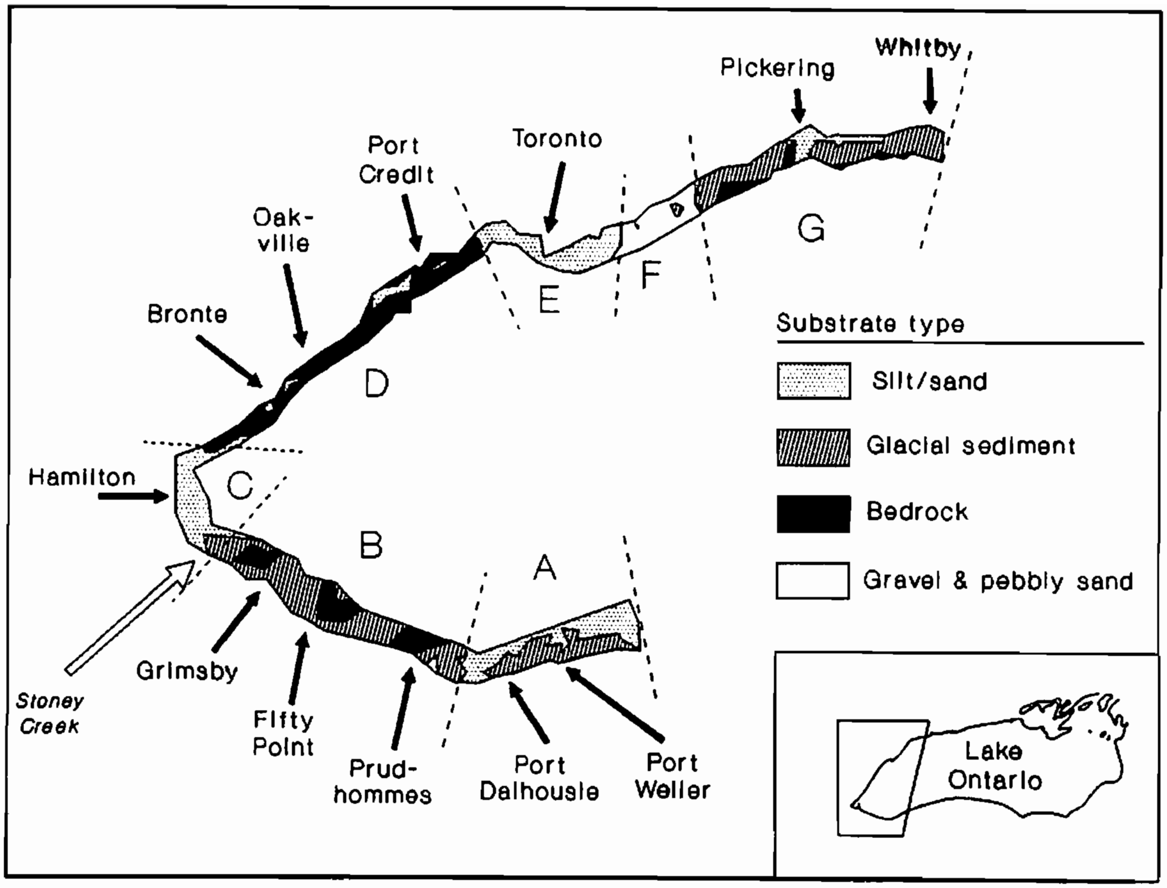

FIG. 1. Map of the survey area. The bottom morphology information which was used to stratify the survey (from Rukavina 1969), is indicated along the shoreline, together with stratum boundaries and designation. The diving sites are indicated by arrows.

effects, and to the understanding of the mechanisms by which the effects come about. To estimate densities of the mussels, and as a pilot for a whole-lake study, we conducted a diving survey in western Lake Ontario.

Methods

Survey Stratification and Diving Locations

The survey was conducted in late August and early September 1991, and covered the nearshore waters of western Lake Ontario, between the Niagara River and Whitby. Substrate maps of bottom between the shore and the 20 m depth (Rukavina 1969) indicated several areas of distinct bottom characteristics. Based on this information we established seven survey areas (Table 1; Fig. 1).

The number of sites surveyed in an area varied. Only a single site was selected in each of the areas characterized by silt or sand (areas C and E), since they were less likely to contain substrate suitable for zebra mussel colonization. Two or three sites were selected in the remaining areas, depending on the size of the area. Area F was not surveyed as a result of time constraints.

At least three dives were made at each site. They were situated along a line perpendicular to the shore, at depths of 3, 8, and 15 m, representing the 0-5, 5-10, and 10-20 m depth zones. An additional dive at 25 m was made at one site in each of the six surveyed areas, to represent depths over 20 m.

TABLE 1. Geographic strata used in the survey, and their characteristics as described in Rukavina (1969).

Stratum	Dive sites	Stratum description
A	Port Weller Port Dalhousie	Nearshore glacial sediment, offshore unconsolidated sediment
B	Prudhommes Grimsby Fifty Point	Glacial sediment with areas of bedrock
C	Hamilton	Unconsolidated sediment
D	Bronte Oakville Port Credit	Prevailing bedrock with areas of unconsolidated sediment
E	Toronto Islands	Unconsolidated sediment
F	Not surveyed	Gravel and pebbly sand
G	Pickering Whitby	Glacial sediment with areas of bedrock and unconsolidated sediment

Ten dives at depths between 6 and 20 m were also made at Stoney Creek to collect data on relationship between echo-sounder records and bottom type. The sampling here was limited to substrate observations, and no samples were brought back from the dives. The Stoney Creek area was chosen because it was known to encompass a variety of bottom types (Rukavina 1969).

Diving

A square aluminum frame, 0.7 x 0.7 m, subdivided by wire into 0.1 x 0.1 m grids was placed on the bottom at a random location and orientation. The diver described the bottom within the frame, noting the proportion of area covered by each of eight substrate categories (Table 2). The categories were based on Anonymous 1987, but one of the categories, exposed hard clay, was never seen in the dives, and will therefore not be discussed. The estimates expressed the proportions taken up by the various types in the top view, rather than the actual surface areas of the three-dimensional substrate. The grid subdivisions of the sampling frame were used as an aid in estimating the proportions. To provide some immediate information, the divers also described zebra mussel densities by quickly estimating the number of mussels visible to the naked eye per grid subdivision. Other observations included the height of relief within the frame, the length of filamentous algae, and in areas of unconsolidated overburden, the sediment thickness and underlaying substrate type. Having described the substrate within one frame, the diver flipped the frame over a marked side to examine the next plot. Ten plots were examined in each dive - five adjoining plots in a straight line, and then another five in a line 90° to the right.

Substrate samples were taken in six pre-specified frames out of the ten observed. An object, usually a rock, was collected from within the frame, closest to a reference point marked on the frame. All rocks from a dive were pooled into a canvas diving bag, and later transferred to plastic bags to be preserved in alcohol. The procedure was modified towards the end of the survey at Toronto, Pickering and Whitby, where individual rocks were placed in separate plastic bags underwater, and preserved separately.

Processing of Substrate Samples

The collected samples were examined in the laboratory. The mussels were isolated under a dissecting microscope, undamaged mussels were counted, and an effort was made to correctly determine the number of crushed mussels. The maximum shell lengths of undamaged mussels were measured on a digitizing tablet, using a microscope with a camera lucida.

The maximum dimension (length) of all rocks was measured. A subsample of five rocks from each site, representing the range of sizes, was also selected for surface area measurement. These rocks were wrapped in aluminium foil of known weight per surface area, and the surface area of the rock was calculated from the weight of the required foil (Reice 1980).

The relationship between the surface area and the maximum dimension of the rocks was examined through analysis of covariance. Simple linear regressions of surface area on length were compared between sites. The data were log-transformed in order to produce a linear relationship. Both factors, the site and the length of the rock were significant, but their interaction term was not, implying that common slopes and site-specific intercepts should be used. However, to maximize predictive power, we used site-specific slopes and intercepts to estimate the rocks' surface areas (Table 3). The total surface area of all rocks collected during one dive was calculated as the sum of the individual rocks' estimates.

TABLE 2. Categories and criteria from Anonymous (1987), used by divers to classify substrate, and pooling of categories for data analysis.

Category	Criteria	Pooled category
Exposed Bedrock		Bedrock
Boulder	>250 mm	Boulder/rubble/gravel (b/r/g)
Rubble	80-250 mm	
Gravel	3-80 mm	
Sand	<3 mm, grit	Unconsolidated
Silt	Not grit	
Soft clay	Not grit, greasy feel	

TABLE 3. Regression coefficients used to estimate rocks' surface areas from their maximum dimension. The equation was $\log_e(\text{surf.area}) = a + b^*\log_e(\text{max.dimenision})$, with units of cm and cm^2.

Transect	a	b
Port Weller	3.11	1.03
Port Dalhousie	1.38	1.65
Prudhommes	0.31	2.17
Grimsby	1.23	1.66
Fifty Point	1.70	1.61
Bronte	0.20	2.12
Oakville	0.91	1.79
Port Credit	0.28	2.01
Pickering	1.90	1.58
Whitby	1.21	1.75

Roughness Estimates from Echo-soundings

The diving locations at Stony Creek were selected specifically to compare bottom roughness estimates based on echo-sounder records from the 1968 survey (Rukavina 1969), with diving observations. The divers were placed within 10 m of the designated positions by using Motorola Mini Ranger positioning equipment. A new echo-sounding was also made at each site to confirm similarity to the historical record. In addition to the ten comparisons at Stony Creek, after completing the field work we found matching echo-sounding records from the 1968 survey for 31 dives at other sites. The matches were based on Loran C coordinates reported by the divers. Thus a total of 41 echo-soundings could be compared to diving observations.

The echo-soundings were classified into four roughness categories (Table 4) based on the maximum relief within

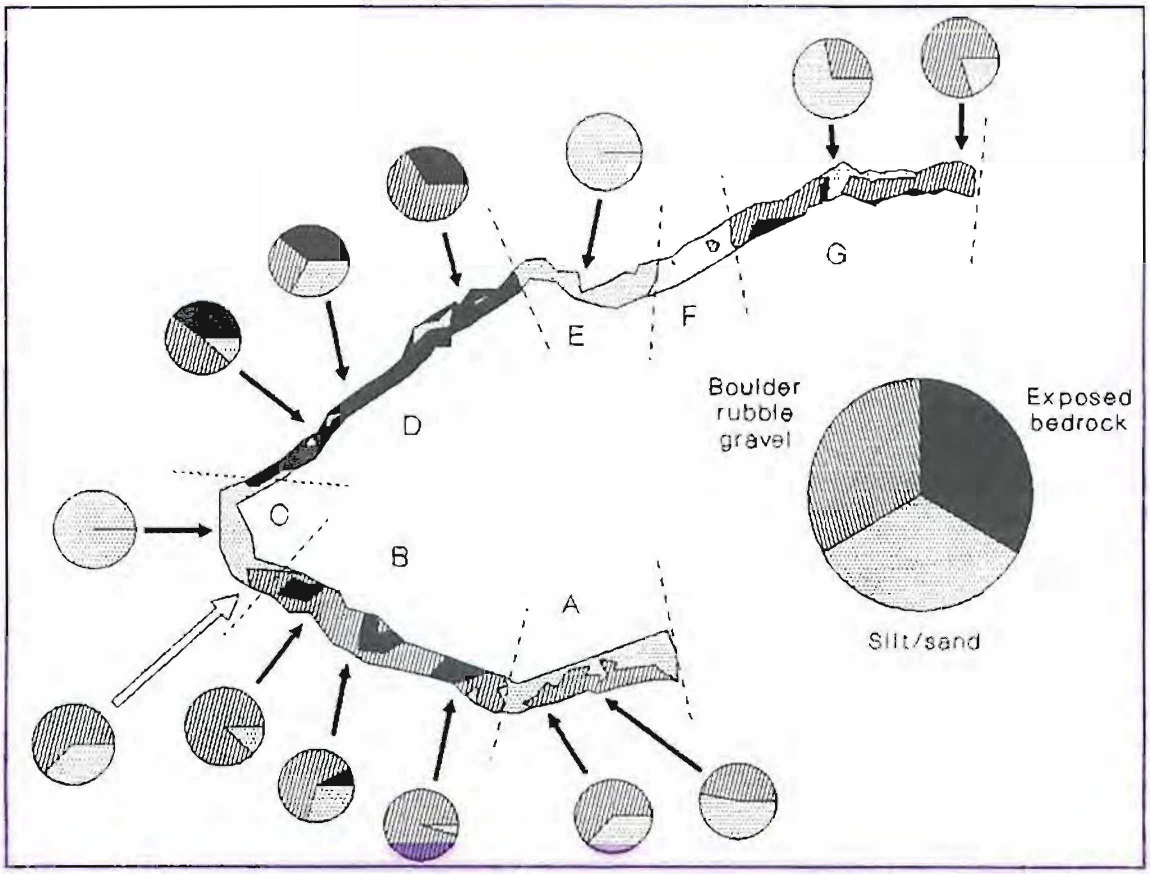

FIG. 2. Summary of divers' substrate observations. Pie charts represent divers observations pooled from all depths at a site. Substrate map is from Fig. 1.

an approximately 200-400 m section. The maximum relief was estimated as the difference between minimum and maximum depths in the section, and adjusted to compensate for the overall bottom slope, and for wave motion.

Results

Diving Observations

The eight substrate types observed by the divers were pooled into three categories in order to ease the analysis and presentation of the data (Table 2). The first two categories - bedrock and boulder/rubble/gravel (b/r/g) - are hard substrates that are suitable for zebra mussel colonization. They differ from one another in the degree and characteristics of relief, and the fact that nearshore b/g/r are moved and abraded during storms and ice periods. The third category is unconsolidated substrate, comprising sand, silt and soft clay. It is assumed to be unsuitable for zebra mussels.

The bottom observations are summarized in Fig. 2. The areas can be characterized as follows:

1) Areas C and E contained unconsolidated substrate at all depths.

2) Area D contained bedrock at all three sites. It was the predominant substrate in 4 out of the 10 dives made in the area, and some bedrock was found in 3 other dives. The other common substrate in this area was b/r/g, and unconsolidated substrate (silt) was also found, especially at the 25 m dive at Oakville.

3) Area A was characterized by b/r/g substrate (mainly gravel) at the shallow dives and unconsolidated substrate (silt) offshore.

4) In area B, b/r/g was found at all depths with the exception of the 3 m dive at Grimsby which was all sand.

5) In area G, the Whitby site had b/r/g at all three depths, though the deepest location was dominated by silt. The Pickering site was characterized by sand at all depths, except 15 m which was predominantly b/r/g.

The Stoney Creek site, which was not part of the standard survey, was characterized by b/r/g at depths up to 12 m, and unconsolidated substrate (silt) at 18 and 20 m.

The divers' descriptions of bottom characteristics were compared to the roughness estimates from echo-soundings. Table 5 summarizes the comparisons for the 41 dives,

TABLE 4. Roughness categories used to classify echo-soundings

Class	Height of relief
1	‹0.15 m
2	0.15-0.3 m
3	0.3-0.6 m
4	›0.6 m

TABLE 5. Comparison of maximum roughness estimates from echo-soundings with divers' observations. The divers' observations were assigned to a bottom type category if the type comprised more than 50% of the inspected area, otherwise the bottom was characterized as "mixed".

Maximum roughness category	Range of roughness (cm)	Divers' observations			
		Silt/sand	B/R/G	Bedrock	Mix
1	0-15	15	1	0	0
2	15-30	1	2	0	1
3	30-60	0	3	1	1
4	>60	0	12	1	3

for which corresponding echo-soundings were found. There was a good correspondence between roughness category 1 (smooth), and the presence of silt and sand. Conversely, silt and sand were not found where the roughness estimates fell into category 3 or 4. The higher roughness categories generally corresponded to boulder/rubble/gravel substrates.

Retrieved Samples

The densities of zebra mussel were calculated for each dive as the ratio of the number of mussels, whole plus crushed, to the sum of surface area estimates of the retrieved rocks. The estimates from individual dives were averaged by area and depth zone (Table 6). The densities generally decreased from area A through to area D, until zero densities were reached in area G (though divers did observe some mussels there). No suitable substrate was found in the intervening areas C and E. The differences in densities due to depth did not follow a clear pattern. In area B, the two shallower depth zones (0-5 and 5-10 m) had higher densities than the third zone (10-20 m), but the opposite was seen in area D. Unfortunately this pattern could not be confirmed in the densely populated area A, since the 10-20 m zone was covered by unconsolidated substrate and no rock samples for examination were found.

The differences in densities between areas and depths were tested in a series of one-way Anovas (combined two-factor analysis of area and depth effects was not attempted because of missing cells). The densities were log-transformed in order to standardize variances. Differences in densities between areas A, B and D were significant ($p<0.05$) in the 0-5 and 5-10 m depth zones, and not significant in the 10-20 m zone. Differences between the three depth zones were found to be significant in area B ($p<0.10$), but not significant in area D. In area A, samples were only available from the two shallower depth zones, and no significant difference was found between them.

The patterns in size composition of the zebra mussel from various areas and depth zones are less clear. It appears that there are no large mussels in deeper water - among the 48 mussels found in the 10-20 m zone there were no mussels over 15 mm. The pooled size composition of mussels from all areas (Fig. 3) also suggests that there is a higher proportion of small mussels in the 0-5 m depth zone. The significance of this observation is difficult to assess, since the pooled sample is heavily weighted by observations from area A, and a sample that is crucial to the comparison remains to be measured.

TABLE 6. Mean densities of zebra mussels in the surveyed areas and depth zones. Densities are expressed as the number of mussels per total surface area of collected rocks.

Area	Depth zone (m)	Mean density (m^{-2})	Std. dev. (m^{-2})
Port Weller	0-5	2722.7	1522.8
	5-10	3804.9	370.4
	10-20	no suitable substrate found	
	20+	no suitable substrate found	
Grimsby	0-5	263.8	159.9
	5-10	381.5	170.5
	10-20	46.5	72.7
	20+	0	-
Hamilton		no suitable substrate found	
Oakville	0-5	8.7	12.2
	5-10	13.7	4.3
	10-20	52.3	49.1
	20+	no sample collected	
Toronto		no suitable substrate found	
Whitby	0-5	0	-
	5-10	0	-
	10-20	0	-
	20+	0	-

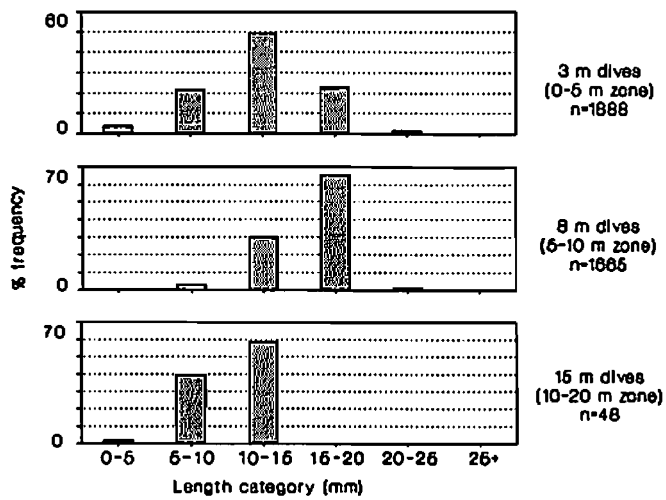

FIG. 3. Size composition of zebra mussel collected in the survey in the 3, 8 and 15 m dives. Data were pooled from all sites.

Discussion

Zebra Mussel Distribution

The overall pattern of zebra mussel densities documented in this survey generally agrees with other sources of information. The pattern of gradual decrease from area A through to area G, is similar to the pattern seen in surveys of planktonic veliger larvae (Schaner 1991, 1992), and it is also consistent with the first detection of zebra mussel at Port Weller (area A) in 1989. On a more detailed level, there are some discrepancies between the results of this and the veliger survey. The densities found in the present survey in area A were higher than those in area B. This was the pattern of veliger distribution in 1990, but the opposite of the veliger distribution in 1991. There is nothing in the size distribution of mussels collected from the two areas in this survey, to indicate differences in the timing of colonization. However, with the high settling mortality that is sometimes characteristic of the species (Mackie et al. 1989), populations of settled mussels may not reflect the veliger populations that produced them.

The depth distribution of the zebra mussel will be limited in Lake Ontario by availability of hard substrate, which generally occurs only at depths of less than 20 m. Limitations imposed by other factors, possibly related to food availability, and to the mussel's physiology, appear to coincide with the limitation imposed by substrate. In our survey, rock samples were collected only from the 3, 5, and 15 m dives, and mussels were found in samples from all three of these depths. However, the divers were also asked to make visual estimates of mussel densities during the 25 m dives, but no mussels were ever observed. Specifically, there were no mussels found in the 25 m dives at Grimsby and Oakville, where there was available hard substrate, and where mussels were present at the shallower depths. A similar restricted distribution was reported by Charlton et al.(1992), who found that artificial substrate samplers in lakes Erie and Ontario were colonized only down to depths of 10-20 m.

There is evidence that within the inhabited zone, at depths less than 25 m, the densities vary with depth. It appears that mussel densities in the 0-5 and 5-10 m zone are higher than in the 10-20 m zone, as seen in area B. This observation fits with the finding that no mussels over 15 mm were ever present in samples from the 10-20 m zone, suggesting that either or both, higher mortality and diminished growth may exist at this depth.

Density Estimates

The density estimates presented so far express the number of mussels per total surface area of the examined rocks. Assuming that the area available for mussel attachment is a constant proportion of the total surface, the statistics in Table 6 provide a good index of the intensity of colonization. However, for other purposes, such as total population estimates, it is desirable to express densities per unit bottom area. We made tentative estimates of such densities, using the following formula:

$$\frac{\#\text{ mussels}}{\text{bottom area}} = \frac{\#\text{ mussels}}{\text{rock surface area}} \times \frac{\text{rock surface area}}{\text{bottom area}}$$

Two elements are involved in the conversion of the total surface areas of the sampled rocks to measures of bottom area: (1) Rocks vary in their surface area per unit of bottom area, and (2) the proportion of bottom area covered by rocks also varies.

To approximate the ratio of rock surface area to bottom area, a few simple geometric shapes were considered. The ratio varies with the shape of the object. Flat objects have a surface area approximately twice the bottom area that they cover, or a ratio of 2.0. Spheres have a ratio of 4.0, and the ratio goes up to 6.0 for cubes. Higher ratios are possible with tall shapes standing on end, but they are of no interest here, since rocks tend to lie with their long axes oriented close to the horizontal. Rocks are probably best approximated as ellipsoids, and given the range of plausible surface to footprint ratios, a value of 3.0 was chosen, half-way between a flat object and a sphere.

The second component of the correction factor accounts for the fraction of bottom area occupied by suitable substrate. The divers described the bottom as proportions of eight substrate categories, which were then pooled as suitable and unsuitable types. The fraction of suitable substrate was therefore included in the correction factor. The overall correction factor is:

$$\frac{\text{rock surface area}}{\text{bottom area}} = 3.0 \times (\text{fraction of suitable substrate in bottom area})$$

Individual conversion factors based on bottom observations were determined for each dive, and applied to the estimate of number of mussels per total rock area from that dive. The tentative corrected density estimates are presented in Table 7. We consider the estimates to be tentative, because of the uncertainty in correcting for the ratio of surface area to footprint ratio. In future surveys this ratio can be re-evaluated through empirical measurements.

Survey Stratification

There was a correspondence between the diving observations and the bottom morphology maps that were used to stratify the survey. The maps were compiled from information based on a 1 km grid, a much coarser scale of resolution than the divers could observe. They indicate the probability with which a bottom type will be encountered in the various areas, but we were concerned that local variability would be too high for the stratification to be

TABLE 7. Densities of zebra mussel ($\#/m^2$) adjusted for the ratio of rock surface area to bottom area. Dive-specific densities were adjusted and then averaged. Areas and depths from which there were no samples are indicated by "-".

	Depth			
Area	0-5 m	5-10 m	10-20 m	20+ m
A	7598.1	10804.6	-	-
B	768.9	1004.2	126.5	0.0
C	-	-	-	-
D	26.0	37.6	148.0	-
E	-	-	-	-
G	0.0	0.0	0.0	0.0

useful. However, upon examining the diving observations, we found a consistency in occurrence and proportions of the various substrate types between dives made within an area. This indicates that the stratification by areas was successful. Only the broad characteristics of large areas were used in the stratification of our survey, but an even greater reliance on the substrate information may have been warranted. For example, the randomly selected Pickering site (area G) is shown by the substrate maps to contain sand deposits, which are otherwise not typical of the area. This was confirmed by the divers. The dissimilarity between inshore and offshore substrate in area A was also seen in the substrate maps, and confirmed by the diving observations. This information can improve the quality of the survey, by allowing better control of the effort spent in areas of low mussel densities .

Echo-sounding information can be similarly used. The relation between echo-sounding roughness estimates and bottom types was tested in this survey, even though it was not used as a stratifying tool. There was a nearly complete correspondence between the lowest roughness category and the presence of silt or sand. Echo-sounding can therefore be used to estimate the extent of unconsolidated substrate, and then to control or eliminate dives made in these areas, thereby increasing the precision and/or decreasing the cost of the survey.

Acknowledgments

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Potential To Avoid Zebra Mussels

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Artificial substrates were installed in Lake Ontario, Lake Erie, and Hamilton Harbour during 1991. The zebra mussel infested all epilimnetic substrates in Lake Erie and Hamilton Harbour. In Lake Ontario, not all epilimnetic substrates were infested because the population is still developing there. Mussels were not found on hypolimnetic substrates. Temperature recordings and turbidity profiles showed that better quality water is available further offshore than is drawn presently, and that temperatures at many depths must be recorded to find water with reliable sub spawning temperatures.

Introduction

The invasion of the Great Lakes by the zebra mussel has caused concern for changes in ecological conditions as well as economic damage. The potential for economic damage results from clogging of intake structures used for municipal and industrial water supplies. Once in the water supply system, the mussels can colonize auxiliary systems and cause plant shutdowns. Most water intakes are situated in water depths of about 10 m or less. These intake depths are ideally matched to the maximum concentration of the zebra mussel veligers which are the planktonic distribution phase (Fig. 1). Currently, the method used to cope with the infestations is to install a small pipe in the intake pipe for the purpose of pumping chlorine out to the intake opening in the lake. The chlorine then poisons the veligers and prevents any large accumulation in the system. Because some mussels may survive in the unaffected areas of intakes where chlorine is not fully mixed in the flow, taste and odour problems, due to the mussels, are not entirely prevented. Chlorination of intakes is causing the manufacture and transport of more chlorine at a time when the general consensus of environmentalists is that chlorine use should be reduced. Alternate control measures are still under development.

Since the mussels spawn in temperatures of 12°C or more, their larvae are present at a time when lakes are stratified. Thus, it is to be expected that the veligers and resulting infestations will be most prevalent in the surface waters or epilimnion of lakes. Therefore, there is often a substantial part of a lake which may have minimum exposure to the mussels. For example, Lake Ontario has an epilimnion about 20 m thick whereas the mean depth is 91 m and the maximum depth is 225 m. Thus, the majority of water in Lake Ontario is in the hypolimnion at about 4°C. In many lakes, half or more of the total volume is cold hypolimnion water which is unsuitable for spawning and unlikely to have many mussels. If zebra mussel do not colonize in these cold waters, intake structures may be moved there to avoid the mussels.

The purpose of this study was to test the hypothesis that zebra mussel infestation would be absent or minimal below the thermocline in lakes.

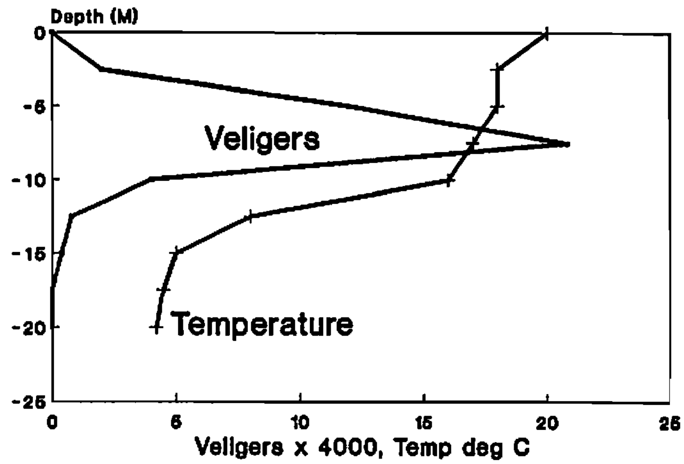

FIG 1. Vertical distribution of zebra mussel veligers in European lakes (after Mackie et al. 1989).

Materials and Methods

In Lake Ontario and Hamilton Harbour, special moorings were installed with artificial substrates at intervals from the surface to the bottom. The substrates were made of three intersecting pieces of aluminum in the form commonly used for radar reflectors. The moorings consisted of a surface marker, an anchor, a ground line to another anchor and another rope up to a subsurface buoy. Substrates were attached to the rope between the subsurface float and anchor. Additional substrates were suspended upwards from the ground line on individual ropes at various depths (Fig. 2). Moorings were installed in early May 1991, and removed in October, 1991. Temperature recordings were obtained at some sites to determine the temperature regime at depths thought to be more suitable for intakes. Profiles of temperature, turbidity, oxygen, pH, and conductivity (Ford and Charlton 1984) were recorded

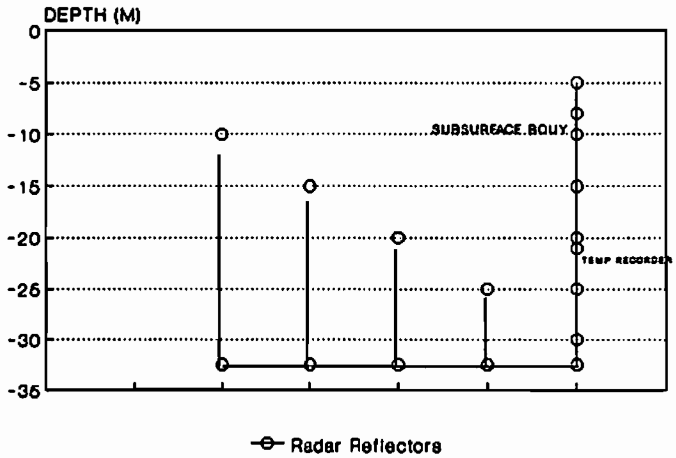

FIG. 2. Mooring used for zebra mussel depth distribution studies in 1991.

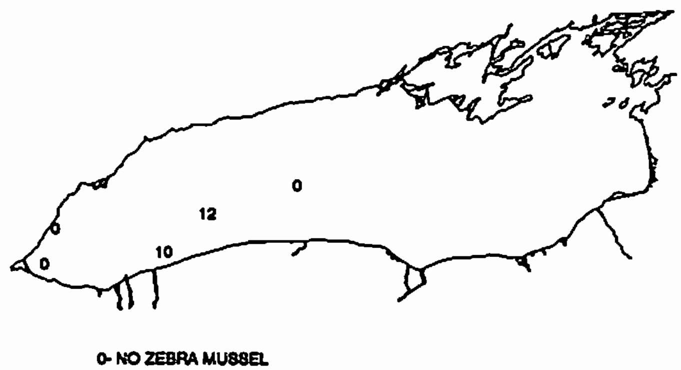

FIG. 4. Maximum depths (m) of zebra mussel infestation on moorings in Lake Ontario 1991.

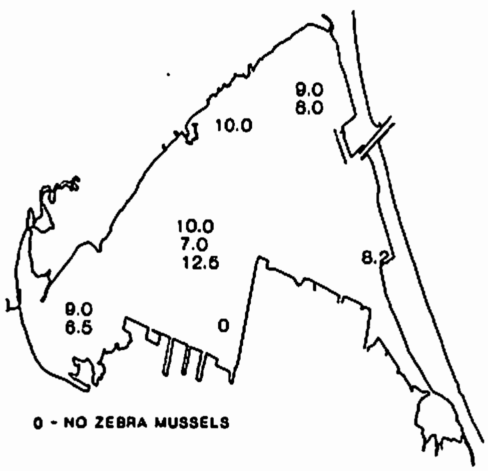

FIG. 3. Maximum depths (m) of zebra mussel infestation on moorings in Hamilton Harbour 1991.

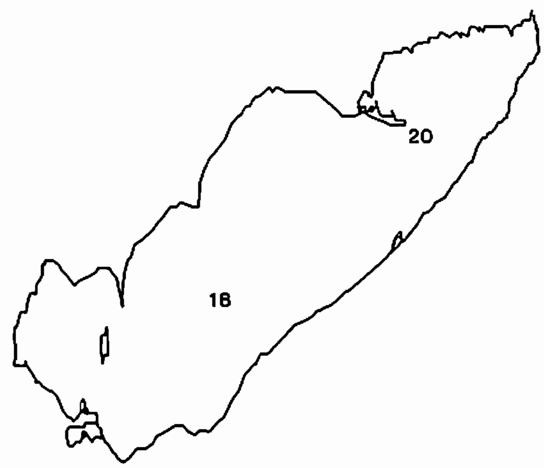

FIG. 5. Maximum depths (m) of zebra mussel on moorings in Lake Erie 1991.

at transects close to the moorings, on several occasions, to determine the quality of water available which may be free of mussels.

Results

Hamilton Harbour

Zebra mussel colonized extensively in the harbour during 1991. Equipment in the harbour comprised sediment traps and current meters as well as a special mooring which was at the centre of the harbour. Maximum depths of zebra mussel colonization are summarized in Fig. 3. At shallow stations in the east and west ends and along the north shore, the mussels extended from the surface to the bottom at 10 m. Individual observations at various times were less than 10 m. In the centre of the harbour and in the south east corner where the depth is 20 m the maximum depth of colonization was 12.5 m.

Lake Ontario

Adult mussels and veligers have been found at stations near shore in Lake Ontario (Schaner 1991). The presence of veligers is, however, sporadic even near shore. Our stations were offshore some kilometres to obtain depths below the thermocline (Table 1).

TABLE 1. Description of Lake Ontario Stations.

Station	Location	Distance offshore(km)
674	Oakville	2.7
690	Hamilton	6.8
209	East of Niagara R.	7.3
623	Olcott	17.3
403	Centre of lake	27.0

Maximum depths of zebra mussel colonization are summarized in Figure 4. Colonization of apparatus was restricted to stations east of the Niagara River (209 and 623). Three of the five moorings inspected had no mussels at any depth.

Lake Erie

Two moorings in the centre of the east and central basins were colonized to depths of 20 m and 18 m respectively (Fig. 5). These moorings were for the purpose of recording oxygen and temperature in the hypolimnia. Bottom depths at these stations were 60 m and 22 m. The thin hypolimnion in central Lake Erie was nearly anoxic by the end of August but the thicker hypolimnion in the

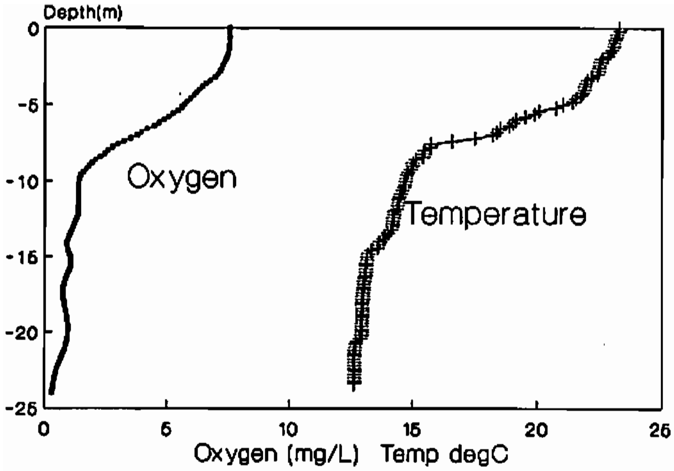

FIG. 6. Typical profiles of oxygen and temperature in Hamilton Harbour during August.

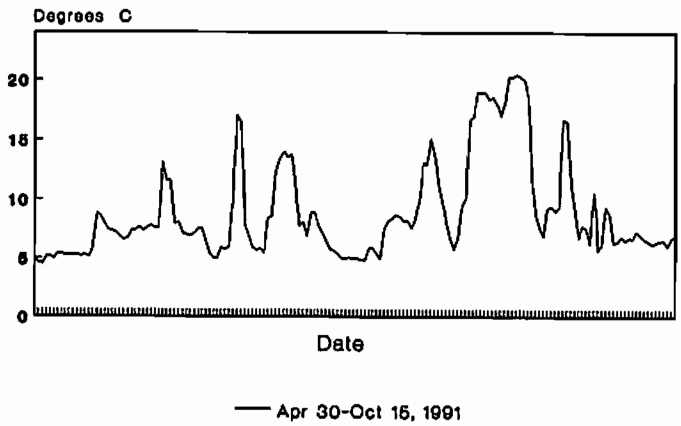

FIG. 7. Daily maximum temperature at a depth of 21 m at station 690 off Hamilton.

east basin was well oxygenated during the entire season. The horizontal distribution of veligers is complete in Lake Erie since structures in the middle of the lake are colonized despite the large distance from the spawning adults.

Discussion

All observations were consistent with a lack of zebra mussel recruitment below the thermocline. The special moorings were designed to minimize the redistribution of mussels down the mooring from active colonization zones in the epilimnion. This may have been unnecessary because even in Lake Ontario and east Lake Erie where oxygen conditions were favourable the mussels did not appear on the moorings below the thermocline.

The distribution of mussels on moorings offshore in Lake Erie and Lake Ontario was fundamentally different. Even though Lake Erie is larger than Lake Ontario the mussels infested structures in Lake Erie when similar structures in Lake Ontario were not infested. This is probably due to the relatively new population in Lake Ontario. The two Lake Ontario locations with infested moorings were probably exposed to veligers in Lake Erie water flowing out the Niagara River. Nevertheless, the infestation did not extend to even the full depth of the epilimnion at these stations.

Low oxygen conditions in the hypolimnia of central Lake Erie and Hamilton Harbour (Fig. 6.) may have contributed to the depth effect. This may be particularly true in the harbour because the water temperatures were often close to 12°C. At this time, the hypolimnion of Hamilton Harbour would seem to be a safe source for industrial water.

The radar reflectors were used to provide a substantial surface area for infestation at discrete depths. Amusingly, zebra mussel were attached to the inexpensive polyethylene rope used to construct the moorings in preference over the metal panels in our early observations. Also, mussels attached to the radar reflectors tended to accumulate mostly in the corners. Assuming impingement on the panels was random we surmise the mussels moved to the corners after they settled on the panels. We have observed mobility of the mussels in aquaria in which individuals travel 10 cm or more per day on the glass walls. These observations perhaps challenge attempts to detect zebra mussel infestation by using plankton nets to capture veligers. It seems that the mussels will settle on almost anything and that a sizable number of veligers must come from a noticeable number of adults. If enough inexpensive substrates such as polyethylene rope are available the mussels will become apparent within a short period of time after the veligers are seen if not before. Standardized settling apparatus would seem interesting but we observe mobility behaviour which may respond to predation, water movements, or even light. Thus, standardized substrates would seem comparable only in limited areas if physical and biological variables are not controlled.

Success in avoiding zebra mussel would depend on avoiding the water containing veligers. This is not straightforward in Lake Ontario. Figure 7 shows temperature recordings at a station near Hamilton, typical of all stations, made during the spawning season. Clearly, even at a depth of 21 m in Lake Ontario, periods of downwelling occur which result in the presence of temperatures greater than 12°C which could be consistent with veliger production. These temperatures can occur at greater depths along the south shore due to the predominant southwest wind. Therefore, sites proposed for water intakes will have to be monitored for the occurrence of downwelling.

The majority of the water intakes on Lake Ontario are at a depth of about 10 m. Surprisingly, the sewage outfalls are in similar depths. The water intakes are often overlain with turbid water from rainstorm runoff and re-suspension of sediment. Additionally, the intakes sample the shallow water of the lake which responds to shoreline nutrient loads by growing *Cladophora* and producing taste and odour problems. Figure 8 compares temperature profiles and percent transmission of white light at a nearshore station (#633) and at an offshore station (#637) with a depth of 35 m . Offshore, surface water clarity tended to be better. At depths below the thermocline, clarity was markedly better. Thus, there is the possibility that water treatment plants could benefit by drawing better quality water if intakes were moved to deeper water. The practicality of deeper sites is partly affected by the distance from shore of the desirable water and the desire of communities to discontinue chlorine use for zebra mussel con-

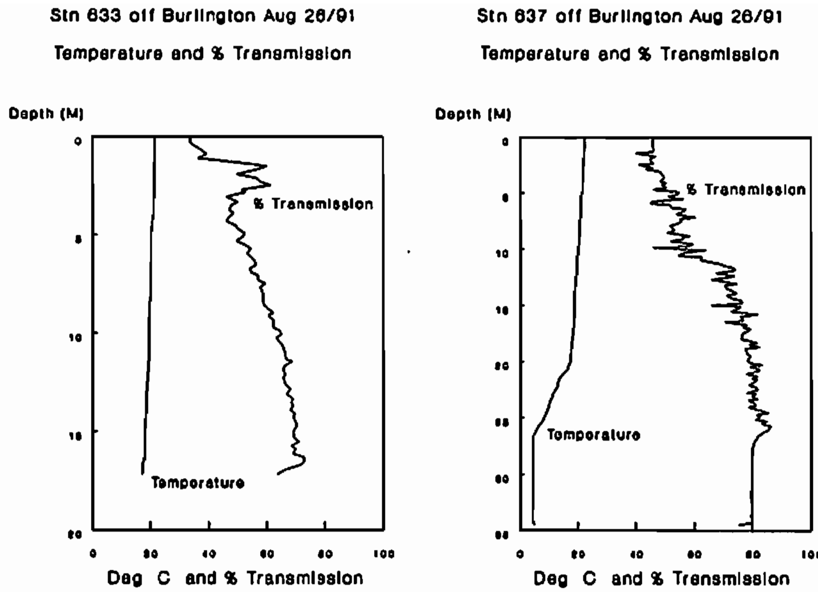

FIG. 8. Comparison of temperature and percent transmission of white light at station 633 nearshore and at station 637 at a total depth of 35 m.

TABLE 2. Distance offshore to lake bottom depth for selected Lake Ontario cities.

City	Distance offshore (km) to bottom depth	
	30 m	40 m
Hamilton	6.4	10.2
Burlington	2.5	3.5
Oakville	2.1	3.2
Toronto	0.7	1.1
Rochester	5.2	6.2
Oswego	3.3	3.6

trol. For many communities deep water is available close to shore (Table 2).

Conclusions

Zebra mussel did not occur below the thermocline and thus the observations support the hypothesis that intake problems may be avoided even in lakes infested with mussels. There may also be concomitant advantages in moving the intakes to draw from deeper water. The observations should be repeated.

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Radio Biotelemetry Survey of Lake Trout Spawning Sites on Lake Ontario - A Feasibility Study.

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Lake Ontario Fisheries Unit, 1991 Annual Report, Section 9

An aerial radio biotelemetry system, designed for the study of spawning lake trout on Lake Ontario, was field tested. Despite less than an optimum antennae configuration, radio-tagged fish could be detected to a depth of 7 m, large offshore areas were systematically surveyed at night, and the position of tagged fish was estimated from aerial surveys to within 500 m of shoreline. Tagged fish activity was consistent with spawning behaviour, and several unique areas of fish activity were identified. At Wellington, tagged fish activity was highest, and at least two individual fish were active in this area. The Wellington site, and two other sites of fish activity (Athol Bay and Spencer Point) were investigated from shore and by diving. At Athol Bay, it was determined that the fish had died or lost its tag. At Spencer Point no areas of extensive rubble or eggs were found. At Wellington, spawning behavior was observed and egg deposition confirmed. Median egg densities were estimated at 42 eggs/m^2, although most eggs (72%) were dead. The spawning rubble extended to a maximum depth of 1.5 m and substrate thickness was only 15 to 30 cm. Survival of lake trout eggs at this site is expected to be low.

Recommendation

1. Implement a full-scale radio biotelemetry study of spawning lake trout on eastern Lake Ontario in 1992, or as funding and staff are available.

Introduction

Native stocks of lake trout were virtually extinct from Lake Ontario by 1950 (Christie 1973). A major international effort is under way to re-establish a naturally reproducing population of lake trout under the auspices of the Lake Ontario Committee of the Great Lake Fisheries Commission, and guided by the *Joint Plan for the Rehabilitation of Lake Trout in Lake Ontario* (Schneider et al. 1983). Stocking of lake trout began in the early 1970s, and since 1985, approximately two million yearling lake trout have been stocked annually (Savoie and LeTendre 1991). Surveillance programs have shown that natural recruitment to the yearling stage is negligible despite a build-up of mature stocks and deposition of viable eggs (Casselman 1991; Schneider et al. 1991).

It has been hypothesized that early spawning, at warm temperatures, prior to natural cleaning of the spawning substrate by wave action, generated by fall winds, has resulted in impaired survival of lake trout eggs (Casselman 1991). However, few Lake Ontario spawning sites have been examined in detail, and observations at specific sites are difficult to put into a whole lake context. For example, lake trout have been observed spawning on shallow man-made breakwaters in most regions of Lake Ontario. Breakwaters are often small and can be subject to extreme wave action and ice impingement at shallow water depths (Sly and Schneider 1984). Similarly, lake trout in spawning condition have been seen congregating at river mouths and traveling upstream in tributaries (Marsden and Krueger 1991). Before we can determine the significance of such observations, we need to evaluate how prevalent these types of spawning behaviors are relative to the selection of traditional sites. Without this knowledge, and some determination of spawning success, it is not clear how vigorously a particular site should be protected or rehabilitated. Central to an understanding of the failure of hatchery lake trout to reproduce is a broad knowledge of spawning site selection, intensity of use, and timing of egg deposition. However, the size of Lake Ontario has precluded the development of a Lake Ontario archetype of spawning site selection and characteristics. The value of such an archetype would be to: (1) identify important spawning sites for protection or rehabilitation, (2) put spawning sites currently studied by researchers into a whole lake context by determining if they are typical, (3) facilitate further study by allowing researchers to choose

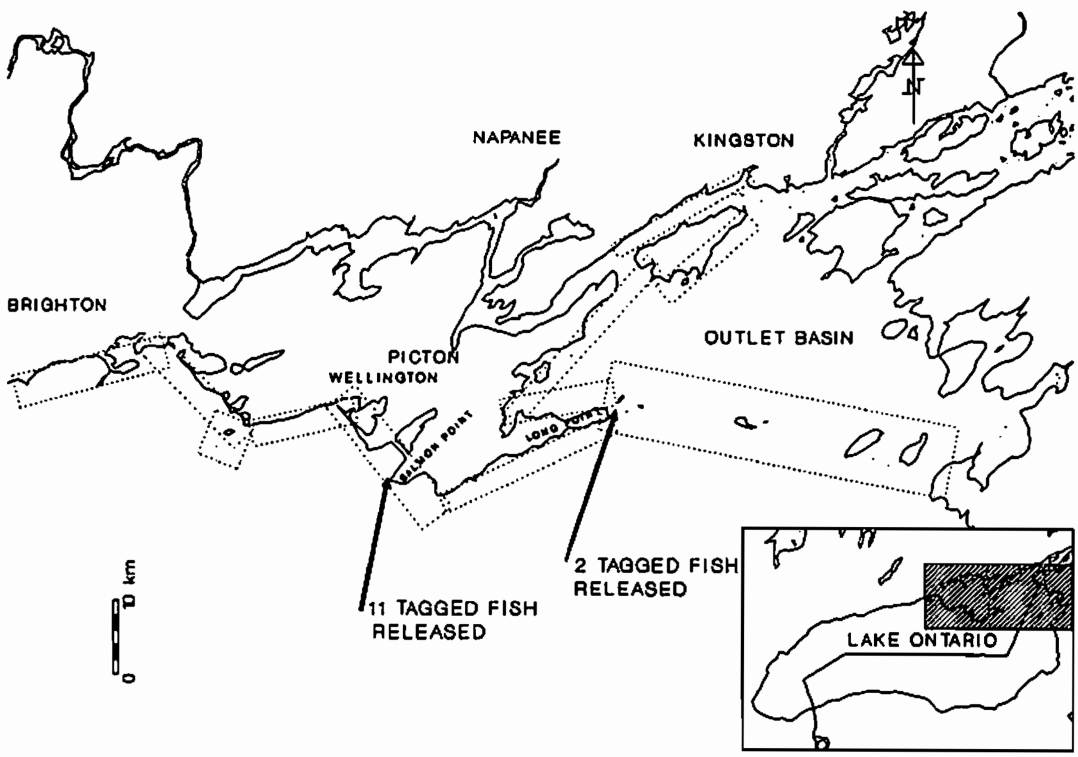

FIG. 1. Eastern Lake Ontario study area. The dotted polygons represent the approximate locations of principal aerial search grids surveyed during the study.

sites with characteristics most conducive to testing particular hypotheses, and (4) provide a test of the hypothesis that hatchery lake trout are predominantly choosing sites or spawning times that severely limit the survival of eggs.

The first step in describing a typical lake trout spawning site would be to systematically locate and characterize a large subset of sites in Lake Ontario. The tracking of fish movement using ultrasonic transmitters has been used to locate lake trout spawning sites in smaller lakes (MacLean et al. 1981; McMurtry 1986). The size of the area to be searched, and extreme weather conditions preclude the use of this technology on Lake Ontario, as fish must be tracked from a boat equipped with an underwater hydrophone. The feasibility of daytime aerial tracking of radio-tagged fish has been demonstrated for Lake Ontario (Haynes and Keleher 1986), however, lake trout spawn at night. Therefore, we set out to develop a nighttime aerial tracking system to monitor lake trout movement during their spawning period. The intent of this study was to demonstrate that this system could be used to effectively search a large area and accurately locate lake trout spawning sites.

Materials and Methods

All field work was completed during the fall of 1991. The study area was the nearshore (depth <10 m), and offshore groups of shoals and islands of eastern Lake Ontario (Fig 1).

Fish Tagging

Over the period from September 5-13, several attempts were made to capture lake trout in the Outlet basin using approximately 100 m of 64 mm mesh gillnet set, overnight, at temperatures less than 12°C. Warm water temperatures resulted in fishing efforts concentrating in water of 15-18 m depth. Only two fish thought to be in good condition for tagging were captured by this method. On September 25, the remaining study fish were obtained from a commercial fisheries trapnet, set in the Wellington area.

Captured fish were placed in cool water (11-16°C) in an aerated live well. Individual fish were prepared for tagging by placement in a solution of anesthetic (MS222). Once the fish had lost equilibrium, radio tags were applied. The radio tags (Lotek Engineering Inc., Aurora, Ontario) were cylindrical in shape, 1.9 cm in diameter by 9.6 cm long, and weighed approximately 35 g. A spinal needle was used to produce a 0.5 mm hole through the musculature below the dorsal fin. Using the needle as a guide, the tag attachment wire was threaded through these holes, back to the transmitter, and permanently fastened. A neoprene backing plate was used to prevent erosion of the flesh by the attachment wire (Fig. 2). The entire tagging procedure usually took less 2 min per fish.

Tracking

The radio tags operated at 149.928 and 149.958 MHz and the output signal was digitally coded to allow for identification of individual fish. A five element, Yagi receiving antennae (Model 206, Sinclair Radio Laboratories, Aurora, Ontario) was mounted below the fuselage on each side of a Twin Otter aircraft. Unfortunately, the desired aircraft mounting bracket and antenna configuration could not be constructed in time to complete the study. The available aircraft mounting bracket was designed for terrestrial tracking at a frequency of 160 MHz and thus antennae element spacing and orientation were not

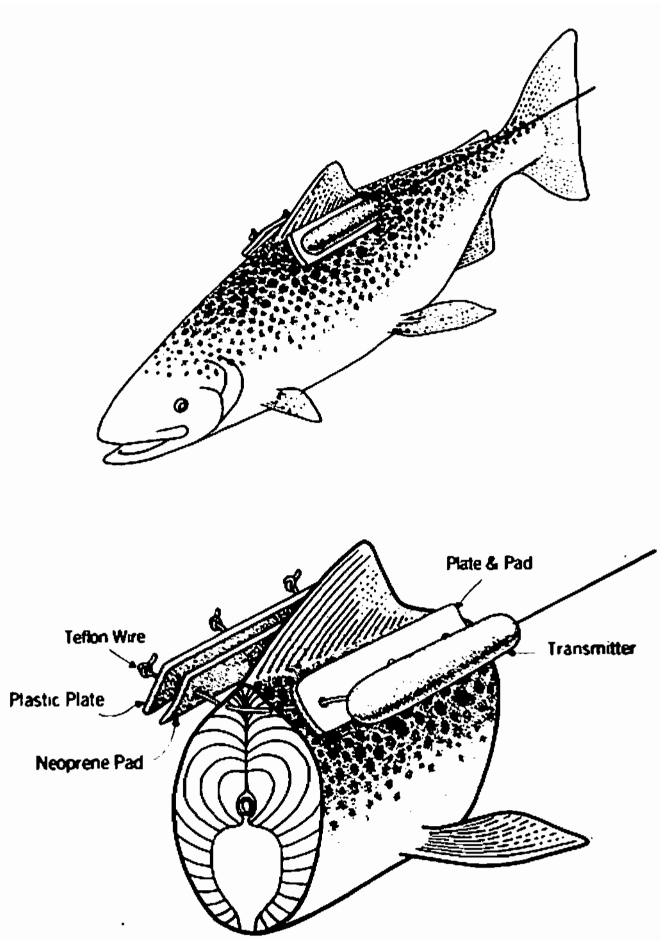

FIG. 2. Illustration of the method of tag attachment (from a study of brown trout, Haynes and Nettles 1983).

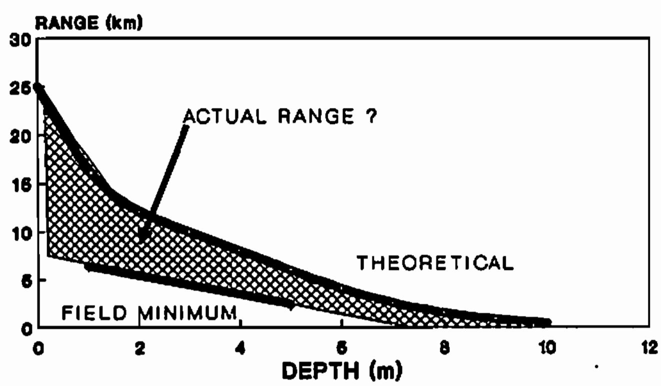

FIG. 3. Relationship between the depth of a radio tag and the range at which it can be detected during aerial surveys. The upper line represents a theoretical maximum, and was based on earlier field trials (Lotek Engineering Inc. 1990). The lower line, designated as "FIELD MINIMUM", was based on limited empirical measurements done during this study. The actual range is within the shaded area.

optimized. The antennae was tuned close to 150 MHz, but the overall loss of detection sensitivity was considerable (>20%). A four element Yagi antenna was used for detection of radio signals from the ground. Prior to the survey, field trials with reference tags at known depths were completed to confirm system performance. The system environment and signals successfully decoded were logged automatically by the receiver (Model SRX-400, Lotek Engineering Inc.). Audible, but undecoded signals, were logged manually.

All aerial tracking was done, at night, from October 22-25, at an altitude of approximately 300 m. Aircraft position was continually logged by recording LORAN-C navigational data directly from the aircraft navigational system using a lap-top computer (Hill and Senese 1991). Schedules and activities varied each night as alternative searching and positioning techniques were tried and various geographic areas were systematically searched. The entire study area (Fig. 1) was searched once, while areas of tagged fish activity were searched several times on successive evenings. The approximate position of a fish was estimated by plotting aircraft position and radio signal logs using geo-referencing computer software (QUIKMAP, Environmental Sciences Limited, Sidney, British Columbia). Estimates of aircraft position were corrected for known sources of bias caused by the inherent inaccuracies in digitized maps and mapping software. Reference flights over visually distinct points of land confirmed the validity of these corrections. Interpretation of fish position accounted for a time lag in detection and logging of received radio signals.

Spawning Site Verification

On October 31, a ground crew attempted to verify the location of tagged fish, as determined by aircraft searches, using a hand-held four element Yagi antennae and receiver. Shorelines were examined for the presence of spawning fish. Areas of suspected spawning activity were searched by divers on November 22, to confirm egg deposition.

Results

Fish Tagging

A total of 13 fish were tagged and released; two fish near Long Point on September 6, and 11 fish at Salmon Point on September 25 (Fig. 1). All fish were tracked immediately after release to confirm that they were swimming actively.

Range

The tracking system was originally designed to detect a tag at a maximum water depth of 10 m using a 1 km search grid. (Lotek Engineering Inc. 1990). As described above, the depth range of the tracking system was below our design expectations because of the unavailability of the appropriate mounting bracket for the Twin Otter aircraft. Field trials with the final configuration confirmed a detection range of at least 5 m, but we expect that our actual range was likely somewhat higher (Fig. 3). Extrapolating from our field trials, we estimate conservatively that tags at a depth of 7 m would be easily detected within our search grids. Lake trout spawning in the Great Lakes

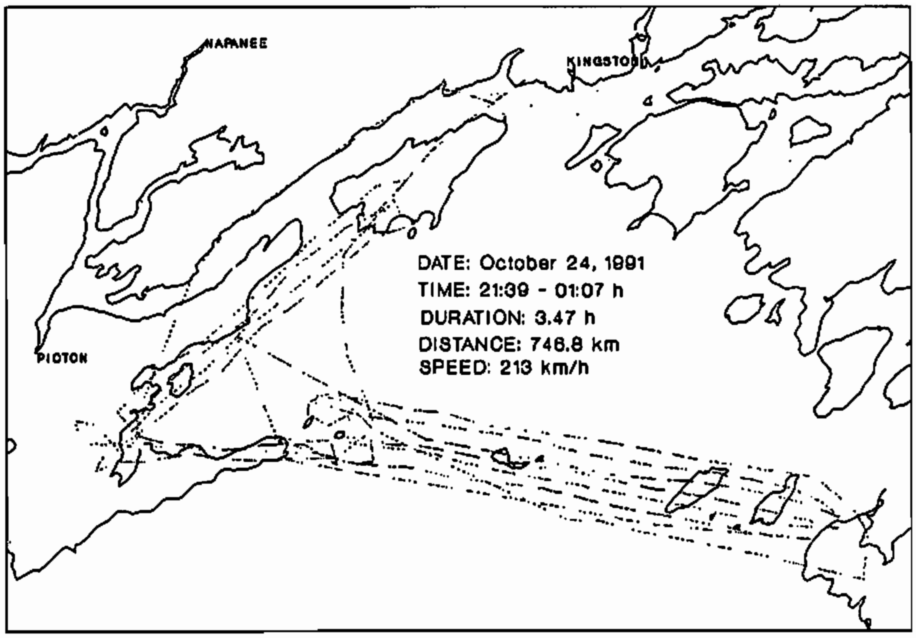

FIG. 4. An illustration of a typical night's aerial search. The dotted line represents the actual flight path of the survey aircraft.

usually occurs at shallower water depths (Thibodeau and Kelso 1990). We estimate that the water depth at which radio signals could be decoded, such that individual tagged fish could be identified, was limited to <2 m.

Searching

Critical to the application of radio biotelemetry to locate lake trout spawning sites is the ability to efficiently search large areas of Lake Ontario at night. Aircraft ground speed, during searching, ranged from 190 to 215 km/h and the navigational systems allowed for precise search grids to be established and maintained (Fig. 1). The result was a very efficient searching capability. For example, using a 1 km grid spacing, approximately one-half of the study area, covering a distance of 750 km, was searched in 3.5 h of flying time (Fig. 4).

Pinpointing Tagged Fish Location

The high aircraft speed, and the broad detection range of shallow tags, meant that only general areas of fish activity could be determined by flying search grids. To be effective as a tool for the study of spawning lake trout, more precise positioning of tagged fish is necessary. The approach we used was to "box-in" a tagged fish by flying a series of perpendicular flight paths while alternating between the left and right antennae. The tag was assumed to be on the side of aircraft that was receiving the strongest signal.

A chance event gave us the opportunity to confirm the effectiveness of this strategy. One tagged fish never changed position throughout the study and its exact position was subsequently determined (as described below under the heading Fish Activity). This allowed us the opportunity to verify the accuracy of our estimates of tagged fish position as determined from the air. In this example, the first flight line, which ran from the southwest to northeast, indicated a moderately strong signal to the right of the aircraft (Fig. 5). In response, the pilot was asked to fly a perpendicular line to the east. Subsequent flight lines essentially "boxed" the tag into an area represented by about 500 m of shoreline (Fig. 5).Certainly, this degree of resolution is adequate to guide ground-based searching efforts to pinpoint the location of a tagged fish.

Fish Activity

Based on the results of our field trials, mapping and subsequent interpretation of aircraft position and radio signal logs, a general pattern of fish activity was determined. Only one of the tags was decoded, such that, we were forced to rely on tag frequency and separation of tag position in time and space to distinguish individual fish. The first evening of flying (October 22) was used to test equipment and establish a reference line for the search grids. No attempt was made to determine tagged fish position.

On the second evening (October 23) a partial search of the western sector of the study area was completed from 21:00 to 23:30 h. General areas of fish activity, identified during the search, were surveyed again from 02:00 to 03:40 h to pinpoint tagged fish location (Fig. 6). Tagged fish position "A" and "B" were detected only on one occasion and their exact position was never fixed. We interpret these signals as coming from fish inhabiting deep water because signals were very weak and intermittent. Tagged fish position "C" was detected as a weak signal early in the evening on a flight line hugging the shoreline. Subsequent searching, using the "boxing" strategy described above, pinpointed the location of this fish some distance offshore near Spencer Point. There was considerable movement of tagged fish in the vicinity of Wellington (tagged fish position "E"-"F"). Early in the evening we detected a very strong signal on a flight line directly over the harbour entrance (tagged fish position "F"). Subsequent flights indicated a strong signal about 2 km to the west (tagged fish position "D") and ap-

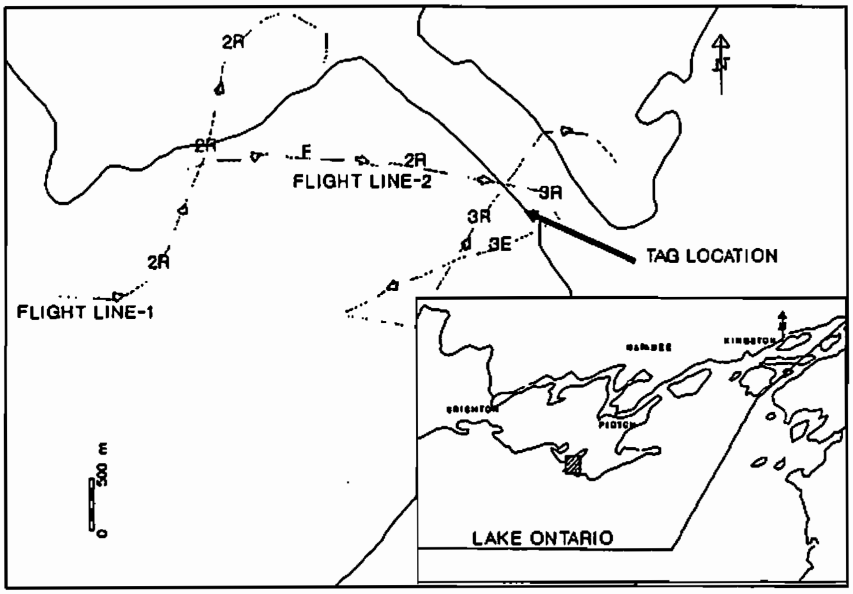

FIG. 5. An illustration of the method used to pinpoint tagged fish position. The dotted lines represents the flight path of the aircraft. The numbering of flight line labels indicates an estimate of signal strength (1 = weak, 2 = moderate, 3 = strong). The lettering indicates the direction of the signal determined by alternate switching between antennae (F= first detected, R = right, L= left, E= equal).

proximately 13 min later a strong signal was detected again close to the harbour entrance. We interpret these signals as the activity of at least two fish. Finally, later in the evening only a brief weak signal could be detected in this area offshore (tagged fish position "E"). The tagged fish position "G" at the southeast corner of Athol Bay did not change throughout the evening.

On October 24, we concentrated on a systematic search of the eastern sector of the study area, from 21:40 to 01:00 h, as illustrated in Fig 4. Radio signals were never detected in this sector of the study area. Later in the evening (02:00 to 04:00 h), we returned to the Salmon Point area to continue searching. No fish were detected in the vicinity of Wellington and two new tagged fish positions ("H" and "I") were evident (Fig. 7). We did not pinpoint the location of tag position "I" only knowing that it was south of Salmon Point and at times could be heard simultaneously with tag position "J" (see "G", Fig. 6), which again did not change position.

On October 25, we concentrated on a search of the areas west of Wellington, from 20:50 to 22:30 h, in an attempt to again detect the weak tag signals evident in this area on October 23 (tag position "A" and "B", Fig. 6). No signals were detected on these flights. We then returned to the Salmon Point area until 22:30 h and attempted to "box-in" the tag detected south of Salmon Point the previous evening. We were successful in pinpointing the location of the tag (Fig. 8). We interpreted tagged fish position "K" as a fish inhabiting moderately deep water (never able to get a strong signal) close to shore east of Salmon Point. Tag position "L" (see "G", Fig. 6; see "J", Fig. 7) had not changed.

Confirmation of Spawning Activity

Based on an initial analysis of tagged fish position, a ground crew was sent to accurately locate tagged fish at Wellington, Spencer Point and the southeast corner of Athol Bay during the early evening on October 31. The entire shoreline from a point 3 km west of Spencer Point to Wellington was searched systematically with a four element Yagi antenna. Here, we failed to detect any tagged fish, however, numerous lake trout were seen congregating and exhibiting spawning behaviour off the breakwater at the entrance to Wellington Harbour. Dead eggs were visible in the shallow water. The ratio of males to females was estimated at about 10:1 (male fish were recognized by the presence of dark lateral colouration, or "bar"). Fish activity at this site was much diminished by 21:00 h. The Athol Bay tag was initially pinpointed from shore to a section of sand beach of approximately 10 m in length. The tag was eventually located in an area of approximately 1 m^2 in size, but not recovered, as it was buried under an unknown depth of sand.

On November 21, divers searched the Spencer Point area. Despite several hours of searching, no eggs or extensive areas of rubble were found. Here, the near shore area consisted of flat, stepped limestone to a depth of about 4 to 5 m. Thin patches of broken rock were observed in fissures and collecting at the bottom of limestone steps.

On November 22, divers surveyed the breakwater at Wellington. Live and dead eggs were observed in all outside areas of the breakwater surrounding the entrance to the harbour in water depths of 0.1 to 1.5 m. Egg densities, as determined by excavating selected areas, ranged from zero to 76 eggs/m^2 eggs with a median density of 42 egg/m^2. The majority (72%) of the eggs were dead. The rubble extended to a maximum depth of 1.5 m and was surrounded by an extensive area of sand. The thickness of the rubble, determined during excavation, ranged from 15 to 30 cm.

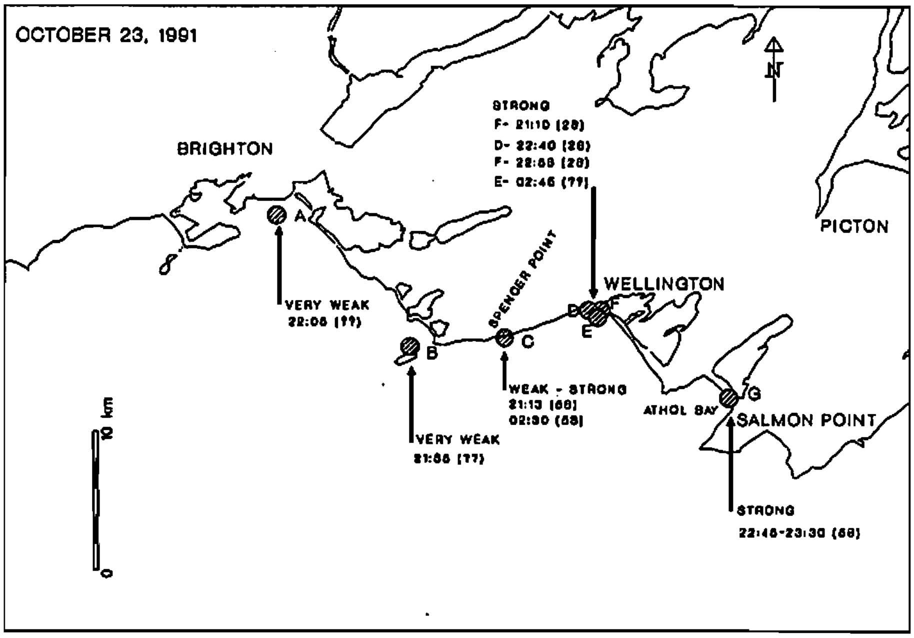

FIG. 6. Tagged fish activity determined on October 23, 1991. The radio signal strength is indicated below the arrow along with the time of detection and radio frequencey of the tag (28 = 149.928 MHz, 58 = 149.958 MHz, ?? = unknown).

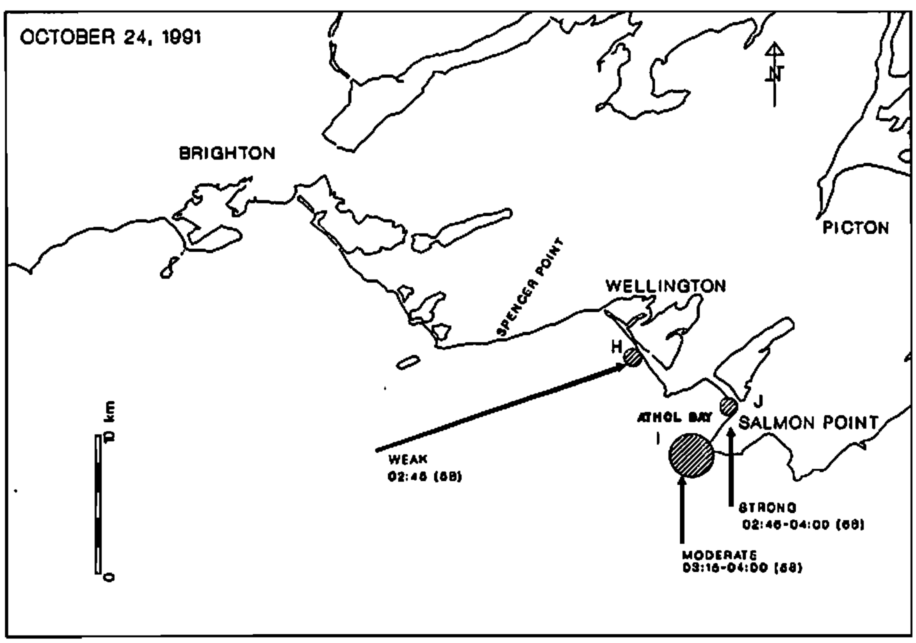

FIG. 7. Tagged fish activity determined on October 24, 1991. The radio signal strength is indicated below the arrow along with the time of detection and radio frequencey of the tag (28 = 149.928 MHz, 58 = 149.958 MHz, ?? = unknown).

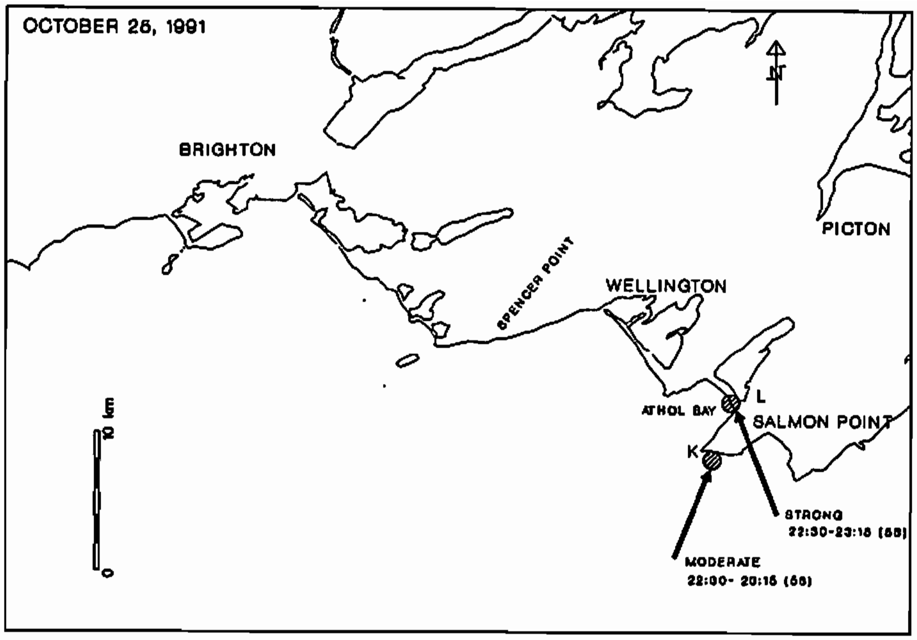

FIG. 8. Tagged fish activity determined on October 25, 1991. The radio signal strength is indicated below the arrow along with the time of detection and radio frequencey of the tag (28 = 149.928 MHz, 58 = 149.958 MHz, ?? = unknown).

Discussion

Our study demonstrates that radio biotelemetry can be used to monitor movements of spawning lake trout on Lake Ontario. Despite less than an optimum antennae configuration we were able to effectively search extensive areas at night to a water depth of 7 m, and pinpointed specific areas of tagged fish activity to within 500 m of shoreline. Most importantly, tagged fish activity in the Wellington area led to the location of a previously undocumented spawning site.

The major requirement for expanding this pilot study to a full-scale study of eastern Lake Ontario would be simply to tag more fish. It may be appropriate to include additional search grids in the northeast sectors of the Outlet basin. Even so, larger areas are well within the range and search capability of the equipment used in this study. Improvements to the pilot study would include: expanding the survey time-frame to the period from mid-September to early November, and deployment of an additional crew to allow for simultaneous ground and air tracking. Also, a number of technical improvements are nearing completion. These include: an improved antenna configuration for the Twin Otter aircraft, more accurate navigational systems, improved navigational computer software, and enhanced automation of radio signal logging. With these improvements it should be possible to enhance the accuracy of determining tag location from the air, and allow for a higher proportion of individual fish to be recognized from decoded signals.

Consideration should also be given to tagging fish in spring to reduce handling stress, and to better achieve an unbiased pre-spawning distribution of tagged fish. The failure to detect any signals east of Salmon Point led us to the conclusion that the two fish released near Long Point did not survive due to the stress of capture and tagging. Assuming that each unique tagged fish position was an individual fish, one can account for 10 of the remaining 11 fish tagged and released at Salmon Point (Fig. 6-8). At a minimum, a total of five individual fish were detected on October 23.

Peak lake trout spawning at Yorkshire Bar, on Lake Ontario, occurred during the last week of October in 1990 (Casselman 1991). This date corresponds to an average surface temperature of 12.4°C for the Outlet basin during that period (National Water Research Institute, Environment Canada, Burlington, Ontario). At Brighton and Wellington, during the same period, temperatures averaged 10.2°C and 11.4°C, respectively. The cooler temperatures lead us to speculate that lake trout in these areas spawn earlier. The activity of tagged fish is also consistent with this conjecture. Weak signals, associated with fish inhabiting deeper water, in the area of Brighton and Nicholson Island were first detected on October 23 (Fig. 6). Despite subsequent searches, these signals were never detected again. These fish either remained in deep water or moved out of the area. We also received antecdotal reports of "thousands of fish" spawning at Wellington on dates corresponding to the aerial portion of the survey when we also detected at least two tagged fish in this area. However, we failed to detect any radio signals over an extensive area during ground surveys on October 31, suggesting that spawning was largely complete by that date. We speculate, that spawning sites in addition to Wellington may have been pinpointed with an earlier survey and quicker dispatching of ground crews.

As a lake trout spawning site, the Wellington breakwater is not ideal. Egg densities were comparable to those observed on Yorkshire Bar (Casselman 1991), but the percentage of dead eggs was higher at Wellington (72%) than at Yorkshire (50%). Substrate thickness was only 10 to 30 cm and likely limiting to egg survival. The shallow water depth of egg deposition (< 1.5 m) and proximity to a large sand beach would likely result in both ice impingement and infilling of the interstitial spaces with sand during storm events. Extensive areas of spawning substrate are not evident in this area and it may be that the breakwater represents the only available spawning substrate in the vicinity. A full-scale radio biotelemetry study would provide a direct test of this hypothesis.

Acknowledgments

Many people contributed to the development and implementation of this project. In particular we would like to acknowledge the ideas and help provided by Larry Onisto of Ontario Hydro, Larry Hill, and Richard Harrison of O.M.N.R. Aviation and Fire Management Centre, Ted Senese of O.M.N.R., Ontario Centre for Remote Sensing, Stewart Strathearn and Jim Lotimer of Lotek Engineering Inc, and Paul Castrucci of Sinclair Radio Laboratories. Mr Dave Baverstock kindly provided lake trout from his commercial trapnet. Dale Dewey helped capture and tag the fish. The flying and navigational skills of pilots "Red" (Robert Seguin) and Al Quinn were invaluable. Jim Hoyle and Phil Smith reviewed a draft of this report.

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Lake Trout Rehabilitation in Lake Ontario, 1991.

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Lake Ontario Fisheries Unit, 1991 Annual Report, Section 10

Progress towards rehabilitation of lake trout in Lake Ontario is described with reference to the terms of the 1983 rehabilitation plan. Stocking in 1991 has increased slightly from the previous year. Re-examination of past stocking levels and survival rates indicates that effective stocking levels have decreased since the early 1980s. Survival rates of adult lake trout have remained around 40%, below the peak level in 1989, and below the 60% target level. Both major sources of mortality - lamprey kills and angling harvest - have increased.

Introduction

Reconstruction of a naturally reproducing population of lake trout is the focus of a major international rehabilitation effort in Lake Ontario. Coordinated through the Lake Ontario Committee of the Great Lakes Fishery Commission, representatives from many cooperating agencies developed the Joint Plan for Rehabilitation of Lake Trout in Lake Ontario (Schneider et al. 1983), which identified a goal, an interim objective, and several strategies for their achievement. The present report is organized similarly to the Joint Plan, with the intention of describing progress toward planned objectives. Assessment and monitoring methods have been described in detail in earlier reports; readers interested in more information should review the appendices in the 1986 Surveillance Report (Schneider at al. 1987).

Strategy 1. Stocking

Since native stocks of lake trout in Lake Ontario are extinct, the major focus of our rehabilitation effort is the establishment of a new Lake Ontario strain(s). This entails rearing and introducing 2.5 million yearlings of various genetic stocks (1.25 million per nation). The Joint Plan calls for assessment of strain performance, and emphasizes the use of progeny of lake trout that survive to maturity in Lake Ontario.

The 1991 stocking of 1.97 million yearling equivalent lake trout represented a 5.7% increase from the previous year, with a 4% decrease in U.S. stocking having been offset by a 15% increase in Canadian stocking (Fig. 1A). The Manitou strain, stocked previously by Canada, was replaced by the Slate Island strain, and small numbers of Lewis Lake fish were stocked by the U.S. after several years' absence. Other strains were stocked at proportions similar to 1990 (Fig. 1B).

Strategy 2. Maximize Recruitment of Stocked Fish

The Joint Plan recommends maximizing recruitment of stocked lake trout by optimizing hatchery rearing practices and stocking techniques. The use of coded wire tags (CWT) for marking fish has made it possible to evaluate the effects of rearing density, time of planting and stocking methods on post-stocking survival. Because of the longer history of CWT use by the U.S., most of the following discussion focuses on U.S. stocked lake trout.

Releases of hatchery-reared lake trout in U.S. waters of Lake Ontario began with 66,000 yearlings of the 1972 year-class (Fig. 2), but mostly fall fingerlings were stocked until the Allegheny National Fish Hatchery began producing yearlings, starting with the 1977 year-class. Releases of yearlings increased to a peak of 1.09 million for the 1982 year-class and then declined to 0.72 million for the 1989 year-class. Plantings of fingerlings were increased in the late 1980s to partially offset the reduced numbers of yearlings. In the past it was assumed that stocking 2.4 fall fingerlings was the equivalent of stocking one spring yearling - hence the "yearling equivalent" statistics. However, several factors affect the survival of hatchery reared fish in their first year after stocking (Elrod et al. 1988, Elrod

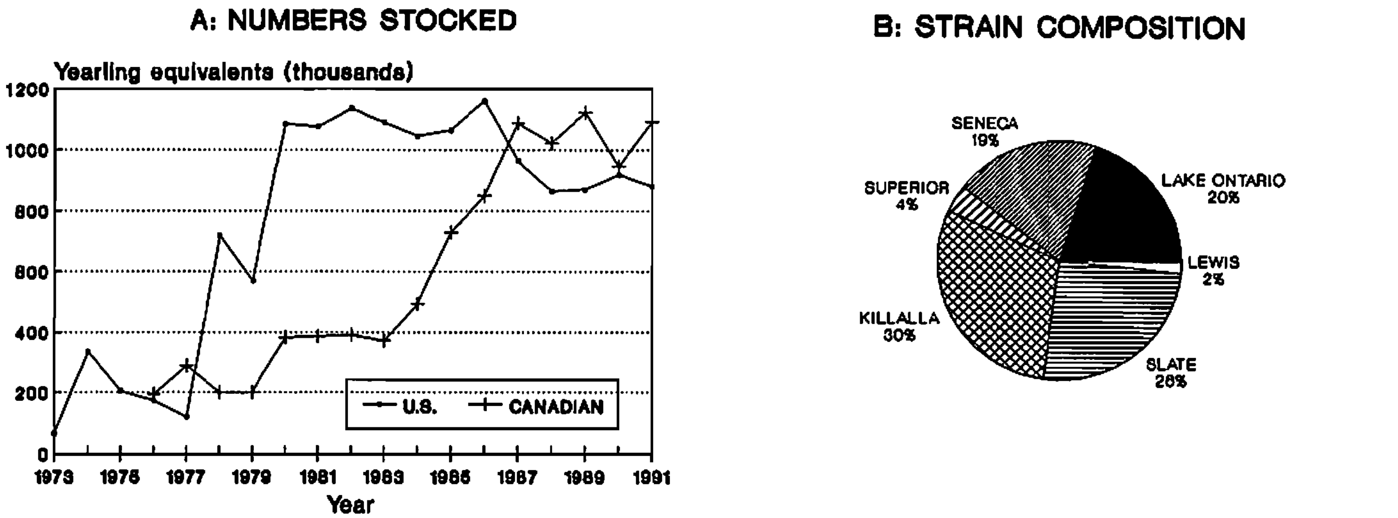

FIG. 1. Lake trout stocking, (A) Total yearling equivalents stocked in Canadian and U.S. waters (1 yearling = 2.4 fall fingerlings). (B) Overall strain composition. Lake Ontario strain is hatchery-reared progeny of stocked fish that survived to maturity in Lake Ontario.

work in progress): (1) the developmental stage at which the fish are stocked (fall fingerlings vs. spring yearlings), (2) the month of stocking in case of the spring yearlings, (3) the rearing density of the fish in the hatchery, and (4) the genetic strain of the fish. Survival in the first year also appears to be negatively correlated with (5) abundance of large lake trout in the year of stocking. Using Superior strain yearlings of the 1979-81 year-classes as the standard, and adjusting for the the above factors, suggests that the effective stocking levels in the U.S. have decreased since the peak in 1980 (Fig. 2).[1]

Similar adjustment of Canadian stocking levels is not possible at this time, because routine use of CWTs has only started recently. It is, however, reasonable to assume that at least one factor, the relationship between yearling survival and adult abundance, is similar, and the effective historical stocking levels may have to be readjusted downward for the 1980s.

Strategy 3. Maintain Survival of Adult Lake Trout at 60-65%

Successful rehabilitation of lake trout in Lake Ontario demands that enough stocked fish survive to produce a viable spawning stock. The Joint Plan prescribes a yearly survival rate of 60-65%. To attain this level, the plan suggests that mortality due to sea lamprey should be minimized, and exploitation by the fishery should be limited.

Survival of Adult Lake Trout

Survival of adults has been monitored using fall gill net samples. Again, the analysis has been limited to U.S. data, due to the long-term use of coded wire tags, which permit accurate aging of tagged lake trout. Catch curve analysis of data from the 1991 fall gill net survey showed 41% yearly

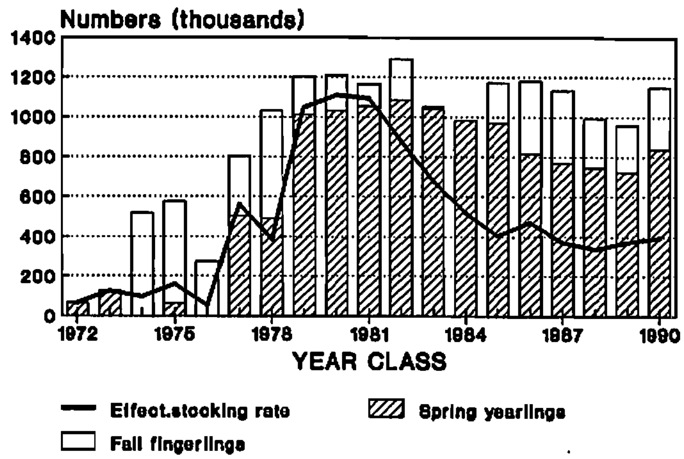

FIG. 2. Effective stocking levels of U.S. fish compared with actual numbers of fish stocked. The effective stocking levels were calculated as the numbers stocked adjusted for (1) developmental stage at stocking, (2) month of stocking of spring yearlings, (3) rearing density in the hatchery, (4) genetic strain, and (5) abundance of large lake trout. The effective U.S. stocking levels shown here are in contrast to the U.S. stocking levels shown in Fig. 1A, which are adjusted only for developmental stage at stocking, using a correction factor which probably overestimates fingerling-to-yearling survival in recent years. Note also, that data for Fig. 1A were compiled by year of stocking, while data in this figure were compiled by year-class of the stocked fish.

1 Due to water supply problems at Allegheny National Fish Hatchery, the effective stocking rate for the 1990 year-class may be revised further downward. The 1991 year-class has also been seriously affected in that no fingerlings were produced for stocking in the fall. Also, a significant proportion of fish scheduled for stocking as yearlings in May 1992 have already been stocked in early winter. Unless the water supply problem is corrected within the next few months, production of the 1992 year-class will also be significantly reduced.

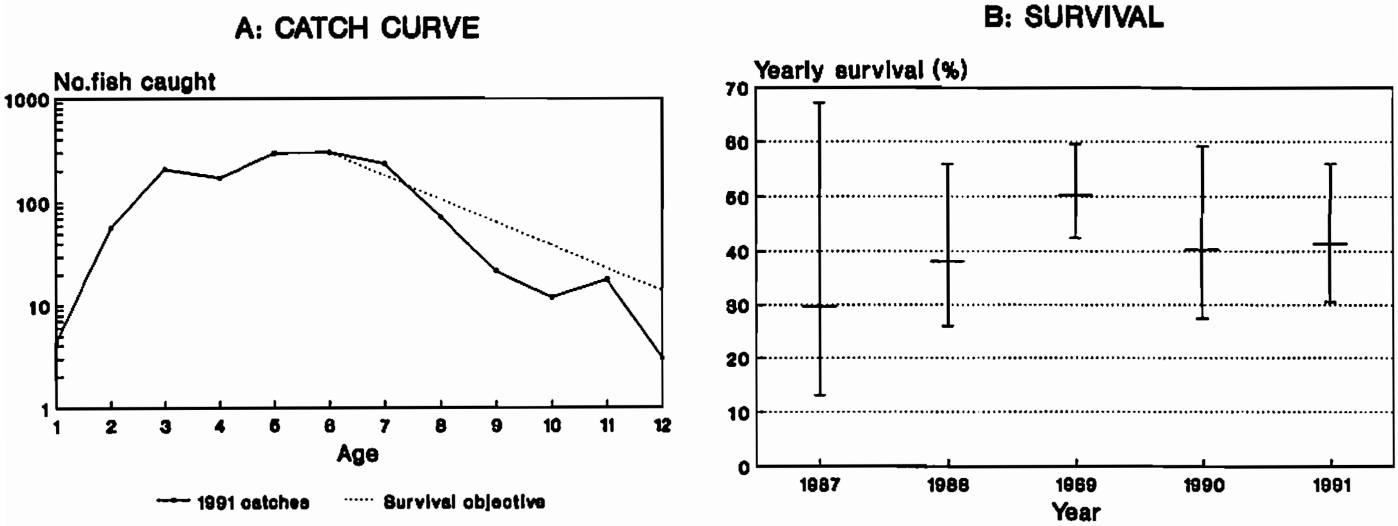

FIG. 3. (A) Catch curve based on catches of U.S. stocked fish in the 1991 fall index gillnet survey; the objective for the lake trout (60%) is also shown. (B) Yearly survival rates for ages 6-10, and 95% confidence limits.

survival of lake trout between ages 6 and 10 (Fig. 3A). This level is similar to 1990, and lower than the 50% survival rate estimated in 1989 (Fig. 3B).

Lower survival is consistent with the recent increases in mortality due to both the lamprey and fishing. Since overall survival of adults has not yet reached the 60-65% target level, efforts should be made to regain the level of control seen in 1989.

Because of our inability to accurately age older lake trout from Canadian stockings, it is difficult to judge the survival of adults in Canadian waters. Comparison of the size composition of the catch between U.S. and Canadian waters, however, provides some insight. Assuming that growth rates of older U.S. and Canadian lake trout are roughly similar (we have no data to dispute this assumption), then differences in size composition should reflect differences in mortality. The largest fish in the fall gillnet survey are usually taken from Canadian waters, suggesting better survival. This observation is consistent with the lower harvest rates of lake trout in the Canadian waters.

Average Age of Mature Females

One of the objectives of the rehabilitation program is to re-establish a sufficiently large spawning stock that encompasses several year-classes. The average age of mature females was selected as an index of age composition. Older average ages indicate populations with more age groups and older fish. The target average age of mature females identified in the Joint Plan is 7.5 yr.

The average age of mature females taken in gill nets in U.S. waters in 1991 was 6.6 yr (Fig. 4). This was similar to 1990, eventhough it was expected that with the recent decrease in survival (Fig. 3A), the average age would decline. Figure 4, however, also shows that the average age of first maturity (the onset) has increased to 5.8. This is the oldest first age of first maturity recorded to date. It appears that the decline in numbers of the oldest fish (due to lower overall survival) has been offset by a decline in numbers of young adults, and thus the average age of mature females has remained unchanged.

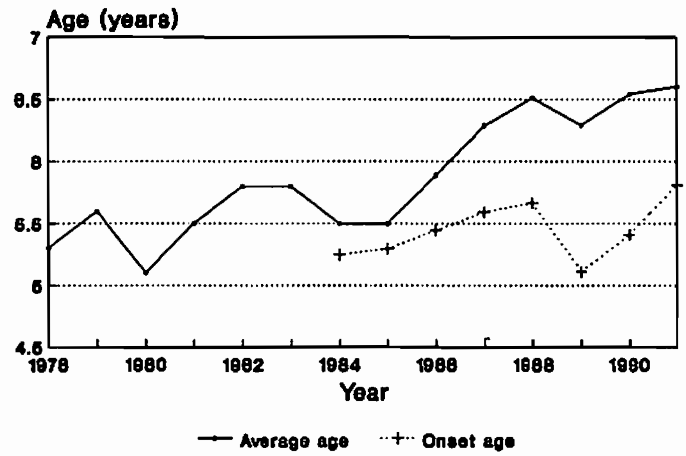

FIG. 4. Maturity statistics for U.S. stocked female lake trout. Average age is the mean age of mature females. Onset age was calculated by the method of Abrosov (1969).

Strategy 3.1. Minimize Losses from Sea Lamprey

Three basic approaches were outlined in the Joint Plan to minimize sea lamprey predation on lake trout. First, and foremost, was the adequate control of sea lamprey recruitment through chemical control, barrier dams and other means. Second, increasing the prey (i.e. lake trout) biomass should ultimately lead to reduced mortality of lake trout, since under conditions of high density of large prey, the lamprey are thought to act more as parasites rather than predators. The third tactic was to stock strains of lake trout that were more resistant to lamprey mortality.

Sea Lamprey Impacts

Density of lake trout carcasses killed by sea lamprey, and average number of A1 (fresh) wounds per lake trout, are the two main parameters used to monitor sea lamprey impacts in Lake Ontario.

In Canadian waters in 1991, the average A1 wounding rate in lake trout over 431 mm was 0.024 wounds/fish, a 28% decline from 1990 (Fig. 5A). In U.S. waters, however, A1 wounds in 1991 increased by 35% to 0.027 wounds/fish. Since 1985, there was no relation between Canadian and U.S. wounding statistics (r = 0.36, P0.05). This suggests that the lamprey impact may vary independently by region.

Since 1982, lake trout carcasses have been collected in bottom trawls from U.S. waters each fall. Results from these surveys provide direct and current evidence of sea lamprey induced mortality on lake trout. In 1991, 29 carcasses were recovered from 289 ha (714 acres) of lake bottom. Carcass density in the 30-99 m depth stratum is the longest and most complete data series (Fig. 5B). In 1991, the density of lamprey-killed lake trout in this stratum was 0.134 fish/ha. This was 61 and 227% greater than in 1990 and 1989, respectively, and it represents the third highest carcass density over the last decade. The increases in carcass density since 1990 correspond directly to the increases observed in A1 wounding rates. Together they confirm that predation by sea lamprey has risen during the past two years.

Expanding the observed carcass density by the bottom area in U.S. waters provides an estimate of the number of lake trout killed by sea lamprey. The minimal estimate for 1991 is 38,000 fish. This approach, however, does not account for the lake trout killed and decomposed before the survey, or killed after the survey. A model was developed to account for these additional losses. The resulting estimate of total loss from sea lamprey predation in the U.S. waters in 1991 was 84,000 fish. It is important to note that this estimate is based on carcass data collected after the gillnet survey on which the survival estimates (Fig.3) are based. Thus the increase in carcass densities reported here will be reflected in next year's survival estimates, which are expected not to improve, and perhaps to decline even further.

As the carcass density fell from 1982 to 1989, the average age and size of carcasses increased (Fig. 5C). Although sea lamprey predation increased in 1990-91, the average size and age of carcasses still generally increased (average age remained constant in 1990, but increased in 1991; median size of carcasses increased in 1990, and then declined slightly in 1991). The overall trends continued to demonstrate that sea lamprey are actively seeking the largest hosts available.

Lake Trout Biomass

The relative abundance of mature lake trout in Lake Ontario, measured in fall gill net surveys, rose substantially throughout the 1980s (Fig. 6A). As a result of the high effective stocking rates in U.S. waters in the late 1970's and early 1980s (Fig. 2), and a decline in mortality due to sea lamprey (Fig. 5B), the population of mature females built up to a peak in 1989. The decline in effective stocking rates beginning with the 1982-84 year-classes, should have been reflected in a decline in numbers of mature females in 1987, when these year-classes began to mature. The abundance of mature females, however, continued to increase until 1989, probably as a result of the major reduction in angling harvest in 1988-89, and of the reduced lamprey mortality. With the upturn of angler harvest in 1990, abundance of mature females showed the first sign of decline.

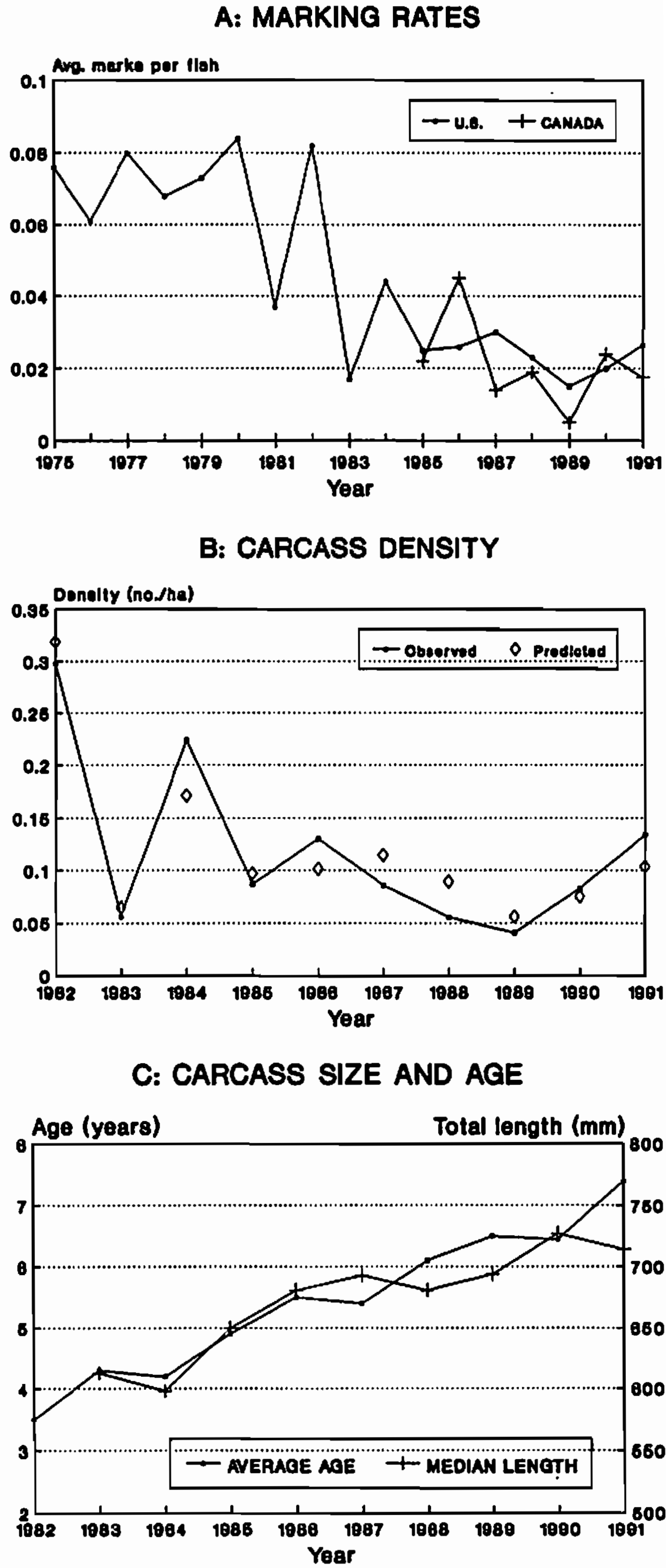

FIG. 5. Lamprey wounding and mortality. (A) Rates of A1 wounding. (B) Carcass densities in U.S. waters; observed densities are estimates based on carcass survey trawls, predicted densities were calculated from A1 wounding rates using relationship: density = 4.018*(wounding rate) - 0.0096, r = 0.964. (C) Size and age of lake trout carcasses recovered from U.S. waters in carcass survey trawls.

In Canadian waters, mature males peaked in 1991, and mature females were 14% below the 1989 peak (Fig. 6B). Immature fish on both sides of the border were below earlier peaks in relative abundance. The declines noted in immature fish from gill net surveys, and the diminished performance of recent U.S. stockings, are cause for concern about future recruitment.

Strategy 3.2. Limit Exploitation

Fishing is the other major controllable component of lake trout mortality in Lake Ontario. Creel surveys provide an effective and reliable method to quantify the angling mortality. This information, together with carcass survey estimates, should permit a reasonable assessment of the management actions necessary to improve survival.

Canadian and U.S. creel surveys do not sample all fisheries. The last Canadian survey in central and Kingston basins occurred in 1987, and will not be repeated until 1992. The U.S. surveys did not include all areas, seasons and fishery types, although a comprehensive survey in 1984 suggested that the recent U.S. surveys (1985-91) accounted for approximately 85% of the total U.S. lake trout harvest.

The sport harvest of lake trout taken by boating anglers in U.S. waters of Lake Ontario (not including the Kingston basin) in 1991 was estimated to be 88,291 fish (Fig. 7). If all U.S. waters, seasons, and fisheries were included, the harvest estimate would have exceeded 100,000. The pattern of harvest since 1985 illustrates the impact of fishing regulations. Before 1988, when the daily limit was three lake trout, yearly harvests by boaters ranged from 85,000 to 90,000. The establishment of a slot limit, protecting lake trout between 635 and 762 mm (25 and 30 in), caused harvest reductions in 1988 and 1989. Relaxation of the slot limit, by narrowing the protected interval to 686-762 mm (27-30 in), resulted in increased harvests in 1990 and 1991.

Survival of adult lake trout is related to mortality from both fishing and sea lamprey, and the recent decline in survival corresponds closely with increased harvest (Fig. 7). The highest adult survival occurred in 1989, when lamprey and angling mortalities were near their lowest levels. The increased harvest since 1990, and the resulting reduced survival, demonstrate the importance of protecting sufficient numbers of adult fish. Because harvest exceeded the planned target of 60,000 fish, and since survival is below the 60% objective, NYDEC has proposed to limit harvest by expanding the slot limit to 660-813 mm (26-32 in), effective October 1, 1992.

The Canadian harvest remains low. The creel surveys here have been expanding in the recent years to cover the spreading salmonid fishery, and currently, boats launched at access points are surveyed throughout the western and central basins. The harvest estimates for this fishery are 6031 and 5384 fish in 1990 and 1991, respectively. Extrapolating to the unsurveyed fisheries would probably double the estimates. The salmonine fishery in the Kingston basin is expanding as well, although it has not been measured since 1987, when the harvest was estimated to be 12,202 lake trout.

There is no quota allocation for lake trout in the Canadian commercial fishery, however, incidental catch of lake trout is an additional mortality factor. The incidental catch in the gill net fishery has not been quantified. Based on limited monitoring of yellow perch and whitefish fisheries, it is assumed that the total incidental catch would

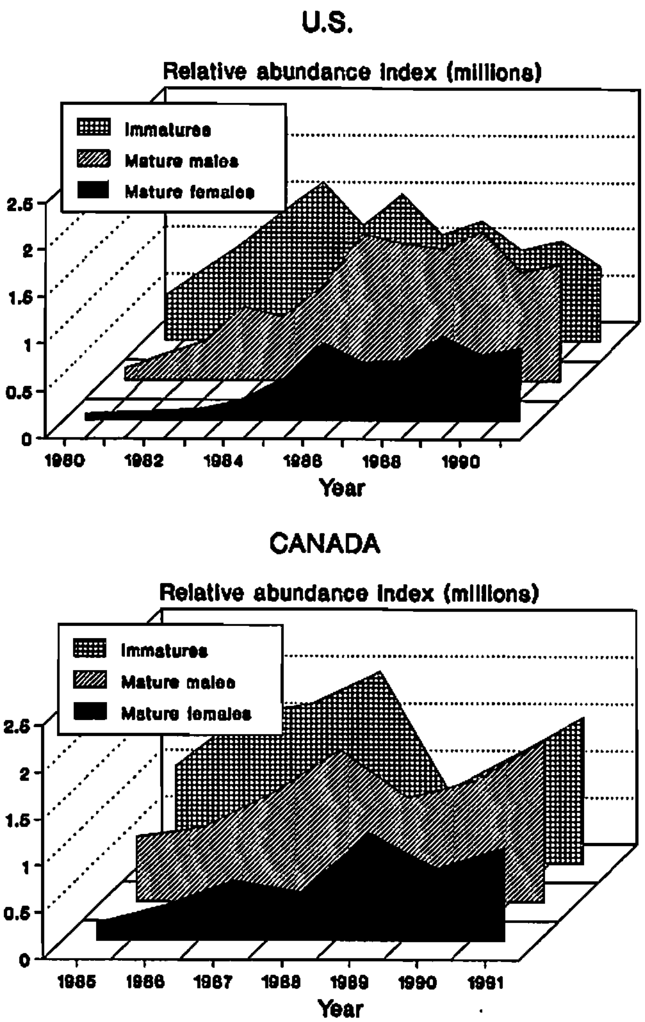

FIG. 6. Relative abundance indices of lake trout in Canadian and U.S. waters. The indices were calculated as weighted sums of caught lake trout, with stratum area (ha) as the weighting factor.

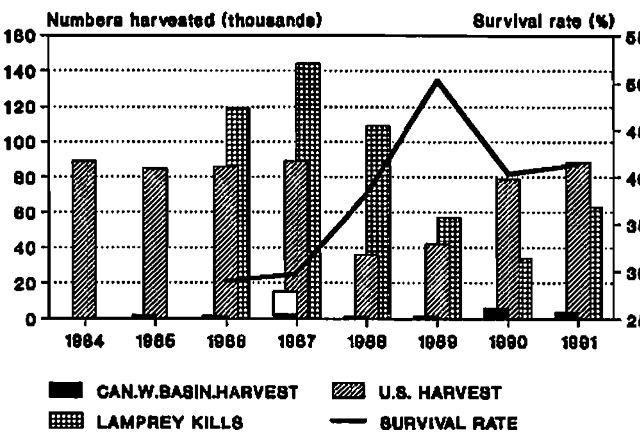

FIG. 7. Numbers of lake trout harvested in various fisheries, and killed by lamprey. The U.S. harvest shown represents approximately 85% of the actual total harvest. The Canadian harvest shown probably represents approximately 50% of actual harvest in the main lake. The Kingston basin was last surveyed in 1987, and the harvest estimate from that survey is shown over the top of the Canadian estimate. Survival rate from Fig. 3A is superimposed to illustrate the effect of angling and lamprey mortality.

be considerably less than the sports harvest from Canadian waters.

Strategy 4. Maximize Natural Reproduction

The Joint Plan did not consider degradation of the ecosystem as a cause in the demise of native lake trout, mainly because the decline started before the period of most intensive eutrophication and contamination. However, habitat quality may hinder rehabilitation. The suggested approach to maximizing reproductive potential of the new Lake Ontario stock involves: (1) improving water and habitat quality, (2) maximizing use of the least degraded spawning and nursery habitat, and (3) determining those conditions on the spawning grounds that may be inhibiting successful reproduction. Activities undertaken in 1991 as part of Strategy 4, centered on efforts to understand conditions that may inhibit reproduction.

Broad knowledge of spawning site selection and timing of egg deposition is necessary to better understand the failure of lake trout to reproduce. A pilot radio biotelemetry study (Stewart and Wood 1992) confirmed that this technique can be applied to systematically determine the location and timing of lake trout spawning over expansive regions of Lake Ontario.

"Egg bags" were used to collect naturally deposited lake trout eggs, and to estimate postspawning egg density in the substrate at Stony Island. The bags consisted of a circular metal rim 37 cm in diameter, to which a 75 cm long mesh bag was attached. They were installed by scuba divers, who dug holes in the substrate, placed the bags in the holes so that the rims were flush with the surrounding terrain, and then filled the bags with the displaced substrate.

In September, three bags were buried at each of 45 sites on the reef. Fifteen sites were situated along each of three transects located near the top (4 m depth), middle (6 m), and bottom (8 m) of the reef. Five of the fifteen sites at each transect contained bags that were covered with mesh in September. During the spawning season in November, these bags were seeded with 50 fertilized eggs, and covered again to prevent further egg deposition, and to exclude predators. Bags at the remaining sites were left uncovered to sample natural egg deposition. One bag at each site was retrieved after the completion of spawning in December, and the remaining bags will be retrieved in early April and mid-May, at the time of peak fry emergence.

Incubators seeded with fertilized eggs were used to estimate embryo survival, fry emergence and predation. One incubator was buried next to each of the 45 covered egg bags. Fifteen incubators were retrieved in December, at the same time as the egg bags. The other incubators will be retrieved in April and May. Fifteen incubators are also kept at the fish hatchery at Cornell University to serve as controls.

Preliminary analysis of data collected in December showed that: (1) postspawning egg densities on Stony Island reef in 1991 were roughly six times greater than in the previous year (e.g., 5500 m^{-2} vs. 920 m^{-2}), (2) sculpin density on the reef in 1991 was roughly six times less than the previous year (4 m^{-2} vs. 24 m^{-2}), (3) egg fertilization was similar to previous year (50%), (4) approximately 60% of the eggs were live, (5) egg survival in the incubators retrieved in December was 85%, and (6) egg survival in the seeded egg bags was 60%.

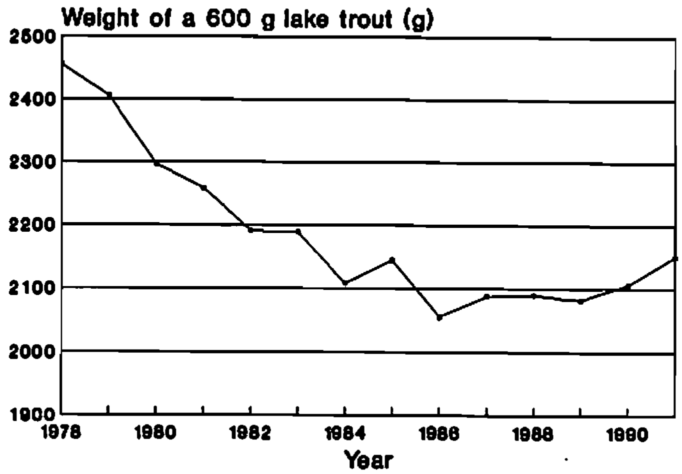

FIG. 8. Weight of a 600 mm lake trout, calculated from yearly length-weight regressions.

During routine sampling conducted by the Lake Ontario Fisheries Unit in 1991, 40 lake trout were collected that by visual examination appeared to be unmarked. Fins, scales, and otoliths of these fish were examined for characteristics that have been shown to differentiate between indigenous fish and those of hatchery origin (Casselman 1991). All of these lake trout had more than 20% chance of being of hatchery origin, so none were classified as indigenous.

Density Dependent Effects

The Joint Plan recognized that density-dependent responses could confound the attainment of plan objectives. The plan forecasted that, as the lake trout population expands, growth rates and fecundity would decline, while natural mortality and age at maturity would increase. These kinds of changes were not intended to forebode a population collapse, rather they are normal responses that should be expected as the population increases.

Growth

Weight-length regressions calculated from fish taken in September gill net surveys are used to estimate condition, by predicting the weight of a 600 mm fish. The predicted weight of a 600 g fish in 1991 increased to 2150 g (Fig. 8). The earlier decline in condition between 1978 and 1986 was associated with an increase in adult abundance (P, r = 0.94). Adult abundance stabilized after 1986, as has the condition of 600 mm fish. The increase in condition since 1990 could be related to the slight decline in adult abundance seen over the same period.

The condition of 600 mm fish may, however, be confounded by changes in the age of maturity, which occurs close to the 600 mm size. Historic data were re-examined by computing separate weight-length regressions for various strains, and using narrow 100 mm size groups rather than all sizes in the regressions. Since 1983, condition has declined somewhat in 400 mm fish, remained fairly constant in 500 and 600 mm fish, and improved in the 700 and 800 mm fish. For example, 800 mm Superior strain lake trout were more than 15% heavier in 1991 than in

1986. All strains generally showed the same trend in condition within each size group. The earlier observation, that the condition of 600 mm lake trout has improved, may therefore be a computational artifact related to trends in the length-weight relationships, and to the fact that the trends are not the same for all sizes of fish. The decline in condition of the small fish suggests that these fish may be displaced to deeper, cooler water, where growth rate would be reduced. Availability of preferred prey could also affect the growth of smaller lake trout.

Forecast

The short-term prospect for a stable, productive lake trout population is poor for U.S. waters, but better for Canadian waters. The following points are used to support this assessment:

1) Recruitment of stocked lake trout has declined precipitously in U.S. waters and this in itself will eventually lead to lower levels of adult fish abundance.

2) The U.S. index of lake trout carcasses killed by sea lamprey in fall 1991 was the highest since 1984 indicating that abundance of older mature females will be lower in 1992 than in 1991. Canadian A1 wounding rates suggest a small decline in sea lamprey induced mortality from 1990 to 1991, however, the level in both years was substantially higher than in 1989.

3) Harvest of lake trout by anglers has remained low in most Canadian waters, but may be expanding in others. U.S. angling harvest in 1992 is expected to continue at levels similar to those in 1990 and 1991. This will contribute to a further decline in adult numbers, and if unchecked, the population of mature females will continue to decline during the mid-1990s.

4) Due to the known increased loss of lake trout to sea lamprey, and because of the likely continued excessive harvest, survival of adults in U.S. waters will not improve in 1992, remaining well below the 60% objective. Survival is expected to remain constant in Canadian waters, except in specific areas that may be subject to intense angler pressure.

5) A lake trout assessment model for U.S. waters, predicts that the population of adult fish (age 5 and older) will decline by approximately 25%, to reach the lowest level observed since 1985. This reduction will be due principally to poor recruitment of young adults. Age 5 lake trout in 1992 are expected to be 55% less abundant than the 1987-1991 average.

Acknowledgments

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Assessment of the Boat Fishery for Salmonids in Western Lake Ontario

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Lake Ontario Fisheries Unit, 1991 Annual Report, Section 11

Anglers were surveyed at launch ramps in the Canadian portion of western Lake Ontario to obtain information on catch, harvest, and effort during April to September 1990 and 1991. Boat trailers were counted at unsurveyed launch ramps to index fishing effort. Effort by anglers who launch their boats from trailers was estimated to be 700,120 angler-hours in 1990 and 662,858 angler-hours in 1991. These estimates were slightly lower than for 1989 likely due to poor weather in 1990 and the economic recession in 1991. Total salmonid harvest dropped 13.0% in 1990 from the previous year, driven by a 33.6% decline in harvest of chinook salmon. However, in 1991 total salmonid harvest increased by 24.8% from the previous year, driven by a 57.1% increase in harvest of chinook. As well, in 1991 brown trout harvests nearly tripled, and coho salmon harvest increased by almost the same rate as chinook. Meanwhile, rainbow trout harvest declined 30.2% in 1991. Harvest rate has generally declined since peaking in 1984, but more recently has leveled off. This may reflect density-dependent changes in survival.

Recommendations

1. Stocking programs and attempts to rehabilitate habitat should continue to reflect a multispecies approach to the salmonid community in Lake Ontario.

2. Continue assessment of the salmonid boat fishery since it provides the only population index for salmonids other than lake trout.

3. Validate expansions for the moored boat (including charters) fishery.

4. Use catch at age analyses of the boat fishery to improve indices of salmonid populations.

Introduction

Angler catches, catch rates and effort in the Canadian portion of western Lake Ontario increased in the early 1980s to a peak in 1986 (Stewart et al. 1990). These increases were coincident with increased stocking (LeTendre and Savoie 1990). However, since 1986 these catches and catch rates gradually declined while angling effort and stocking stabilized (Stewart et al. 1990; Bowlby and Savoie 1991; LeTendre and Savoie 1990). No reasons for these declines have been reported to date.

This report provides updates for 1990 and 1991 on the boat fishery for salmonids in the Canadian portion of western Lake Ontario. For the purposes of this report western Lake Ontario is considered to be west of Point Petre, Prince Edward County, Ontario.

Methods

1990

The design generally followed past access point surveys of anglers at launch ramps in western Lake Ontario (Daniels and Savoie 1986; Stewart et al. 1990), but was modified as described below. Detailed methods were reported by Savoie (1990). Anglers who launched their boats at selected ramps (Table 1) in western Lake Ontario were surveyed for catch, harvest, and effort information during April to September 1990. Each ramp was surveyed on two weekdays and two weekend days each month.

Additional effort data were collected by counting the number of parked boat trailers at all ramps that were used by salmonid anglers in western Lake Ontario (Table 2). Counts were made on one weekday and one weekend day each week during April to September between 10:00 and 15:00 h. Trailer count data from April and May, and some angler survey data from September were not used because routine audits invalidated these data. Data from April and May, 1991, adjusted for relative effort, were used for expansions.

1991

The design was similar to above (Savoie 1991a, 1991b). However, anglers were surveyed at fewer ramps (Table 3), which were thought to be representative of the fishery. As well, anglers catch information was collected at two ramps in Wellington on April 20, 1991. After discussion with anglers and a local tackle shop owner, we felt that the catch rates on this day were typical for April and May at this location, and we were justified in using the data.

Trailer counts were made to estimate additional effort at other launch ramps (Table 4). Counts were made as above but only on weekend days, because the counts on weekend days were highly correlated with counts on weekdays (Fig. 1).

Total Boat Fishery Expansions

Launch daily anglers represent about one-half of the boat fishery in the Canadian portion of western Lake Ontario (Stewart et al. 1990). Thus, the expansion of the launch daily fishery provides a more accurate reflection of harvest and effort in the boat fishery. Bowlby (1991) expanded launch daily angler harvest of rainbow trout, coho salmon and brown trout, and effort to the total boat fishery for 1983 to 1989 based on the harvest and effort of moored boat anglers (including charters) in 1989 (Stewart et al. 1990). Here, we have applied the expansions used by Bowlby (1991) to these species, as well as chinook salmon and lake trout for the years 1982 to 1991.

Results and Discussion

Launch Daily Anglers

Effort by launch daily anglers (anglers who launch boats from trailers at ramps) was estimated to be 700,120 angler-hours in 1990. Based on estimates by Stewart et. al (1990) effort dropped only 2.1% from 1989 to 1990. However, effort in this fishery dropped to an estimated 662,858 angler-hours in 1991, a drop of 5.3% from 1990. Based on comments by anglers and charter boat operators, the lower effort in 1990 likely reflected poor weather, while the lower effort in 1991 possibly reflected the poor economic conditions of the current recession. Effort peaked in July and August in 1990 and 1991 (Fig. 2), likely as a result of the Toronto Star Great Salmon Hunt derby and the Oshawa-Whitby This Week Salmon Derby.

Catch, catch rates (CUE), harvest and harvest rates (HUE) for salmonids in 1990 (Table 5) continued the declining trend since 1986 (Stewart et al. 1990). Since effort changed little over this time period, declines in CUE and HUE reflected the catch and harvest. Total salmonid harvest dropped 13.0% in 1990 from the previous year. Chinook salmon has dominated the harvest since 1985 (Stewart et al. 1990). Thus, it is not surprising that this drop was driven by a 33.6% decline in harvest of chinook salmon. Anglers responded to the poor fishing for chinook by harvesting more lake trout and rainbow trout. However, in 1991 catch, CUE, harvest, and HUE for salmonids rebounded (Table 6). Despite lower effort, total salmonid harvest in 1991 increased by 24.8% from the previous year, and this was driven by a 57.1% increase in harvest of chinook. As well, brown trout harvests nearly tripled, and coho salmon harvest increased by almost the same rate as chinook. Meanwhile, rainbow trout harvest declined 30.2% in 1991.

Reasons for these declines and increases in harvest are unclear. Complimentary increases and declines in the harvest may be the result of anglers turning to an alternate species when the preferred species (usually chinook) are unavailable. Alternatively, biological reasons related to density-dependent survival, or to habitat variability might alter the relative abundance of salmonids or their distribution in Lake Ontario. For whatever reason, a diversity of species choice for the anglers appears to provide overall stability in the catches. Stocking programs and attempts to rehabilitate habitat should continue to reflect a multispecies approach to the salmonid community in Lake Ontario.

Total Boat Fishery

Longer term trends in harvest, HUE, and effort are presented for the total boat fishery (Fig. 3). Harvest and effort trends reflect those presented by Stewart et al. (1990) since they are expanded from similar data. Harvest shows a general decline since 1986 to a level of 180,000 salmonids in 1991. Effort shows relatively little variation since 1986 and was 1.321 million angler-hours in 1991. The overall pattern of HUEs presented here differs substantially from CUEs presented by Stewart et al. (1990). Here, HUE for all salmonids peak in 1984 and then gradually declined. The data presented by Stewart et al. (1990) show CUE for all salmonids peaking in 1986 before beginning to decline. However, on a species-specific basis the patterns of their CUE and our HUE data were remarkably similar. Stewart et al. (1990) used data collected during the Toronto Star Great Salmon Hunt derby at only two locations. Their data reflect locations and times that anglers specifically targeted coho and chinook (more recently entirely chinook) and therefore does not reflect the entire fishery. The HUE data presented here more accurately reflect the whole fishery. CUE was prone to errors as it relied on accurate species identification and reporting of released fish by anglers. Alternatively, HUE was derived from species identifications and harvest numbers that are verified by trained technicians. Moreover, HUE may suffer from variability in release rate. For instance, anglers might release more fish when CUEs are higher. Nevertheless, we feel that HUEs are robust in reflecting long term trends. Currently, we are working with several catch at age methods for indexing abundance, and we feel these methods will prove superior to these simple CUEs and HUEs.

The HUE data from the angler fishery provide a reasonable index of abundance for salmonids other than lake trout. HUEs peaked in 1984, the same year that stocking approached the 8.2 million ceiling (LeTendre and Savoie 1990). We suggest the decline in HUE since 1984 reflects a density-dependent decline in survival. The more recent leveling in HUE may also reflect leveling in survival as fish populations and their age structures may have stabilized. These considerations are important for salmonid management in Lake Ontario, and as such, we should continue our assessment of the salmonid boat fishery.

By necessity of the expansion methods these trends reflect the launch daily fishery. We have collected charter boat information, and hope to chart the growth of the fishery by moored boats by obtaining information on the number of slips rented through the years. These data should be used to validate and refine these expansions.

Acknowledgments

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TABLE 1. The survey month for each launch ramp surveyed on western Lake Ontario during 1990.

Launch ramp	Apr	May	Jun	Jul	Aug	Sep
St. Catharines Game and Fish Assoc.	X	X	X	X	X	X
Fifty Mile Point Conservation Area	X	X	X	X	X	X
Bronte Beach Park			X	X	X	X [1]
Port Credit Ramp	X	X	X	X	X	
Bluffer's Park (MTRCA)			X	X	X	X
Whitby Government Ramp	X	X	X	X	X	X
Port Darlington Ramp (CLOACA)			X	X	X	X [2]
Ontario Street Ramp (Brighton)			X	X	X	X [1]

[1] - sampled twice
[2] - sampled once

TABLE 2. Mean daily trailer count by month and day type during 1990 at launch ramps along Lake Ontario.

Launch ramp	Weekend				Weekday			
	Jun	Jul	Aug	Sep	Jun	Jul	Aug	Sep
Queenston sand docks	3	3	7	5	2	1	1	2
Niagara-on-the-Lake	2	2	3	4	0	1	1	1
St. Catharines Game and Fish	6	19	36	23	4	7	18	6
R.W. Marine (Port Dalhousie)	0	0	0	0	0	0	0	0
Beacon Motor Inn (Jordan Harbour)	0	0	0	0	0	0	0	0
Campbell's Boats (Jordan Harbour)	6	9	7	5	2	4	2	5
Grimsby Municipal Ramp	1	2	3	2	1	1	0	1
Foran's Marine (Grimsby)	1	4	6	2	1	0	2	1
Lakecourt Marine (Grimsby)	0	1	1	0	0	1	0	0
Fifty Mile Point Conservation Area	10	15	24	8	5	6	9	4
Fisherman's Wharf (Hamilton)	13	27	48	16	3	7	9	3
Mohawk Canoe Club (Burlington)	5	20	32	11	7	9	19	9
Bronte Beach Park	7	24	41	17	3	8	15	10
Coronation Park (Oakville)	0	0	0	0	0	0	0	0
Shipyard Park (Oakville)	2	9	22	5	1	3	5	1
Busby Park (Oakville)	1	0	0	0	0	1	0	1
Port Credit Ramp	8	30	74	24	6	10	29	7
Lake Promenade Park (Lakeview)	4	17	47	12	3	6	14	3
Marie Curtis Park (MTRCA)	3	13	23	6	1	3	7	1
Humber Bay West (MTRCA)	16	61	60	15	6	15	18	3
Ashbridges Bay (MTRCA)	14	49	27	6	1	9	12	2
Bluffer's Park (MTRCA)	29	94	73	14	5	39	46	7
Frenchman's Bay East (Pickering)	0	1	1	0	0	0	0	0
Port Whitby Marina	5	16	1	1	2	10	10	0
Whitby Government Ramp	5	32	25	3	0	3	6	1
Port Oshawa Marina	4	18	9	2	2	7	7	0
Port Darlington Ramp (CLOCA)	6	27	16	3	2	9	8	1
Port Hope Marina	4	16	10	3	2	8	7	2
Cobourg Yacht Club	1	7	5	1	1	4	3	0
Ontario Street Ramp (Brighton)	6	26	20	2	1	17	17	2
Brighton Marina	1	4	1	0	0	1	0	0
Gosport Government Ramp	1	2	2	0	0	0	1	0
Wellington Beach Ramp	4	22	15	1	0	9	10	0
Wellington Government Ramp	6	19	13	1	1	8	9	0

TABLE 3. The survey month for each launch ramp surveyed on western Lake Ontario during 1991.

Launch ramp	Apr	May	Jun	Jul	Aug	Sep
St. Catharines Game and Fish Assoc.	X	X	X	X	X	X
Fifty Mile Point Conservation Area	X	X	X	X	X	
Port Credit Ramp			X	X	X	X
Bluffer's Park (MTRCA)			X	X	X	X
Port Darlington Ramp (CLOACA)			X	X	X	
Ontario Street Ramp (Brighton)			X	X	X	

TABLE 4. Mean daily trailer count by month on weekends during 1991 at launch ramps along Lake Ontario.

Launch ramp	Apr	May	Jun	Jul	Aug	Sep
Queenston sand docks	8	8	8	6	8	8
St. Catharines Game and Fish	22	31	9	16	24	31
Beacon Motor Inn (Jordan Harbour)	0	1	0	0	0	0
Campbell's Boats (Jordan Harbour)	6	6	8	10	4	4
Grimsby Municipal Ramp	1	1	2	3	1	0
Foran's Marine (Grimsby)	4	6	4	7	5	3
Lakecourt Marine (Grimsby)	0	2	0	1	2	0
Fifty Mile Point Conservation Area	5	17	16	20	15	11
Fisherman's Wharf (Hamilton)	9	22	18	29	27	14
Mohawk Canoe Club (Burlington)	3	8	8	14	16	1
Bronte Beach Park	3	9	15	26	35	3
Coronation Park (Oakville)	0	1	1	1	1	1
Shipyard Park (Oakville)	1	2	7	21	17	10
Busby Park (Oakville)	0	2	1	0	1	2
Port Credit Ramp	3	8	19	39	47	36
Lake Promenade Park (Lakeview)	1	5	26	22	32	10
Marie Curtis Park (MTRCA)	0	1	11	17	8	3
Humber Bay West (MTRCA)	2	9	34	71	46	13
Ashbridges Bay (MTRCA)	3	6	15	80	24	7
Bluffer's Park (MTRCA)	3	9	44	65	84	22
Frenchman's Bay East (Pickering)	0	0	0	0	1	0
Duffin Creek	2	3	3	4	2	1
Port Whitby Marina	0	0	1	1	1	1
Whitby Government Ramp	3	4	14	26	23	8
Port Oshawa Marina	1	1	9	10	12	3
Port Darlington Ramp (CLOCA)	2	3	16	28	28	9
Port Hope Marina	0	3	6	16	14	6
Cobourg Yacht Club	2	1	6	9	3	2
Ontario Street Ramp (Brighton)	4	9	11	33	15	2
Brighton Marina	0	0	0	3	1	0
Gosport Government Ramp	0	0	2	5	2	0
Wellington Beach Ramp	14	6	13	28	16	4
Wellington Government Ramp	10	6	9	25	11	2

TABLE 5. Catch statistics for launch daily anglersin western Lake Ontario during 1990.

Species	Catch	Harvest	CUE	HUE
Bowfin	12	12	0.000	0.000
Alewife	60	0	0.000	0.000
Salmoninae (unidentified species)	1,115	353	0.002	0.001
Coho salmon	8,147	4,495	0.012	0.006
Chinook salmon	50,619	26,100	0.072	0.037
Rainbow trout	35,114	18,082	0.050	0.026
Atlantic salmon	222	150	0.000	0.000
Brown trout	2,662	1,011	0.004	0.001
Lake trout	15,218	6,031	0.022	0.009
Northern pike	248	86	0.000	0.000
Common carp	11	0	0.000	0.000
Rock bass	57	0	0.000	0.000
Smallmouth bass	424	275	0.001	0.000
Largemouth bass	180	0	0.000	0.000
Yellow perch	3,623	3,119	0.005	0.004
Walleye	49	49	0.000	0.000
Freshwater drum	383	0	0.001	0.000
Total salmonines	113,097	56,222	0.162	0.080

TABLE 6. Catch statistics for launch daily anglers in western Lake Ontario during 1991.

Species	Catch	Harvest	CUE	HUE
Alewife	209	0	0.000	0.000
Salmoninae (unidentified species)	4,546	1,297	0.007	0.002
Coho salmon	9,988	6,903	0.015	0.010
Chinook salmon	71,818	40,990	0.108	0.062
Rainbow trout	23,561	12,620	0.036	0.019
Atlantic salmon	278	65	0.000	0.000
Brown trout	6,179	2,889	0.009	0.004
Lake trout	17,292	5,384	0.026	0.008
Northern pike	813	285	0.001	0.000
White sucker	358	83	0.001	0.000
Rock bass	289	0	0.000	0.000
Pumpkinseed	237	0	0.000	0.000
Smallmouth bass	1,705	954	0.003	0.001
Largemouth bass	112	0	0.000	0.000
Yellow perch	1,806	144	0.003	0.000
Walleye	209	209	0.000	0.000
Freshwater drum	1,271	414	0.002	0.001
Total salmonines	133,662	70,148	0.202	0.106

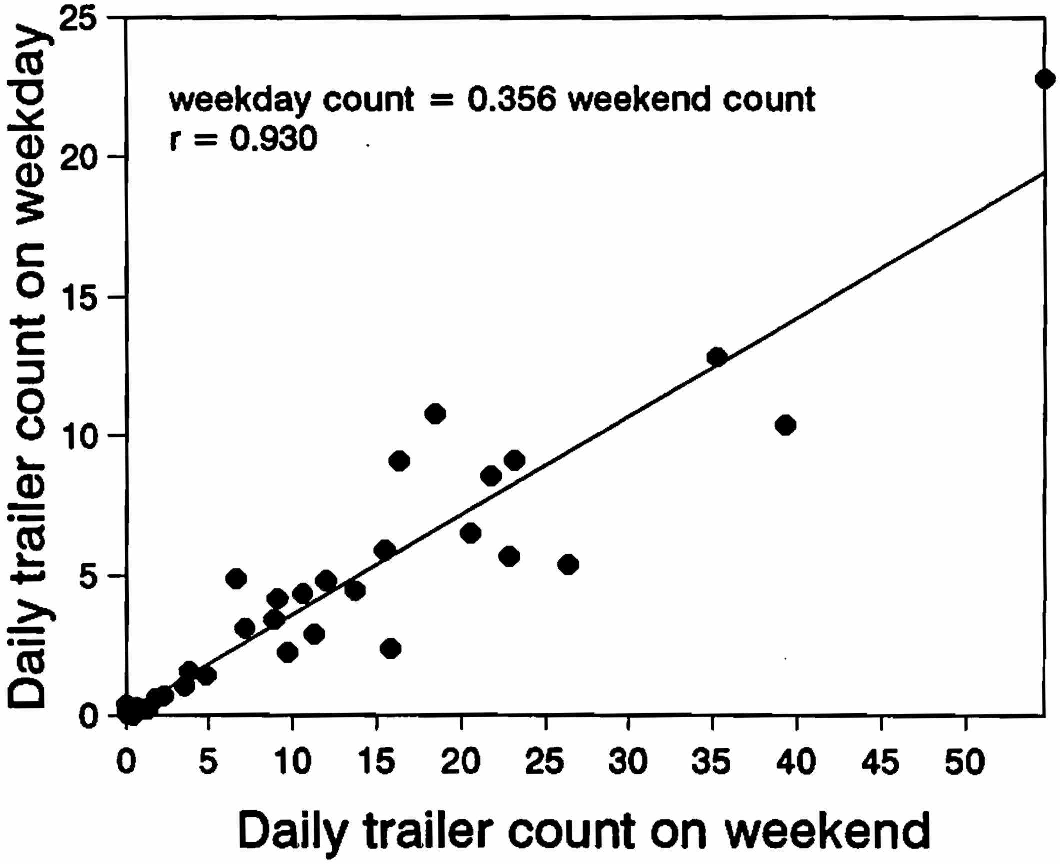

FIG. 1. The relationship between mean weekday and mean weekend daily trailer counts for 32 launch ramps (Table 2) along Lake Ontario during June - September 1990. Means were calculated with equal weight on a monthly basis. R.W. Marine and Coronation Park were not used here because no trailers were counted there in 1990.

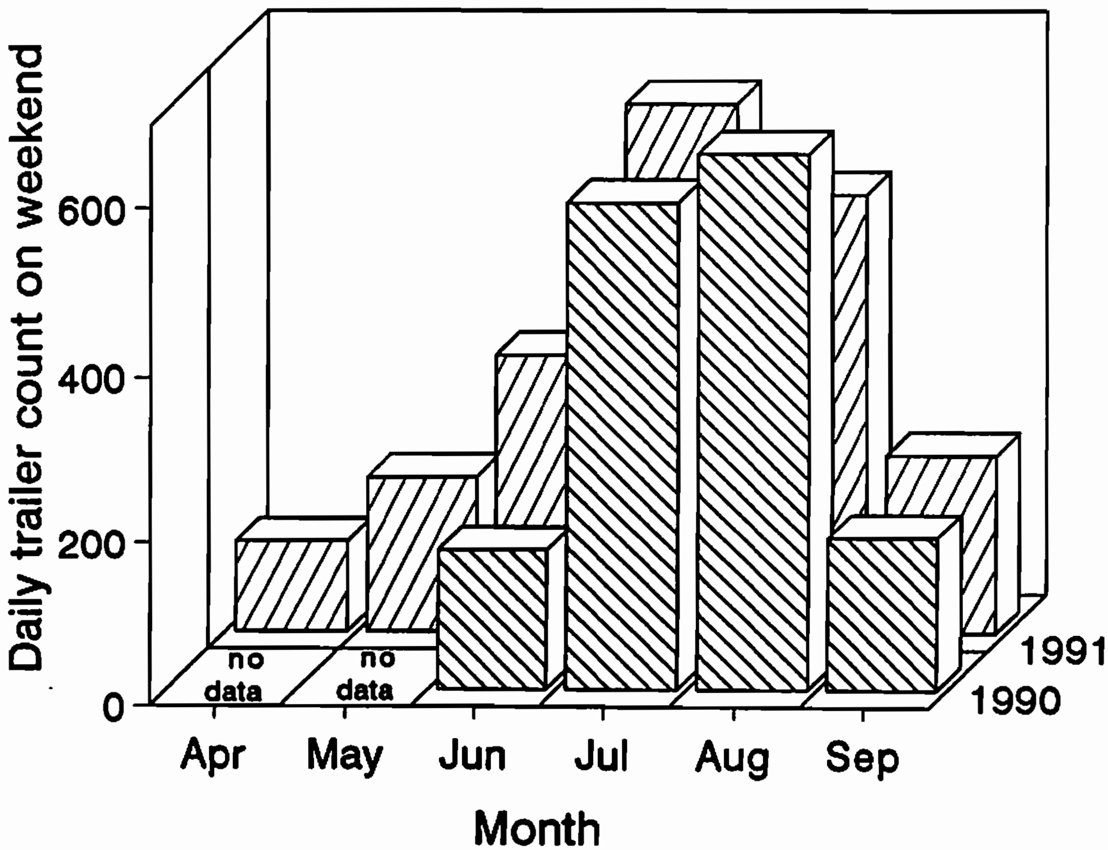

FIG. 2. Total weekend trailer count by year and month for 1990-1991 and April-September at launch ramps along Lake Ontario.

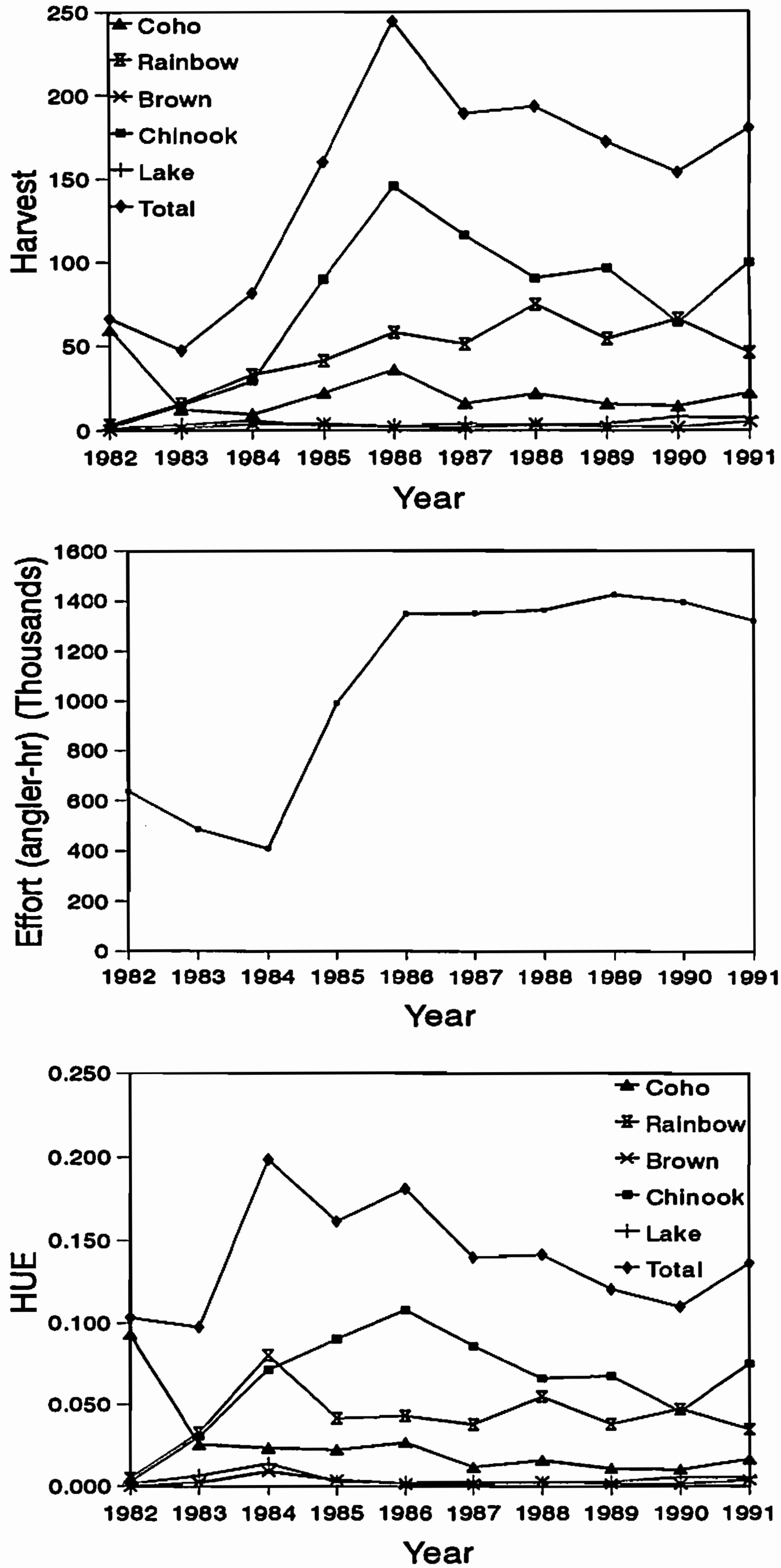

FIG. 3. Trends in harvest, effort, and harvest rate (HUE) for the Canadian portion of western Lake Ontario.

Hydroacoustic Surveys of Lake Ontario, 1991. A Progress Report.

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Lake Ontario Fisheries Unit, 1991 Annual Report, Section 12

Introduction

Recent efforts to develop a predator-prey model for Lake Ontario have demonstrated the need for information on absolute abundances of the prey fish stocks. After examining several scenarios simulating an alewife die-off, Jones (1990) concluded that "Clearly, and not surprisingly, the model is extremely sensitive to the alewife scaling factor. This result underlines the importance of obtaining credible whole-lake alewife biomass estimates."

Until recently, the estimates of alewife and smelt abundances were relative measures derived from bottom trawling surveys (O'Gorman et al. 1991; Mathers 1992). These surveys only covered parts of the lake, they did not account for fish that were more than 1 m off the bottom. Midwater trawling surveys of the prey species were initiated in 1990 (Mathers et al. 1991) to complement the information from bottom trawling surveys, and to allow assessment of the extensive areas in the Canadian waters, where bottom characteristics do not allow bottom trawling.

Hydroacoustic surveys were initiated on Lake Ontario to provide an alternative method for estimating abundances of pelagic fish, and to supplement the information gathered in the trawl surveys. A small scale hydroacoustic survey was conducted by OMNR in 1990 (Schaner and Mathers 1991) in conjunction with the midwater trawling program. In 1991, the New York Department of Environmental Conservation and the Ontario Ministry of Natural Resources conducted a series of three hydroacoustic surveys to provide the first whole-lake estimates of prey abundance, to begin development of "in-house" hydroacoustic expertise, and, most importantly, to establish that the two agencies can effectively implement hydroacoustic surveys on an annual basis.

Due to the novelty and complexity of techniques involved in the processing of hydroacoustic data, and also to some equipment problems, the data are still being analyzed. This report, written to provide information on the progress of the work, briefly describes the 1991 surveys, and outlines some initial results. We expect that the information collected in these surveys will be fully assimilated in time to plan for the 1992 season.

In 1991, OMNR was also involved in another, independent, hydroacoustic project. A research group from the University of Maryland, led by Dr. Steve Brandt, conducted a hydroacoustic survey concurrent with the OMNR midwater beam trawl program in Canadian waters in July. The results of this survey are described in Section 13 of this report (Mathers et al. 1992).

The Surveys

Surveys were conducted in the spring (May 10-16), summer (July 26-Aug 6) and fall (Oct 18-24). All work was done at night, at least one hour after dusk, and one hour before dawn. Each survey was organized as a series of cross-lake transects that were designed to allow completion of a transect in a single night (Fig. 1). Each transect started at the 10 m depth at one shore, and ran to the same depth at the opposite shore. Two boats were used in the survey. One boat hydroacoustically sampled the full length of the transect, and the other conducted midwater trawls at locations and depths that were selected based on monitoring of the acoustic signal. Temperature profiles were measured from the hydroacoustic boat at frequent intervals along the transect.

The details of the hydroacoustic system varied, but a Biosonics Model 101 echo sounder with a 420 Hz dual beam transducer (6 and 15° beam widths) fitted in a V-fin was used in all three cruises. A dual trace oscilloscope and a paper chart recorder were used to monitor the process. The signal was digitized and recorded on video cassette (spring and summer) or Digital Audio Tape (fall).

The recorded signal from the spring cruise was processed at the Great Lakes Laboratory of the USFWS

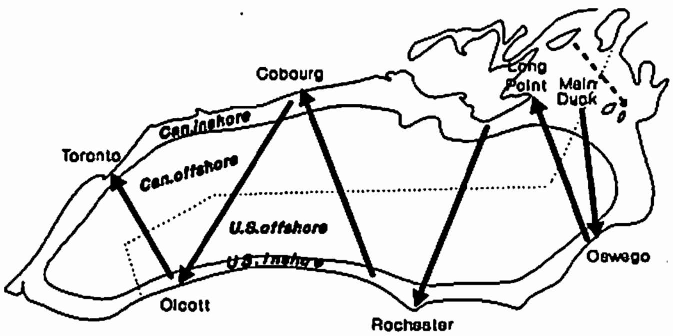

FIG. 1. The survey design. Six transects were sampled in each of the three surveys, but in the October survey the transect from Main Duck to Oswego was replaced by the transect shown by the dashed line. The spatial stratification used for the initial estimates is shown by the dotted line.

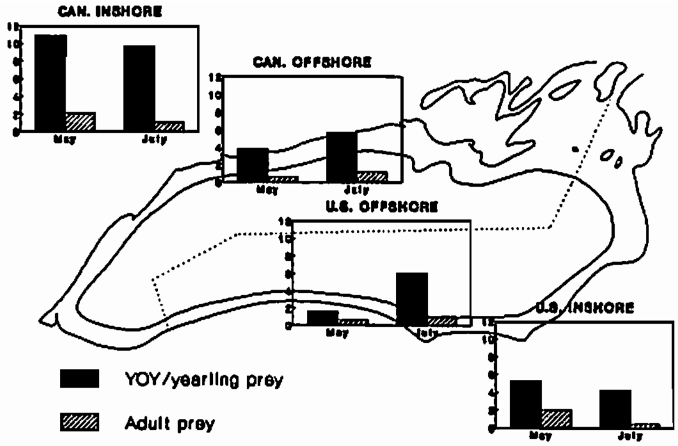

FIG. 2. The size composition of detected targets categorized into fish size groups. Pooled data from all spatial strata.

at Ann Arbor, Michigan, using a Biosonics Model 221 Echo Integrator, and Biosonics Model 181 Dual Beam Processor. During the summer cruise, the signals were processed aboard the hydroacoustic boat in real time, using the same equipment. This equipment was not available for the fall cruise, and the signal from that cruise remains to be processed.

A midwater trawl with 57 m^2 opening was used for ground truthing. In the spring and summer, when a chartered fishing vessel was used for trawling, the net was towed for 30 min at 3 knots. The R/V "Seth Green" (NYDEC) was used for trawling in the fall, and the better trawling capability of the vessel allowed us to trawl at 3.5 knots, increasing the chances of catching large predators.

Some Initial Results

A simple stratification has been adopted for the initial inspection of the data, dividing the lake into U.S. and Canadian, inshore (<60 m) and offshore waters (Fig. 1). This division reflects some of the density patterns that were seen during the field work.

The initial estimates of the total numbers of targets have been calculated for the May and July surveys. The lakewide totals are very similar, at 27.5 billion targets in May, and 29.4 billion targets in June, respectively. The similarity of the two estimates is reassuring, since the spatial and bathymetric distributions of fish in the two surveys were quite different (see below).

For the purposes of this analysis, the acoustic target strengths, which are directly related to the fish size, have been classified into three categories,[1] roughly corresponding to: (1) YOY/yearling prey (alewife and smelt), (2) adult prey, and (3) predators. Both surveys were characterized by the predominance of the YOY/juvenile prey (Fig. 2), which accounted for 80% or more of the numbers. Adult prey made up most of the remaining numbers, and only approximately 1% of the targets corresponded to predator-size fish.

The spatial distribution of the prey fish changed from spring to summer (Fig. 3). In May, more fish were found in the nearshore areas than in July. The difference was especially pronounced in the case of adult prey, but to a lesser degree it was also seen in the younger prey. Also remarkable were the large numbers of young prey fish found in the nearshore Canadian waters, a concentration that was only slightly diminished, when the fish moved offshore in July.

The bathymetric distribution of the detected targets also changed from spring to summer (Fig. 4). In May, when the water column was not stratified, most of the targets were found in the upper 5 m layer, and the numbers decreased sharply with depth. With the established thermal structure in July, the targets were still concentrated in the upper layers, but the distribution was more even.

Further Analysis of the 1991 Data

The processing of the acoustic signal from the October cruise remains to be completed. With the data from all three cruises available, the first major task will be the reconciliation of hydroacoustic data with the catches from trawls that were done concurrently. This will allow determination of trawling efficiencies for the two dominant species, alewife and smelt, and it will subsequently guide application of the trawling data to the acoustic target counts in order to partition the hydroacoustic data by species.

1 The relationship between acoustic target strength and fish size follows a power relationship. Love's equation (Love 1971) was used here to convert acoustic strengths to fish sizes. YOY/yearling prey were defined as targets less than -45 dB, corresponding to fish smaller than 103 mm, adult prey were defined as -45 to -39 dB (103 to 212 mm) and predators were defined as targets over -39 dB (212 mm).

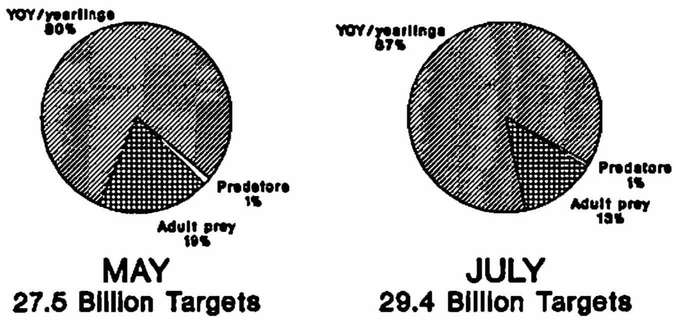

FIG. 3. Population abundances (billions) of prey fish in the four spatial strata, estimated from the spring and summer surveys.

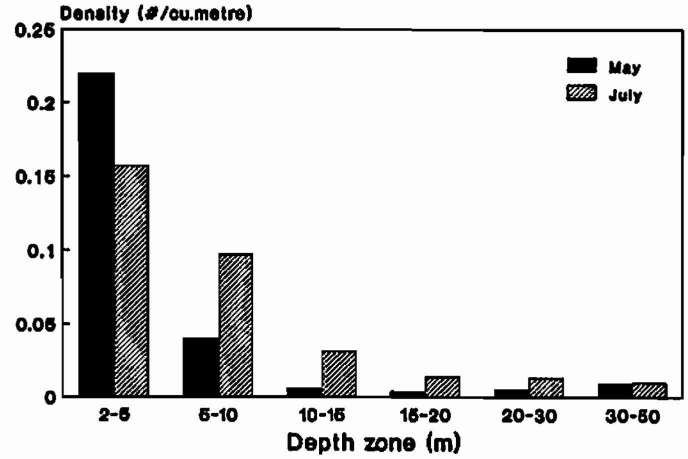

FIG. 4. Depth distribution of acoustic targets in the spring and summer surveys.

Mathers et al. (1992) have conducted a trawling/hydroacoustic survey in the Canadian waters at the same time as our July cruise. We hope that reconciliation of findings from these two independent surveys will reveal the strengths and/or weaknesses of the technique, and of the way in which it has been applied.

The major question that we hope to address with the current information is the design of a standard hydroacoustic survey of the prey species. Several factors are involved. The timing of the survey (season) will be chosen to coincide with the most favourable vertical and horizontal distribution of the fish, but the practical aspects of scheduling conflicts with other programs will also be considered. The spatial stratification and sampling effort allocation should maximize the precision of the whole-lake estimates, but must also consider the practicalities of daily schedules, and the location of suitable ports. The choice of ground truthing gear is also being considered, and we hope to compare our results with those obtained with the smaller beam trawl by Mathers et al. (1992), so that the most effective and practical gear can be chosen.

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Alewife and Smelt Abundance Estimates from Midwater Beam Trawl and Hydroacoustic Surveys in Canadian Waters of Lake Ontario, 1991.

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Stratified indices of prey fish abundance were calculated from a midwater beam trawl survey conducted in Canadian waters of Lake Ontario during late summer, 1991. The abundance index for older, i.e. yearling and older fish, smelt increased from 1990. Young-of-the-year (YOY) smelt (*Osmerus mordax*) and older alewife (*Alosa pseudoharengus*) abundance indices were similar to 1990 estimates. A low YOY alewife index suggests a small 1991 year-class. Concurrent with trawling, absolute abundance was measured with hydroacoustic gear for four groups of fish: YOY prey, older prey, small predators, large predators. Regression models relating hydroacoustic measurements to trawl catch were used to expand trawl indices to biomass. Estimates of alewife and smelt biomass in Canadian waters of Lake Ontario were 23 and 33 kg/ha, respectively.

Recommendations

1. Continue to use the midwater beam trawl to index the abundance of smelt and alewife in Canadian waters.
2. Continue to estimate alewife and smelt total biomass using beam trawl indices expanded by regression with hydroacoustic measurements.

Introduction

High levels of salmonid stocking during the past decade (Savoie and LeTendre 1991) and increasing numbers of naturally reproduced salmonids (Bowlby 1991) have dramatically increased salmonid abundance in Lake Ontario. These fish provide the basis for a world-class recreational fishery valued well over $200 million in 1989 (Kerr and LeTendre 1991). This fishery depends on healthy, abundant salmonid stocks which, in turn, depend on abundant stocks of prey. Alewife (*Alosa pseudoharengus*) and smelt (*Osmerus mordax*) are the major prey of salmonids in Lake Ontario (Brandt 1986). Monitoring the distribution and abundance of alewife and smelt populations is critical to the management of Lake Ontario fisheries.

Bottom trawling surveys for alewife and smelt have been conducted annually throughout U.S. waters of Lake Ontario since 1978 (O'Gorman et al. 1991). An extension of these surveys provides an index of smelt abundance for Canadian waters west of Toronto (Mathers 1992). However, bottom trawl surveys in Canadian waters are restricted to the western end because substrate is not suitable for bottom trawling elsewhere. These indices of abundance are valuable indicators of population status. However, bottom trawling surveys cover only 58% (by surface area) of Lake Ontario, while management objectives are being stated in terms of lake-wide measurements. For example, Kerr and LeTendre (1991) set the long-term management objective of maintaining primary prey fish at an average annual biomass of 110 kg/ha. Furthermore, managers throughout the Great Lakes are increasing their reliance on multi-species production models (e.g. Stewart et al. 1981) which require lake-wide estimates of prey biomass.

For several years, U.S. and Canadian agencies, have been developing techniques to provide managers with lake-wide estimates of absolute abundance and biomass of alewife and smelt. Two approaches show promise: midwater trawling and hydroacoustics. Hydroacoustic surveys measure absolute abundance of fish, however, they are not able to distinguish between fish species. Conversely, midwater trawling surveys provide relative abundance indices of prey species but do not measure absolute abundance.

The 1989 midwater beam trawl survey provided details on methodology and the distribution of prey species in the water column which are the basis for the current survey (Schaner et al. 1990). In 1990, a midwater beam trawl survey provided lake-wide indices of smelt and alewife abundance which were relatively precise (Mathers et al. 1991). Schaner and Mathers (1991) found that smelt were caught more efficiently by the beam trawl than were alewife.

This survey used midwater beam trawls and hydroacoustic measurements concurrently. Objectives of this report are:

1) provide abundance indices for YOY and older alewife and smelt based on midwater beam trawl catches for Canadian waters of Lake Ontario,

2) estimate absolute prey abundance by using hydroacoustics, and

3) investigate the relationship between trawl catches and hydroacoustic measurements and determine how these approaches might be combined to estimate species-specific absolute biomass.

Trawling Methods

Six sampling locations - eastern, central, Cobourg, Oshawa, Port Credit, and offshore - were selected based on general morphology of the lake basin, and to allow comparison to other prey fish surveys (Fig. 1). Transects were chosen from within each location. Limnological strata (epilimnion, metalimnion, hypolimnion, and unstratified) were selected based on summer distributions of alewife and smelt (Schaner et al. 1990). Trawls were made at randomly chosen depths from along each transect in each of the limnological strata (Table 1).

Sixty-six midwater tows were completed at night (21:40 to 03:06 h) between July 15 and August 14, 1991. Tows were at a vessel speed of 2 knots, and 20 min durations, starting when the net reached the target depth and ending when retrieval began. All tows were made from the RV Steelcraft.

The midwater trawl was 3 m wide, 3 m high and 11.8 m long with a 12.7 mm stretched mesh codend. Metal pipe was attached along the top and the bottom of the trawl mouth to maintain a 2.7 m horizontal opening. The vertical opening of the net (2.3 m) was maintained by floats attached to the top bar and weights attached to the bottom bar. The net was towed by a single cable, with bridles running to the four corners of the net's mouth. More details on the trawl construction are described by Gjernes (1979). The volume of water filtered during a 20 min trawl was 7,907 m^3.

During 1991, tows in surface water were conducted differently from the previous surveys to reduce disturbance by the survey vessel. Two additional, large floats, 60 cm in diameter, were attached to the upper beam of the trawl in order to suspend the trawl at the appropriate depth. This allowed the trawl to be fished 100 m behind the boat in water which was less disrupted. Surface trawls made in previous years were only 20 to 40 m behind the survey vessel.

During the survey, temperature profiles were taken at each station to determine boundaries between the limnological zones. The thermocline was defined as the portion of the water column which had a temperature change of greater than, or equal to, 1°C/m. Trawling depth at the station was randomly selected from within the desired limnological strata. Trawls were between 0.5 m below the surface and 7 m above the bottom. Towing depth and vertical opening of the trawl was monitored with a Furuno CN-8 net recorder using an acoustic link.

Captured fish were separated by species, counted and weighed in aggregate. Total lengths were recorded for all fish to the nearest 5 mm. Total length, weight, and otoliths were taken for a subsample of fish from each location.

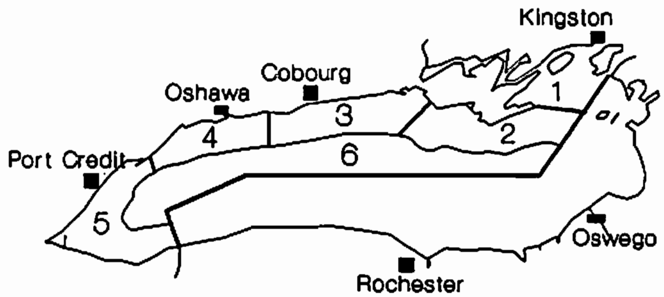

FIG. 1. Map of Lake Ontario showing the locations used in the 1991 midwater trawling surveys. 1 = eastern, 2 = central, 3 = Cobourg, 4 = Oshawa, 5 = Port Credit, and 6 = offshore (bottom depth >79 m).

TABLE 1. Volume (km3) and number of midwater trawls (shown in brackets) for each location and limnological strata used in the 1991 survey of Lake Ontario. Volumes presented, for all locations except 'Offshore', represent water <80 m depth. The offshore location refers to all water >79 m.

Location	Epilimnion	Metalimnion	Hypolimnion	No Stratification
Eastern	6 (4)	3 (3)	11 (2)	0 (0)
Central	9 (6)	7 (6)	59 (3)	0 (0)
Cobourg	5 (2)	5 (4)	43 (2)	7 (3)
Oshawa	1 (2)	1 (2)	18 (1)	12 (3)
Port Credit	3 (2)	1 (3)	23 (3)	13 (3)
Offshore	24 (5)	13 (4)	429 (3)	0 (0)

Estimates of smelt and alewife abundance, and their variances, were made using a stratified random sampling design (Krebs 1989). Catch, for each strata, was expressed as the average number of fish caught per 20 min tow. Mean catches were then expanded by the volume of water filtered by the trawl and the volume of each limnological strata. The volume of each limnological strata was determined within each location using the surface area and the depth of the thermocline, observed during the sampling (Table 1).

Hydroacoustic Methods

A Biosonics model 102 dual-beam (10 and 25°) echosounder, operating at 120 kHz, was used to measure fish abundance and acoustic target strength. The sampling rate was 40 pings/min, and the pulse width was 5 ms. All data were recorded using a 40 log R (range) time varied gain (TVG) to correct for signal spreading loss.

Pulses were transmitted and received by the echosounder (via the transducer). Received signals were digitized and stored on video tapes for analysis in the lab. Equipment performance was monitored in real time using a chart recorder and oscilloscope. Reference voltages were recorded at the beginning of each tape, and were used to calibrate the signals during analysis. The entire system was calibrated twice during the cruise by measuring the target strength of a tungsten-carbide reference sphere of known target strength (Foote et al. 1987). Comparing measured target strengths to the known target strength of the sphere allowed system calibrations to be accurately adjusted.

Data was processed using both echo-squared integration (Thorne 1983) and dual-beam analysis (Traynor and Ehrenberg 1979). Echo squared integration (using a Biosonics model 211 echo integrator) was performed using the return signal from the narrow (10°) beam to calculate the relative fish density in a given volume of water. These relative fish densities were converted to absolute densities using system performance parameters and results from the dual beam analysis. Echo-squared integration values were corrected by back-calculating a 20 log R TVG from the 40 log R TVG. Relative densities were obtained with a resolution of 310 m horizontal and 2 m vertical, below a depth of 3 m.

Dual-beam analysis (using a Biosonics model 281 dual beam processor) was performed to determine the acoustic target strength (in dB) of single targets. The dual-beam analysis system uses concentric transducers, a narrow and wide beam, so that the target's position in the beam, or angle off the axis, can be calculated. Once the angle off the axis and intensity of the returning signal is known, a target strength can be calculated. Only data between 0.5 and 5.0° off the axis were used in these analysis. An algorithm was employed to distinguish single targets from multiple targets. Only single targets were used in the calculations of target strength. Fish length was estimated from target strength values using the empirical relationship derived by Love (1971). The mean target strength obtained during each sample was used to convert the relative echo integration values into measures of absolute abundance.

Results and Discussion

Midwater Trawl Catch Rates

Catches in the midwater beam trawl were dominated by alewife and smelt, making up 16 and 81%, respectively, of the total catch of all species. Threespine stickleback (*Gasterosteus aculeatus*) made up 3% of the total catch while lake herring (*Coregonus artedii*) and American eel (*Anguilla rostrata*) represented less than 1% each.

Total lengths of alewife, caught in the trawl, ranged from 18 to 185 mm (Fig. 2) while smelt total lengths ranged from 21 to 173 mm (Fig. 3). After examination of the length frequency distributions, all alewife and smelt less than 50 mm total length were classified as YOY. Fish beyond 50 mm will be referred to as older alewife and older smelt. The mean weights of YOY and older alewife were 0.2 and 19.3 g, respectively. The mean weights of YOY and older smelt were 0.4 and 7.6 g, respectively.

Catches of YOY alewife were low at all locations (Table 2). The highest catches were observed in the epilimnion of the central location (Fig. 4). YOY alewife were not caught in trawls in the hypolimnion at any location.

Older alewife were caught in moderate numbers at all locations. The lowest catches were observed at Port Credit and offshore locations (Table 2). Catches tended to be highest in the metalimnion and unstratified waters (Fig. 5). The exception was the eastern location, were the highest catches were in the hypolimnion. These fish may have moved to deep waters because the surface water temperatures were relatively warm (averaging 22.4° C) and the thermocline was relatively deep (averaging 7 to 10 m below the surface).

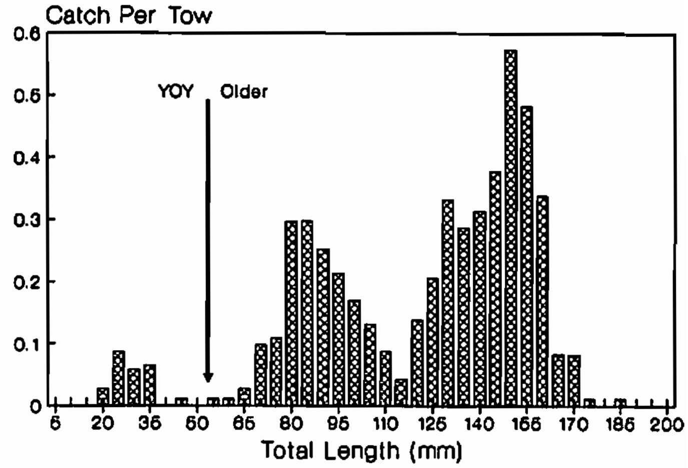

FIG. 2. Total length (mm) distribution of alewife caught during the 1991 midwater trawling survey on Lake Ontario. Data were pooled from the entire survey.

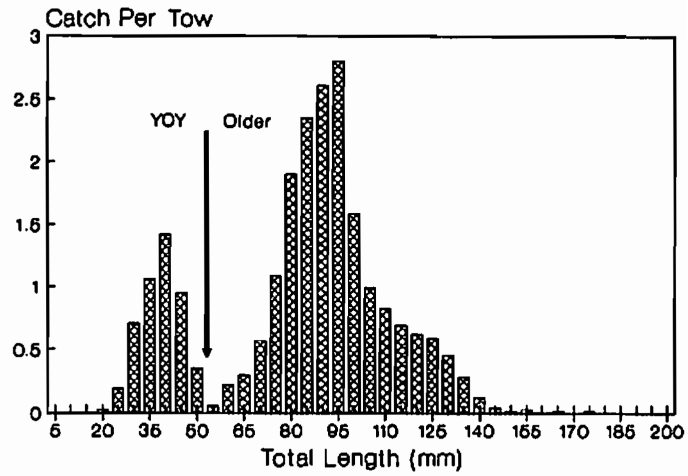

FIG. 3. Total length (mm) distribution of smelt caught during the 1991 midwater trawling survey on Lake Ontario. Data were pooled from the entire survey.

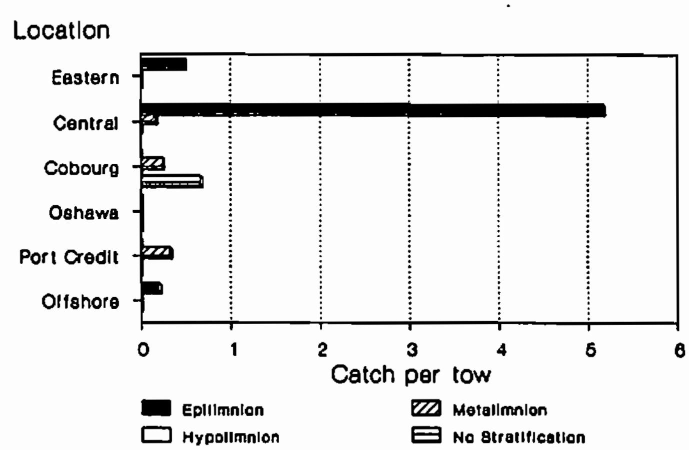

FIG. 4. Mean catch (fish/20 min trawl) of YOY alewife in the limnological strata and locations sampled during the 1991 midwater beam trawl survey on Canadian waters of Lake Ontario.

TABLE 2. Catch summary (fish/20 min trawl) for all species, by location, from midwater trawling in Lake Ontario during the summer of 1991. The catches of alewife and smelt are separated into YOY and older fish based on length-frequency analysis.

Species	Eastern	Central	Cobourg	Oshawa	Port Credit	Offshore
YOY alewife	0.2	2.1	0.3	0.0	0.1	0.1
Older alewife	13.0	18.5	9.5	19.4	3.2	4.8
YOY smelt	2.8	4.4	25.1	11.3	2.2	21.3
Older smelt	46.4	27.2	84.2	149.0	33.5	5.4
Lake herring	0.1	0.0	0.0	0.0	0.0	0.0
American eel	0.0	0.1	0.0	0.0	0.0	0.0
Threespine stickleback	0.3	1.7	1.7	1.6	1.7	6.1

Catches of YOY smelt were moderate. The highest catches were observed at Cobourg, Oshawa, and offshore locations (Table 2). Catches in the epilimnion and metalimnion tended to be higher than the hypolimnion (Fig. 6).

Older smelt were caught in relatively high numbers with the best catches being observed near Oshawa and Cobourg (Table 2). The distribution of these fish in the water column differed greatly between locations (Fig. 7).

Midwater Trawls Indices of Abundance

The mean catches for each group of alewife and smelt were calculated for each limnological zone and location. These catches were then expanded by the volume of water filtered by the trawl and the volume of each limnological strata (Table 1). These data were then summed to produce abundance indices for each species group (Table 3). These values should not be viewed as absolute abundances, since some fish avoid the trawl. However, they do provide a precise volume weighted measure of relative abundance, or index, which can be compared among years or locations (Mathers et al. 1991).

The 1991 index of older alewife in Canadian waters was 248 million fish; the coefficient of variation (CV) for this estimate was 25%. This index is similar to the 1990 beam trawl index of 203 million older alewife for Canadian waters (Mathers et al. 1991). The 1991 index of older smelt (1,567 million fish, CV = 32%) was higher than the 1990 index (581 million fish).

The YOY smelt index was 292 million fish (CV = 26%) which is similar to the 1990 estimate for this group (286 million fish). The 1991 alewife YOY index was 8 million fish (CV = 55%), which is much lower than the 1990 estimate (1,002 million fish). It is clear that the 1991 alewife year-class is weak - although the relationship between the YOY index, absolute abundance, and year-class strength needs verification (see "Comparisons of Hydroacoustic Measurements and Trawl Catches" below).

Hydroacoustic Measurements and Abundance Estimates

Hydroacoustic measurements of fish density ranged between 0.00 and 1.27 fish/m^3. On average, the highest densities were observed at 5 m below the surface and declined dramatically as depth increased (Fig. 8). One exception was the eastern location, which tended to have high densities near the bottom. The trawl catches of older alewife and older smelt in deep waters at the eastern location also tended to be higher than at other locations (Fig. 5 and 7).

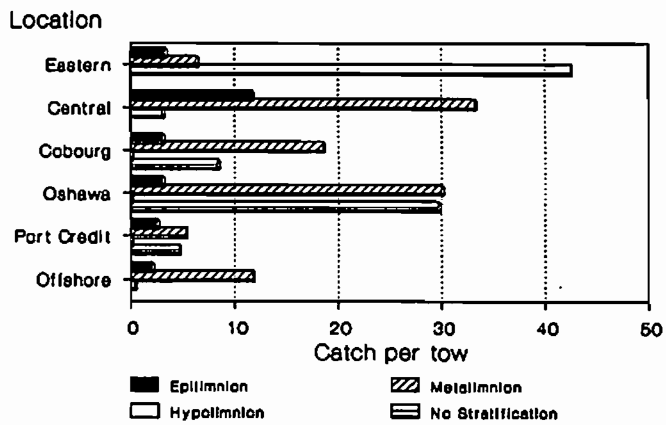

FIG. 5. Mean catch (fish/20 min trawl) of older alewife in the limnological strata and locations sampled during the 1991 midwater beam trawl survey on Canadian waters of Lake Ontario.

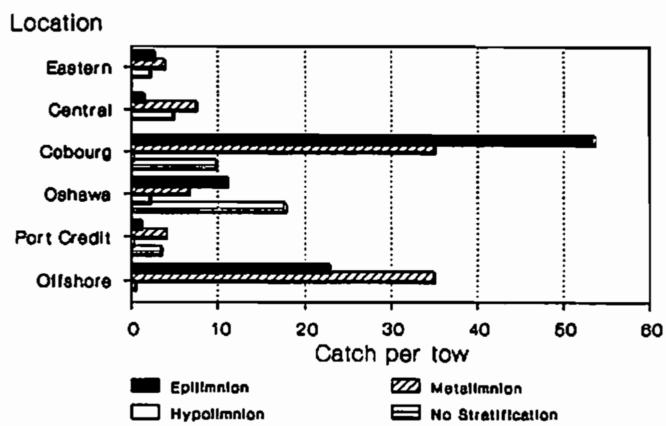

FIG. 6. Mean catch (fish/20 min trawl) of YOY smelt in the limnological strata and locations sampled during the 1991 midwater beam trawl survey on Canadian waters of Lake Ontario.

TABLE 3. Stratified index of abundance (millions of fish) and coefficient of variation (shown in brackets) for alewife and smelt in August, 1991 in Lake Ontario. Separate estimates were made for YOY and older fish. Estimates are based on catches in midwater beam trawls and are prone to the biases of this gear (see text).

Location	Older alewife	YOY alewife	Older smelt	YOY smelt
Eastern	62	›1	121	11
Central	64	6	142	32
Cobourg	19	1	332	64
Oshawa	49	›1	367	34
Port Credit	9	›1	223	7
Offshore	44	1	383	145
Canadian Waters	248 (25%)	8 (55%)	1,567 (33%)	292 (26%)

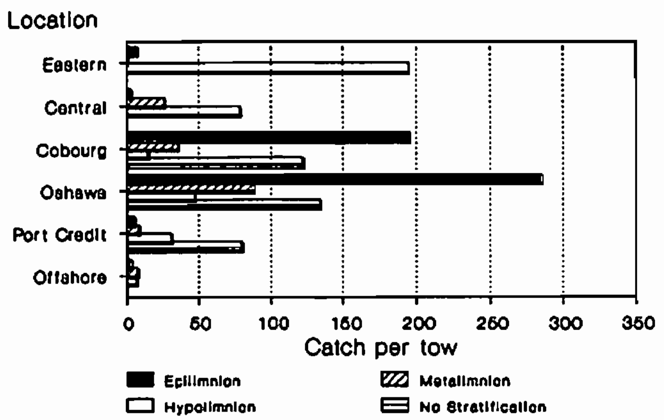

FIG. 7. Mean catch (fish/20 min trawl) of older smelt in the limnological strata and locations sampled during the 1991 midwater beam trawl survey on Canadian waters of Lake Ontario.

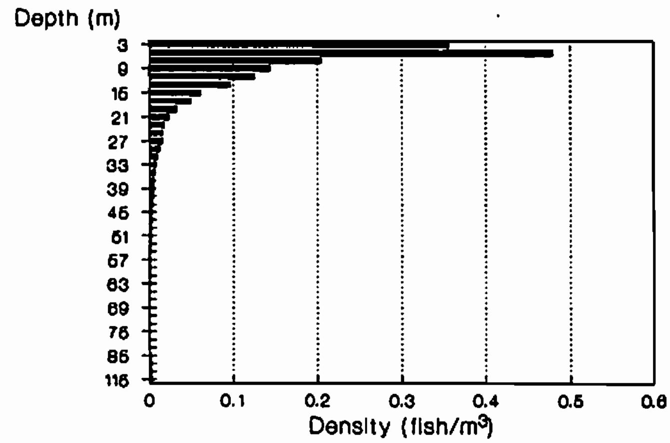

FIG. 8. Mean hydroacoustic density (fish/m^3) at the range of water depths below the surface sampled during the 1991 midwater trawling survey on Lake Ontario.

Target strengths ranged from -77 dB to -21 dB (Fig. 9). Love's equation (Love 1971) was used to breakdown the target strengths into four groups corresponding to the sizes of fish observed in the trawls: YOY prey, older prey, small predators, and large predators (Table 4, Fig. 9). Mean density of each size-group was calculated for each limnological zone and location. These densities were then expanded by the volume of each limnological strata and summed to produce abundance estimates for each size-group (Table 5).

A total of 26 billion fish (CV = 16%) was estimated for the Canadian waters of Lake Ontario (Table 5). YOY prey were by far the most abundant group representing 76% of the total. Older prey represented 22% of the total. Small and large predatory fish were estimated at 590 (2%) and 37 (0.1%) million fish, respectively. This estimate of large predators is in the same order of magnitude as the numbers of large salmonids estimated for Lake Ontario based on stocking rates and assumed survival rates (M. Jones, OMNR, RR#4, Picton, Ontario, K0K 2T0, pers. comm.).

Examination of the abundance index from the trawl (Table 3) and hydroacoustic absolute abundance estimates (Table 5) suggest that the trawl does not capture YOY and older prey with equal efficiency. The ratio of YOY to older prey for the hydroacoustic abundance estimate is 3.4:1, while for the trawl indices the ratio is 0.2:1. This suggests that the trawl catches older prey fish more efficiently than it catches YOY prey fish.

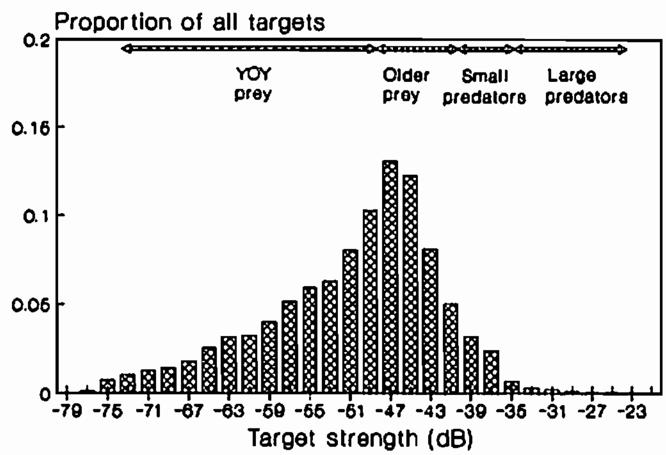

FIG. 9. Distribution of the target strengths (2 dB intervals), pooled data from entire survey. Correspondence to fish sizes was calculated with Love's equation (Love 1971).

TABLE 4. Target strength ranges chosen to represent fish groups. Loves' equation (Love 1971) was used to calculate the length of fish within the range.

Group	Target strength range	Fish length
YOY prey	-75 to -47 dB	‹82 mm
Older prey	-46.9 to -39 dB	82 to 212 mm
Small predators	-38.9 to -33 dB	213 to 438 mm
Large predators	-32.9 to -16 dB	›438 mm

TABLE 5. Estimated absolute abundance of fish (millions) in Lake Ontario during 1991 using hydroacoustic data. The estimates were made separately for each target strength category (see Table 4).

	Target Strength Group				
Location	YOY Prey	Older Prey	Small Predators	Large Predators	Total
Eastern	2,914	889	113	4	3,919
Central	3,878	676	42	3	4,599
Cobourg	3,944	698	105	15	4,762
Oshawa	1,598	566	54	5	2,223
Port Credit	1,971	1,012	106	2	3,090
Offshore	5,721	1,980	170	8	7,879
Total	20,026	5,821	590	37	26,472

Comparisons of Hydroacoustic Measurements and Trawl Catches

Active fishing gears, such as trawls, are unlikely to capture all fish species and all sizes of fish with equal efficiency. Hydroacoustic gear, however, should measure abundance of all fish of similar size, without bias between species. Unfortunately, at this time hydroacoustic data cannot be used to distinguish between fish species (Brandt et al. 1991). Comparison of the midwater beam trawl catches to the concurrent hydroacoustic measurements provides an opportunity to verify that trawl indices are proportional to actual fish abundance. It also provides the opportunity to make absolute abundance estimates for each prey species-group. Abundance estimates are easily converted to biomass with mean weights.

To compare the two types of fishing gear, we selected hydroacoustic data which corresponded to the trawl data in location, depth, and time. There were 47 samples with complete data. Comparisons were made between the portions of each data set which corresponded most closely in terms of the size of fish in each group, e.g. catches of YOY alewife and YOY smelt in the trawl were compared to the hydroacoustic density of YOY prey (Table 4).

Our approach was to produce a regression model relating trawl catches of alewife and smelt to hydroacoustic measurements of absolute abundance. A linear multiple regression model, with the intercept set to zero, was chosen. This model allowed separate expansions of smelt and alewife trawl indices into absolute abundance estimates. Examination of the model residuals indicated that transformation to a non-linear model was not necessary to stabilize variance. Also, log-transformed data only explained an additional 2% of the variance in predicted abundance and did not allow expansion of the trawl indices.

A correlation exists between hydroacoustic measurements of YOY prey and trawl catches of YOY alewife and YOY smelt (model $F = 5.28$, $p = 0.0087$, Table 6). The regression indicates that hydroacoustics measured 25 YOY smelt for every 1 captured by the trawl. Similarly, 169 YOY alewife were measured by hydroacoustics for every 1 captured by the trawl. Although the trawl was not efficient at capturing YOY prey, the correlation analysis suggests that the beam trawl catches do provide a good index of YOY prey abundance.

A similar regression analysis suggested that the trawl catches provide a good index of the abundance of older prey species. A correlation exists between hydroacoustic measurements of older prey and the trawl catches of older smelt and older alewife (model $F = 10.93$, $p = 0.0001$, Table 6). The regression indicated that hydroacoustics measured 3 older smelt for every 1 captured by the trawl. Similarly, 5 older alewife were measured by hydroacoustics for every 1 captured by the trawl.

The slopes of the regression lines (Table 6) were applied to the trawl indices to expand them to represent absolute abundance. These data indicate that 1,158 million older alewife and 3,875 million older smelt were present in Canadian waters of Lake Ontario during the 1991 survey. The absolute abundances of YOY fish were 1,330 million alewife and 7,185 million smelt. When these data were converted to biomass, the standing stock of alewife and smelt averaged 55 kg/ha for Canadian waters (Table 7). Separate estimates for each region ranged from 31 to 144 kg/ha and all fell below the management objective of 110 kg/ha (Kerr and LeTendre 1991) at all locations except Oshawa.

TABLE 6. Summary of results of multiple regression analysis of hydroacoustic measurements vs. catches of alewife and smelt from midwater beam trawls in Lake Ontario, 1991. The Y variables are the density of fish measured by hydroacoustics adjusted to represent specific size-groups of fish (Table 4). The X variables are the densities of fish captured in the midwater beam trawl. Regression 'F' statistics (and probability of F = 0) are given for both smelt and alewife.

Y	X1	X2	Regression Equation	Smelt F (P>F)	Alewife F (P>F)
YOY	YOY smelt	YOY alewife	$Y = 24.6X1 + 169.1X2$	5.5 (0.0237)	4.6 (0.0378)
Older prey	Older smelt	Older alewife	$Y = 2.5X1 + 4.7X2$	14.3 (0.0005)	2.9 (0.0979)

TABLE 7. Estimated standing stock (kg/ha) of alewife and smelt in August, 1991 in Lake Ontario. Estimates were based on midwater beam trawl indices which were expanded using regression analysis between trawl catches and hydroacoustic measurements. Separate estimates were made for YOY and older fish.

Location	Older alewife	YOY alewife	Older smelt	YOY smelt	Total
Eastern	61	0	25	1	87
Central	34	1	16	2	53
Cobourg	13	0	47	5	65
Oshawa	55	0	85	4	144
Port Credit	8	0	39	1	47
Offshore	10	0	18	3	31
Canadian Waters	23	0	30	3	55

Abundance estimates from the bottom trawling program conducted in western Lake Ontario during the spring of 1991 was 640 million yearling and older smelt (Mathers 1992). The beam trawl absolute abundance estimates (i.e. corrected by regression with hydroacoustics) for the corresponding waters is 713 million older smelt. Although confidence limits for these estimates were not calculated it is likely that they are not statistically different.

Our approach to combining hydroacoustic and trawl data differs from the technique used in previous surveys. Brandt et al. (1991) estimated total abundance of all prey species from hydroacoustic measurements. The total abundance was then divided into species components based on the relative abundance of the prey measured by bottom trawls. Their approach assumes that there are no differences in availability or catch efficiency of the trawl among the different species or different sizes of individuals within a species (Brandt et al. 1991). Our approach to combination of the hydroacoustic and trawl data does not make this assumption and provides an alternative method of estimating absolute abundance of a mixed-species assemblage.

Even though the regression models presented above are statistically significant, the proportions of the total variation explained by our regression models were not large. The YOY prey and older prey regression models, respectively, accounted for 19 and 31% of the variation in the hydroacoustic data. A perfect correspondence between the two gears cannot be expected, however, future surveys should attempt to reduce this variation as much as possible. A variety of factors are likely contributing to the unexplained variation. For example, the efficiency of the trawl may vary with the light conditions. Also, the survey vessel is more likely to disrupt the fish distribution near the surface than it is in the deeper layers. If the survey was conducted at a time of year when prey are not near the surface, these potential problems might be minimized.

Future changes in hydroacoustic technology may also improve the relationship between trawl catches and hydroacoustic measurements. Brandt et al. (1991) suggested that the most critical assumption in estimating fish abundance with hydroacoustic data concerns the relationship between target strength and fish size. For example, Burczynski et al. (1987) found that the lengths of YOY smelt caught in trawls were larger than the lengths estimated from hydroacoustic data. Accurate partitioning of hydroacoustic measurements into fish size categories should be verified for the Lake Ontario pelagic fish community. If the phenomenon observed by Burczynski et al. was true for Lake Ontario, then the efficiency of the midwater beam trawl for YOY prey may not be as low as the regression analysis above suggests.

Management Implications

It is difficult to provide recommendations to managers from a survey which has been running for only 2 yr. However, these data are important because they provide information on both alewife and smelt populations from the entire Canadian waters of Lake Ontario. Our survey showed that regional variation in prey abundance is high (Table 7; Fig. 4-7) which underlines the importance of lake-wide surveys.

The observation with the most importance to managers is the low YOY alewife index, which suggests a small 1991 year-class. The previous survey (Mathers et al. 1991) suggested that the 1990 year-class of alewife was much larger. O'Gorman et al. (1991) show wide variation between years in yearling alewife abundance, and attribute this variation to the changes in the density of the spawning stock of alewife. Consecutive weak year-classes of alewife and/or coincident low abundances of both older and YOY fish would be reason for concern about population status.

Results of this survey suggest that the current biomass of alewife and smelt in Lake Ontario (55 kg/ha) is below the previously established management objective of 110 kg/ha for all prey species (Kerr and LeTendre 1991). At this time, we do not interpret this discrepancy to mean that prey biomass is lower than is necessary to maintain the production of top predators. Additional surveys are needed to verify or refine the management objective of 110 kg/ha.

Results in this, and previous reports (Mathers et al. 1991; Schaner and Mathers 1991) suggest that the midwater beam trawl survey provides precise indices of smelt and alewife populations in all Canadian waters of Lake Ontario. The index of YOY abundance should (after verification) provide early warning of year-class failures. Expansion of the midwater beam trawl indices to estimate absolute abundance using hydroacoustic measurements is a promising prey stock assessment technique. This approach meets the increasing need for comprehensive lakewide estimates of absolute biomass of alewife and smelt.

Acknowledgments

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Status of Selected Fish Populations of Eastern Lake Ontario

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Lake Ontario Fisheries Unit, 1991 Annual Report, Section 14

The status of lake whitefish, lake herring, white perch, smallmouth bass, yellow perch, and walleye populations in eastern Lake Ontario and the Bay of Quinte were reported. Lake whitefish catches were down in the Assessment nearshore gillnetting program but I concluded that the 1991 catches were low as a result of unusually warm water conditions. Lake whitefish catches continued their long-term increase, since 1980, at the deep-water Research index gillnetting sites in the eastern basin of Lake Ontario, and catches of young-of-the-year (YOY) lake whitefish in trawling programs indicated a continuation of good recruitment, particularly for the Bay of Quinte stock. Lake herring remain abundant in the Flatt Point area only. However, catches at Flatt Point, in Assessment nearshore gillnets, were down slightly in 1991 compared with 1990. White perch abundance was up nearly 6-fold in the 1991 Assessment nearshore gillnetting program in the eastern basin, but down over 80% in Bay of Quinte Research index gillnets. I hypothesized that white perch migrated from the Bay of Quinte, to the eastern basin, prior to both index netting programs. Catches of smallmouth bass in the eastern basin were the highest recorded since the Assessment nearshore gillnetting program began in 1986. Yellow perch catches were variable among geographic areas and years. Although relatively strong year-classes have been produced in recent years, yellow perch populations have not generated large numbers of marketable-sized fish since the early 1980's. Thus, significant increases in the yellow perch commercial harvest are unlikely in the near future. Index gillnetting and trawling programs, and angling surveys indicate that the eastern Lake Ontario walleye population has never been greater or more productive.

Recommendations

1. Determine age-specific lake whitefish (Bay of Quinte stock) and walleye population estimates from 1991 mark/recapture program on the Bay of Quinte.
2. Examine the suitability of using index trawling sites, other than the Timber Island site, to index the abundance of Lake Ontario stock (young-of-the-year) YOY lake whitefish.
3. Adopt, and routinely implement, techniques to discriminate Lake Ontario lake whitefish stocks.
4. Assess the magnitude of the smallmouth bass sport fishery in eastern Lake Ontario using information collected during the angling survey planned for this area in 1992.
5. Process a backlog of age structures to determine age and growth characteristics of the eastern Lake Ontario smallmouth bass population.
6. Conduct an age and growth study designed to investigate the relative impacts of: (1) commercial fishing, (2) YOY and older alewife abundance, and (3) large predator abundance, on yellow perch abundance and population size structure.
7. Conduct a size/age-specific analysis of walleye abundance in the eastern basin of Lake Ontario to test the hypothesis that increased abundance here has resulted from the migration of increasingly large numbers of mature fish from the Bay of Quinte.
8. Study geographic variation in the production of YOY walleye in the Bay of Quinte.
9. Incorporate water temperature modeling in the development of fish population abundance indices for the new, 1992 eastern Lake Ontario fish community index netting program.
10. Develop gear conversion factors which will permit direct comparison of fish population abundance indices as measured by different gear types: mono- vs. multifilament gillnets, gillnets of 1.83 m vs. 2.44 m in height, and three-quarter "Western" vs. three-quarter "Yankee Standard" bottom trawls.
11. Examine fish migration/movement patterns between the Bay of Quinte and eastern Lake Ontario.

Introduction

Assessment and Research groups of the Lake Ontario Fisheries Unit (LOFU) conduct several annual index net-

TABLE 1. Lake Ontario Fisheries Unit Assessment and Research index netting programs from which species-specific catch data were used to assess and update the population status of several species of management interest. Numbers in table represent total numbers of each species caught in 1991. The total numbers of species and fish caught are also indicated.

	Assessment		Research	
Species	Lake Ontario nearshore gillnetting	Outboard trawling	Lake Ontario gillnetting/ trawling	Bay of Quinte gillnetting/ trawling
Lake whitefish	69		730/194	307/
Lake herring	165			
White perch	60			353/
Smallmouth bass	351			
Yellow perch	1652	2187		6603/
Walleye	528			1217/853
Total no. species	29	29	19/17	25/23
1992 catch	16535	6339	10005/52101	13273/16164

ting programs on Lake Ontario and the Bay of Quinte. Collectively, these programs are used to detect long-term changes in the eastern Lake Ontario fish community. Also, by providing trend-through-time indices of species abundance, these programs deliver timely, stock-specific information to fisheries managers.

The objective of this report is to update the status (last reported by Stewart 1991a, 1991b) of several species of management interest: lake whitefish, lake herring, white perch, smallmouth bass, yellow perch, and walleye. The status of lake trout is updated in Schneider et al. (1992), and that of forage fish, alewife and smelt, in Mathers (1992a).

Description of Programs

The majority of data in the stock status report comes from the Assessment nearshore gillnetting program. These data are supplemented by the results of several other LOFU index netting programs (Table 1). The programs are described below.

Assessment Nearshore Gillnetting Program

The LOFU Assessment group has conducted a fish community index gillnetting program at three sites in the eastern basin of Lake Ontario since 1986, and at three central basin sites since 1988. In 1991, multifilament gillnets were set along depth-stratified transects at five locations (Melville Shoal, Flatt Point, Rocky Point, Wellington, and Brighton), and at a single depth at one site (Middle Ground) from mid-July to mid-August (Fig. 1). Traditionally, gillnets are set at a sixth depth-stratified transect location (Grape Island), but in 1991 a comparative netting study (mono- vs. multifilament) was conducted here at a single depth (7.5 m) only. The results of the comparative netting will be reported elsewhere.

At transect locations, nets were set parallel to bottom contours, on the bottom, at 7.5, 12.5, 17.5, 22.5, and 27.5 m. The depth of the single net set at Middle Ground was 5 m.

Each gillnet consisted of eight multifilament panels with a graded series of mesh sizes from 1.5 to 5 in (38 to 127 mm) with 0.5 in (13 mm) intervals. There was 15 ft (4.6 m) of 1.5 in mesh, 75 ft (22.9 m) of 2 in mesh, and 150 ft (45.7 m) of each of the remaining mesh sizes. Gillnets were set in the afternoon and lifted the following morning. Three sets were made at each location/depth combination in a rotational fashion.

Catches of each species from each gillnet panel were extrapolated to 100 m, and then summed by mesh size to produce a standardized catch per gillnet lift.

Initial inspection of the trend-through-time data indicated that transects, in the same geographic area and with similar trends in species abundance, could be grouped. Specifically, mean catches were determined for transects grouped as follows: Melville Shoal and Grape Island (hereafter referred to as eastern basin), and Wellington and Brighton (hereafter referred to as central basin). Catches at the Flatt Point and Rocky point transects were unique, and were reported separately.

The data were summarized by calculating a mean catch per lift for lake whitefish and lake herring at the 22.5 and 27.5 m depths for each transect, and for white perch, smallmouth bass, yellow perch and walleye at the 7.5 and 12.5 m depths.

Yellow perch abundance, calculated as per Stewart (1991b), was also reported for the Middle Ground index site for the years 1979 to 1991.

Assessment Outboard Trawling Program

The LOFU Assessment outboard trawling program, initiated in 1988 (Bowlby 1989), is designed to index the abundance of 'small' fish in the Bay of Quinte and the nearshore habitats of eastern Lake Ontario. 'Small' fish include YOY and yearlings of large-bodied species, in addition to small-bodied, prey species. The outboard trawling program methodology and results for the 1991 field season are described by Hoyle (1992a). Here, I use abundance indices for YOY and yearling yellow perch, as reported by Hoyle (1992a) for the years 1988 to 1991.

Research Lake Ontario Gillnetting and Trawling Programs

Beginning in 1961 index gillnetting has been conducted once a month, from May to August, at up to six deep-water sites (26 to 38 m; Fig. 1) in the eastern basin of Lake Ontario. An annual index of lake whitefish abundance was reported by Casselman (1989) for the years 1961 to 1988. Here, I present these data graphically, and update them to 1991.

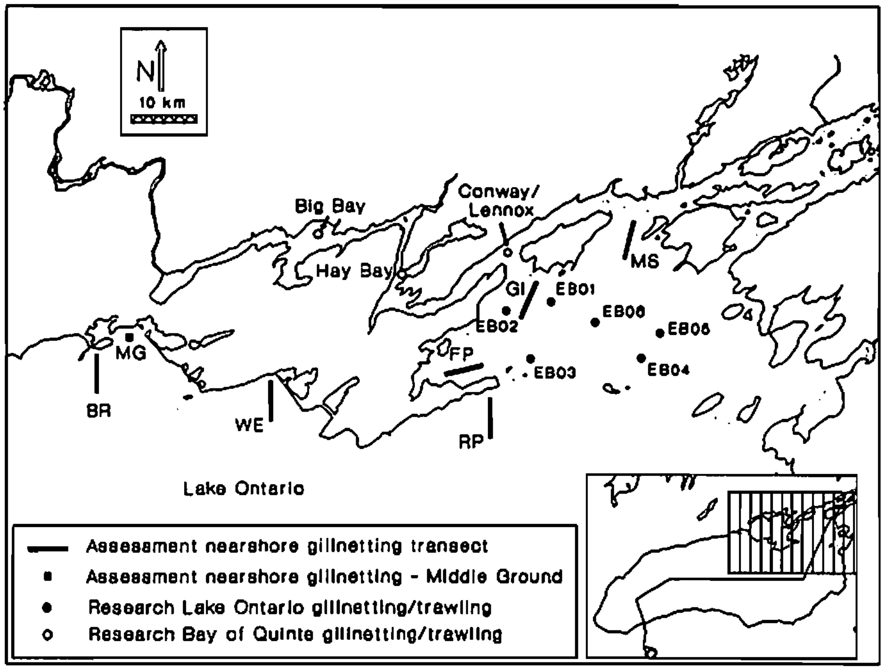

FIG. 1. Map of eastern Lake Ontario showing Lake Ontario Fisheries Unit index netting locations. Assessment nearshore gillnetting program includes depth-stratified transects at Brighton (BR), Wellington (WE), Rocky Point (RP), Flatt Point (FP), Grape Island (GI), and Melville Shoal (MS), and a single depth site at Middle Ground (MG). Research index gillneting and trawling programs on Lake Ontario include six sites in the eastern basin (EB01 to EB06 inclusive; EB03 is also known as the Timber Island site. Research index gillneting and trawling programs on the Bay of Quinte include Big Bay, Hay Bay, Lennox (gillnetting), and Conway (trawling).

Also, once a month from May to August since 1972, a three-quarter "Yankee Standard" No. 35 bottom trawl has been used at six similar deep-water sites. Trawls are of 12 min duration and cover a distance of 1/2 mile (804.7 m). Here, I report the mean catch-per-trawl during August of YOY lake whitefish at the Timber Island site (EB03; Fig. 1).

A more detailed description of these programs is reported by Casselman (1992).

Research Bay of Quinte Gillnetting and Trawling Programs

Index gillnetting has been conducted annually at up to 10 sites on the Bay of Quinte since 1972, but most recently at three sites. In early years, nets were set once a month from May to August, but since 1988 nets were set in June and August only. The 1991 netting on the Bay of Quinte utilized a gillnet that was 8 ft (2.44 m) in height compared to 6 ft (1.83 m) in previous years. I calculated mean catches of white perch, yellow perch, and walleye at three Bay of Quinte sites, Big Bay, Hay Bay, and Lennox (Fig. 1), adjusted to 100 m per mesh size and to 1.83 m (6 ft) in height. Here, results are reported for the years 1986 to 1991 to allow comparison to the Assessment nearshore gillnetting program on Lake Ontario.

Since 1972, a three-quarter "Western" bottom trawl has been used to complement the Bay of Quinte gillnetting program at similar sites sites and times. The trawls are of 6 min duration and 1/4 mile (402.3 m) distance. Here, I report the August mean catch-per-trawl of YOY lake whitefish at the Conway site (Fig. 1). Trawl catches were adjusted to 12 min duration for comparison to the Lake Ontario trawls.

A more detailed description of these programs is reported by Hurley (1992).

Results and Discussion

Assessment Nearshore Gillnetting Program

Ninety gillnet lifts were made, between July 8 and August 8, during the 1991 Assessment nearshore index gillnetting program on Lake Ontario. A total of 16,535 fish, representing 29 species, were caught (Table 1). The nearshore index netting program was designed to measure "point-in-time" fish population abundance indices and, as such, is carried out over a short time-frame, 1 mo, at a time of year when environmental conditions (e.g. water temperature) are relatively stable. However, an outstanding feature of the 1991 index netting program was that water temperatures changed tremendously over the study period (Fig. 2). High winds during the course of netting operations pushed warm surface waters against the north shore of Lake Ontario causing deep, cold waters to move out into the lake. Fewer numbers of cold-water species were caught after this event. Therefore, the 1991 abundance indices must be interpreted with caution.

The change in temperature was most dramatic at central basin transects (Brighton and Wellington). The effect was less dramatic at the other transects, but nonetheless, the trend to warmer water temperatures over the course of the study meant that the fish community changed from cold-water species to warm-water species at the 17.5 and 22.5 m netting depths.

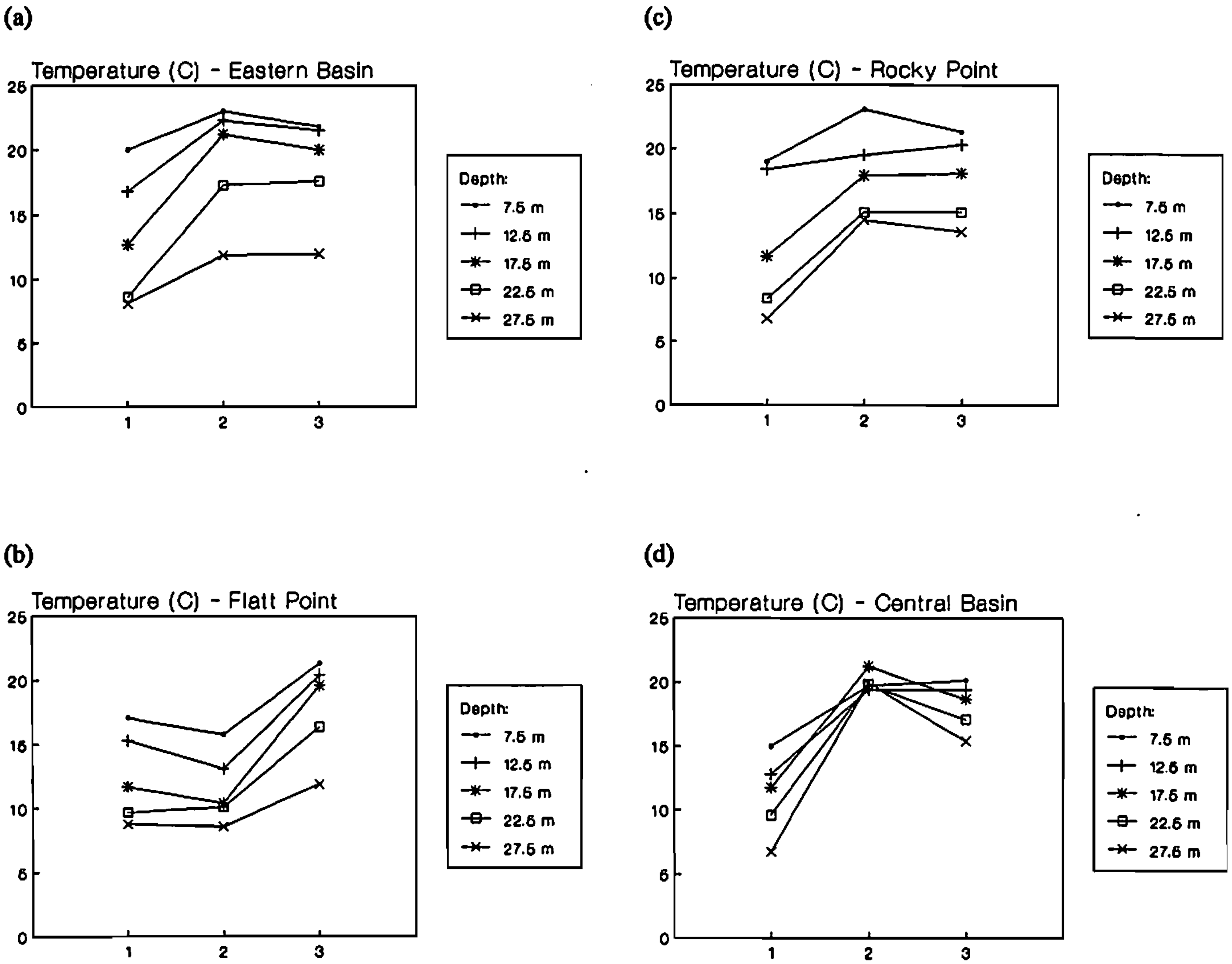

FIG. 2. Lake Ontario water temperatures (°C) at depth of gillnet gear. The x-axis represents successive visits (mid-July to mid-August, 1991) to depth-stratified transects: (a) eastern basin (Melville Shoal), (b) Flatt Point, (c) Rocky Point, and (d) central basin (mean of Wellington and Brighton transects).

Stock Status

The following discussion is a species-specific update of population status using trend-through-time abundance data.

Lake whitefish

Adults — Catches of lake whitefish in Assessment index gillnets declined in 1991, except for the central basin transects where there was a slight increase (Fig. 3). Catches in the Research index gillnets have increased since 1985 (Fig. 4). The disparity in these results can be explained, at least in part, by water temperature patterns observed during the 1991 field season (Fig. 2). The increase in lake whitefish abundance in the Research index nets, located in the deepest areas of the eastern basin, likely reflect a movement of fish to the deeper, colder waters, as nearshore waters warmed. Highest catches were observed at the deepest Research site (EB06, Fig. 1) in late August.

Lake whitefish catches in the eastern basin of Lake Ontario are thought to be comprised of two stocks (Christie 1967; Hoyle 1992b), but their relative abundance is not known. Lake Ontario lake whitefish stock discrimination techniques (Casselman 1990) should be adopted, and routinely implemented in LOFU index netting programs beginning in 1992.

Mark/recapture population estimates indicate that the Bay of Quinte spawning stock population size has increased tremendously in recent years, 3.2 times higher in 1988 than 1987 (Bowlby 1990). The 1991 mark/recapture program has not been analyzed to date. I recommend that a high priority be placed on this analysis since the mark/recapture program population estimates are, presumably, not influenced by variation in water temperature as are the current abundance indices from index gillnetting programs (see above).

Without implementation of routine stock discrimination techniques, neither population estimates or relative abundance indices are available for the Lake Ontario stock (Stewart 1991a). However, commercial harvest reports suggest that the Lake Ontario spawning stock has also increased in abundance recently (P. Smith, Ontario Ministry of Natural Resources, R.R. 4, Picton, Ontario, pers. comm.).

Juveniles — Two Research bottom trawling sites have been used to index the abundance of YOY lake whitefish (Stewart 1991a). The two sites, Timber Island and Conway, are thought to represent Lake Ontario and Bay of Quinte stocks, respectively. This assumption must be tested using stock discrimination techniques (see above).

Catches were very low at the Lake Ontario site (Timber Island, Fig. 5). However, moderate numbers were caught in trawls at other eastern basin sites (not presented here). Also, the annual YOY lake whitefish abundance indices presented in Fig. 5 are based on trawling on one day in August. Future index netting will be replicated on each of three dates in August.

The second largest number of YOY lake whitefish since 1974 was captured at the Conway site on the Bay of Quinte (Fig. 5). Large numbers of larval lake whitefish were also observed in the Bay of Quinte during lake whitefish early life history studies in April and May, 1991 (Hoyle 1992b).

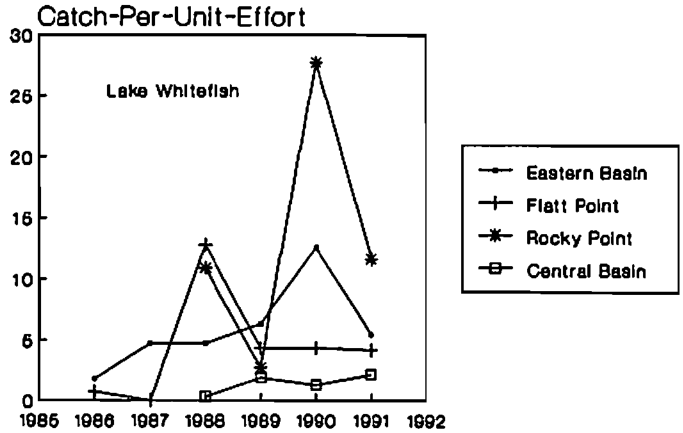

FIG. 3. Mean catch-per-gillnet lift (38 to 127 mm stretched mesh adjusted to 100 m of each mesh size) of lake whitefish, at 22.5 and 27.5 m water depths, in the Assessment nearshore index gillnetting program on Lake Ontario. Eastern basin represents mean catches at Melville Shoal and Grape Island (except in 1991 when it was Melville Shoal only). Central basin represents mean catches at Wellington and Brighton.

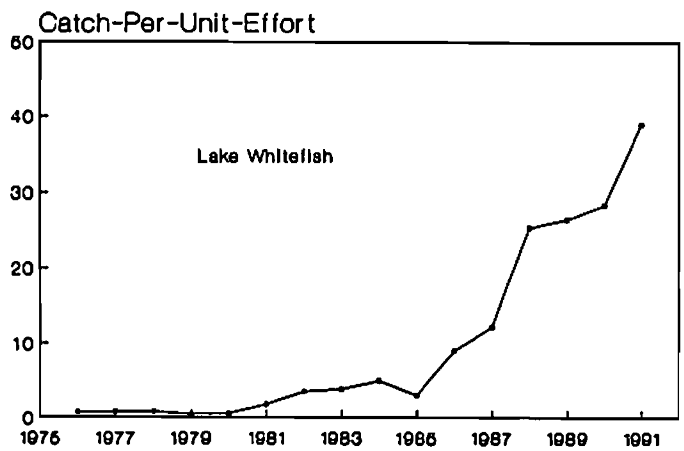

FIG. 4. Mean catch-per-gillnet lift of lake whitefish, at three to six deep-water (26 to 38 m) sites sampled once during June, July, and August, in eastern Lake Ontario Research index gillnets.

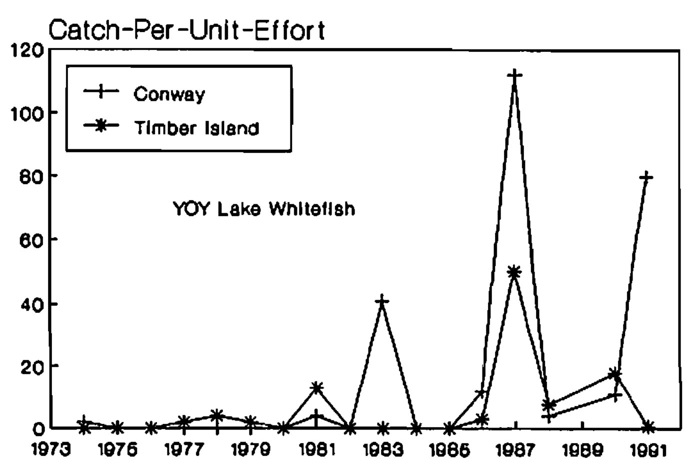

FIG. 5. Mean catch-per-trawl (804.7 m distance and 12 min duration) of YOY lake whitefish in the Bay of Quinte (Conway site; three-quarter "Western" bottom trawl) and Lake Ontario (Timber Island, EB03 site; three-quarter "Yankee Standard" No. 35 bottom trawl).

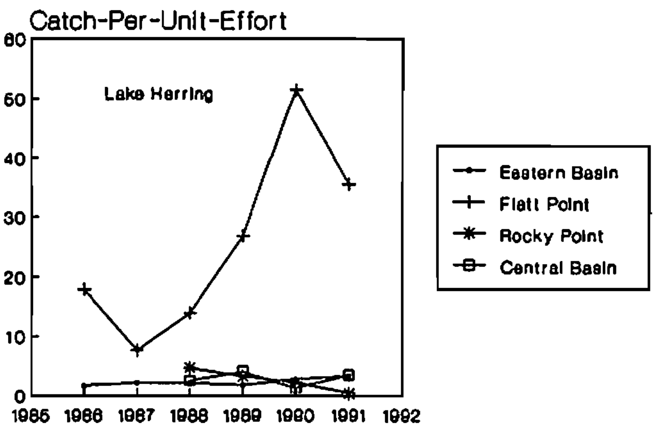

FIG. 6. Mean catch-per-gillnet lift (38 to 127 mm stretched mesh adjusted to 100 m of each mesh size) of lake herring, at 22.5 and 27.5 m water depths, in the Assessment nearshore index gillnetting program on Lake Ontario. Eastern basin represents mean catches at Melville Shoal and Grape Island (except in 1991 when it was Melville Shoal only). Central basin represents mean catches at Wellington and Brighton.

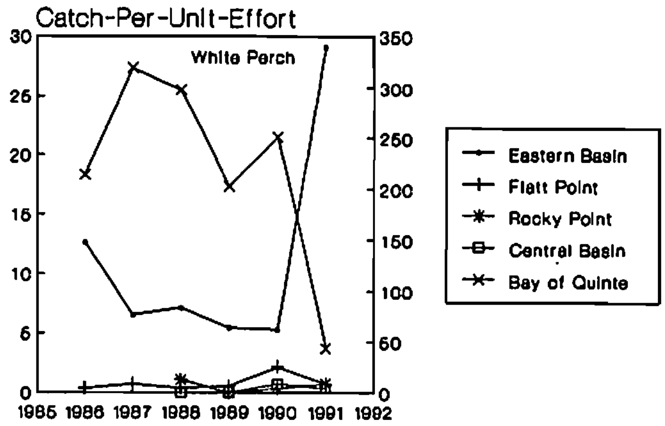

FIG. 7. Mean catch-per-gillnet lift (38 to 127 mm stretched mesh adjusted to 100 m of each mesh size) of white perch at 7.5 and 12.5 m water depths in the Assessment nearshore index gillnetting program on Lake Ontario, and in the Research index gillnetting program on the Bay of Quinte. Eastern basin represents mean catches at Melville Shoal and Grape Island (except in 1991 when it was Melville Shoal only). Central basin represents mean catches at Wellington and Brighton. Bay of Quinte represents the mean catches at three sites, Big Bay, Hay Bay, and Lennox.

Lake herring

Assessment nearshore gillnets indicate that lake herring are abundant at only one location, Flatt Point. Here, 1991 catches were down 30% from 1990 after having increased consistently since 1987 (Fig. 6).

White perch

Assessment nearshore gillnets indicate that white perch are abundant at eastern basin transects (Melville Shoal and Grape Island), but rarely caught at the other Lake Ontario transects (Fig. 7). White perch numbers in the eastern basin increased nearly six-fold in 1991 compared to 1990 while declining by over 80% in the Bay of Quinte. One explanation for these observations is that white perch migrated from the Bay of Quinte to Lake Ontario, prior to LOFU index gillnetting programs in 1991.

Smallmouth bass

Assessment index gillnets indicate that smallmouth bass are abundant at the eastern basin and the Rocky Point transects. Here, their numbers doubled from 1990 to 1991 (Fig. 8). These areas have a tremendous potential to provide quality smallmouth bass angling. An eastern basin angling survey, planned for 1992, should provide information as to the extent of this fishery.

Also, the addition of an index gillnetting transect between Long Point and Main Duck Island, and the interpretation of a backlog of aging material, both planned for 1992, will allow for improved surveillance of eastern Lake Ontario smallmouth bass.

Yellow perch

Assessment nearshore gillnetting and Research index gillnetting indicate that yellow perch decreased slightly or remained steady at Lake Ontario sites but increased in the Bay of Quinte (Fig. 9). However, as described above, the Bay of Quinte gillnets used in 1991 were 8 ft (2.44 m) in height compared to 6 ft (1.83 m) in previous years. Although the 1991 catches were adjusted to reflect this change in the height of nets used, the effect due to the larger nets relative to a real change in yellow perch abundance is not known. If the increase in abundance of Bay of Quinte yellow perch is real, it is likely due to a strong year-class in 1987 which showed up as yearlings in the 1988 Assessment outboard trawling program (Fig. 10).

In 1991, at the traditional yellow perch index site (Middle Ground, Fig. 11), catches increased slightly, both in total numbers and in the proportion of commercially marketable-sized individuals (7.5 inches total length). However, the current abundance of yellow perch does not compare with the high levels observed in the early 1980s, following a severe alewife die-off during the winter of 1977 (O'Gorman and Schneider 1986).

Although total numbers of yellow perch were also high in 1986, the abundance of marketable-sized fish has remained low. The population size structure is consistent with overexploitation (Mathers 1989). However, the commercial harvest has, since 1985, been small relative to the harvest during the 1970s, immediately prior to the increase in the abundance of large yellow perch in 1980 (Fig. 11) and subsequent increase in the commercial harvest in 1981 (Fig. 12).

There has been an increase in the abundance of large piscivores, i.e. salmonids (mainly lake trout and chinook salmon) and walleye, in eastern Lake Ontario during the 1980s. Thus, one hypothesis to explain the lack of large yellow perch is that total mortality, caused by the combined effects of predation and commercial fishing, has increased since the early 1980s and has prevented large yellow perch from becoming abundant.

Alternatively, or in addition, yellow perch length-at-age may have declined since the early 1980s such that few fish are reaching large sizes.

An age and growth study is planned for 1992. This study is designed to investigate the relative impacts of: (1) commercial fishing, (2) YOY and older alewife abundance, and (3) large predator abundance, on yellow perch abundance and population size structure. The study will use age structure and abundance data collected from the late 1970s through 1991.

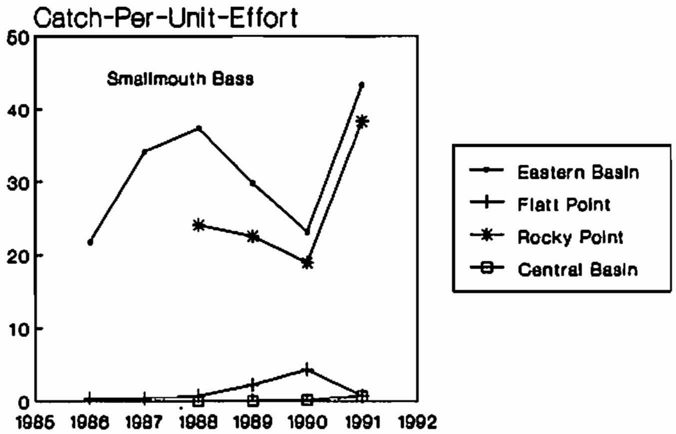

FIG. 8. Mean catch-per-gillnet lift (38 to 127 mm stretched mesh adjusted to 100 m of each mesh size) of smallmouth bass, at 7.5 and 12.5 m water depths, in the Assessment nearshore index gillnetting program on Lake Ontario. Eastern basin represents mean catches at Melville Shoal and Grape Island (except in 1991 when it was Melville Shoal only). Central basin represents mean catches at Wellington and Brighton.

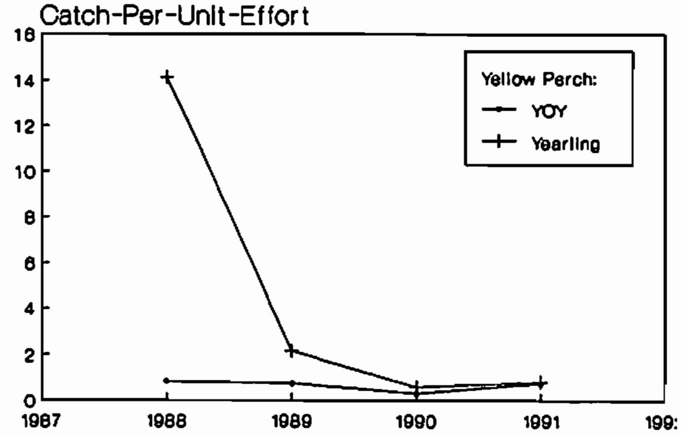

FIG. 10. Mean catch-per-trawl (402.3 m distance, 6 min duration) of YOY and yearling yellow perch in the Assessment outboard trawling program on the Bay of Quinte (mean at 11 sites).

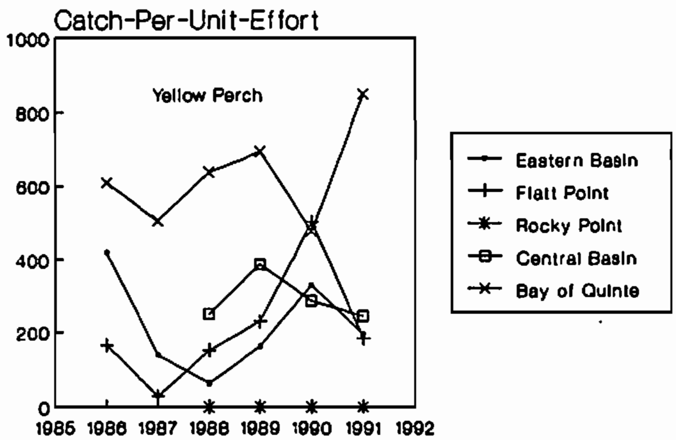

FIG. 9. Mean catch-per-gillnet lift (38 to 127 mm stretched mesh adjusted to 100 m of each mesh size) of yellow perch at 7.5 and 12.5 m water depths in the Assessment nearshore index gillnetting program on Lake Ontario, and in the Research index gillnetting program on the Bay of Quinte. Eastern basin represents mean catches at Melville Shoal and Grape Island (except in 1991 when it was Melville Shoal only). Central basin represents mean catches at Wellington and Brighton. Bay of Quinte represents the mean catches at three sites, Big Bay, Hay Bay, and Lennox.

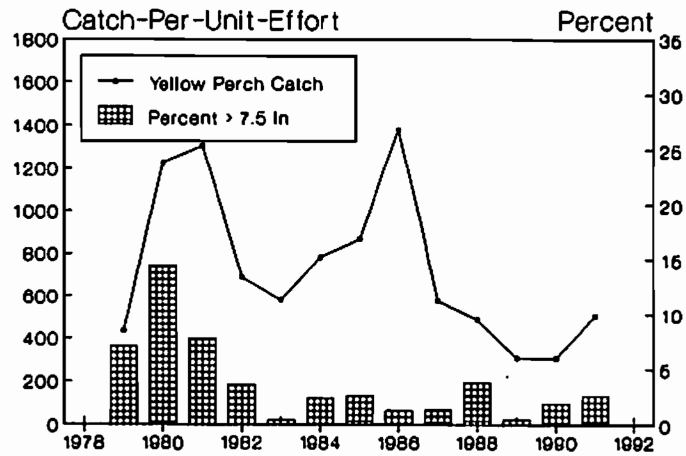

FIG. 11. Mean catch-per-gillnet lift (38 to 127 mm stretched mesh adjusted to 100 m of each mesh size) of yellow perch at the Middle Ground site of the Assessment nearshore index gillnetting program on Lake Ontario and the proportion of the catch greater than 7.5 inches total length.

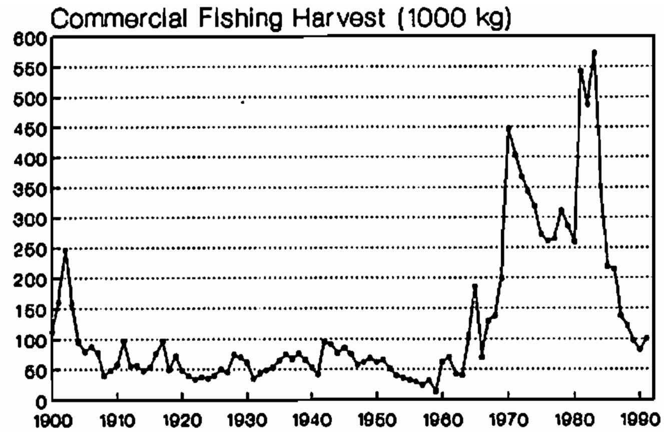

FIG. 12. Commercial harvest of yellow perch in the Canadian waters of Lake Ontario. The large majority of the harvest comes from eastern Lake Ontario.

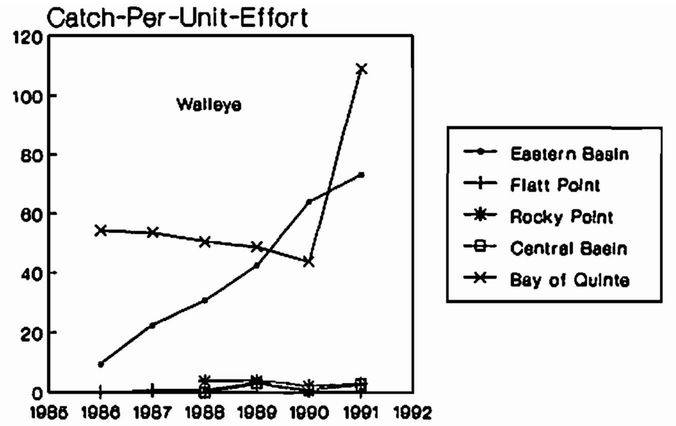

FIG. 13. Mean catch-per-gillnet lift (38 to 127 mm stretched mesh adjusted to 100 m of each mesh size) of walleye at 7.5 and 12.5 m water depths in the Assessment nearshore index gillnetting program on Lake Ontario, and in the Research index gillnetting program on the Bay of Quinte. Eastern basin represents mean catches at Melville Shoal and Grape Island (except in 1991 when it was Melville Shoal only). Central basin represents mean catches at Wellington and Brighton. Bay of Quinte represents the mean catches at three sites, Big Bay, Hay Bay, and Lennox.

Walleye

Adults — Assessment nearshore gillnetting indicate that the walleye population in the eastern basin has increased steadily since 1986 (Fig. 13). Mathers (1991a) postulated that the increasing numbers of walleye in the eastern basin could be accounted for by the post-spawn migration of increasingly abundant mature walleye from the Bay of Quinte.

In the Research Bay of Quinte gillnets, walleye numbers remained stable from 1986 to 1990 then increased in 1991. As was the case for yellow perch, the effect due to the larger nets relative to any change in walleye population abundance has not been determined.

Angling surveys in 1991 indicate that the Bay of Quinte angling fishery has never been larger or more productive (Mathers 1992b).

Juveniles — YOY walleye in the Bay of Quinte, although down 38% from 1990, show a general increasing trend since the early 1980s in Research bottom trawls (Fig. 14). An increase in the number of index trawling sites in 1992, will allow examination of regional variation in YOY walleye production in the Bay of Quinte.

Future Directions

Program amalgamation

Beginning in 1992, Assessment and Research index netting programs will be amalgamated into a single program — the eastern Lake Ontario fish community index netting program. The process of amalgamation will result in gear standardization, improvements to the experimental designs of the original programs, and will eliminate sampling redundancies, while maintaining the continuity and integrity of the historic data series. Improved experimental design and a streamlined, more coordinated program, will make better our ability to detect changes in the eastern Lake Ontario fish community.

Indices of abundance

Program amalgamation will continue after the 1992 field season in the sense that species/stock-specific indices of population abundance, for which there has, to date, been multiple approaches, will be reviewed and consolidated. Essential to the development of new abundance indices will be water temperature considerations. As demonstrated by the 1991 Assessment nearshore index gillnetting program, variation in water temperature can complicate interpretation of fish abundance indices. Water temperatures in Lake Ontario are highly variable and this has a profound effect on fish distribution patterns (Stewart 1991c).

One implication of developing new indices of abundance is that some efforts will be required to calculate these indices from historical data series.

Other biological attributes

Stock/species status assessment could also be enhanced with a greater use of biological attribute data (e.g. age and growth). Biological indicators, such as those proposed by OMNR (1983), can be used to interpret past trends in species/stock abundance, and, more importantly for fisheries managers, are critical to predict future trends in abundance. Toward this end, an aging plan has been developed (Mathers 1991b), and a greater commitment will be made, beginning in 1992, to process and interpret a backlog of aging material.

Gear

In the amalgamated, eastern Lake Ontario fish community index netting program, monofilament gillnets with standardized specifications will replace multifilament nets which varied in their specification among former programs. Also, the new program will adopt the bottom trawling gear, formally used on Lake Ontario only, for all trawling activities. These measures will alleviate operational concerns associated with construction, inventory, and use of multiple gear types, and will allow for more direct comparison of fish population abundance indices across a wide geographic area. The Research group of LOFU has con-

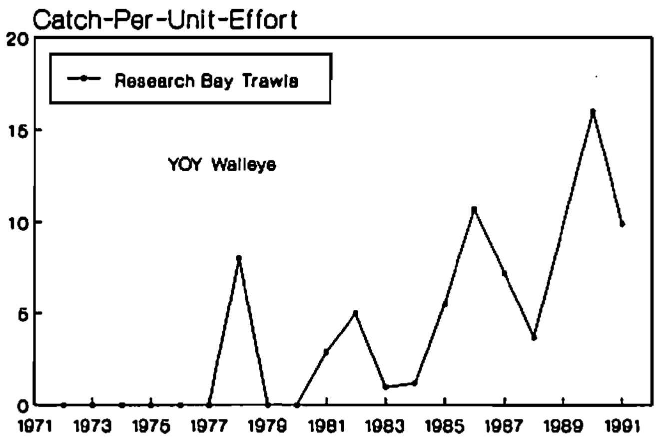

FIG. 14. Mean catch-per-trawl (402.3 m distance and 6 min duration) of YOY walleye in the Bay of Quinte (mean of three sites, Big Bay, Hay Bay, and Conway using a three-quarter "Western" bottom trawl).

ducted gear comparison studies (Casselman 1991; Hurley 1991) which will us to compare catches from the old and new gear types (e.g. Hurley 1992).

Seasonality and fish migrations and movements

Generally speaking, seasonal migrations and movements of fish between the Bay of Quinte and Lake Ontario are not well understood. Studies designed to address this issue, would allow for interpretation of point-in-time index netting results in the context of the seasonal patterns of fish migration and movement, and should be supported.

Acknowledgments

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Lake Ontario Stocking and Marking Program for 1991

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This report summarizes the characteristics of fish stocked into Lake Ontario from Canadian and American sources for 1991. Stocking trends since 1968 for both countries are also summarized herein. Information such as; numbers of fish, planting location, egg source, strain, age and size at stocking, and marks applied is provided. Proposed stocking numbers by species and their expected distribution for 1992 are presented. Since 1984, American and Canadian fisheries managers have been adhering to a stocking cap of 8.2 million (+/- 5%) fish for Lake Ontario. The total number of salmon and trout planted into Lake Ontario from all sources in 1991 was 8,184,525. The Province of Ontario waters received 2,706,055 salmonids, while New York waters received 5,478,470. In addition, 121,817 walleye were stocked by private groups in New York waters of Lake Ontario. In February of 1991, the Ontario Ministry of Natural Resources announced the closure of three older provincial fish culture stations and the termination of the coho salmon rearing program. New York State managers are continuing their experiments with triploid (sterile) chinook salmon, Seeforellen trout (strain of large brown trout) and Skamania trout (summer run rainbow trout). The provincial Atlantic salmon rehabilitation experiment is continuing despite some problems in obtaining a sufficient number of eggs.

Introduction

The Lake Ontario fish stocking and marking program report is prepared annually as a joint New York Department of Environmental Conservation (NYDEC) and Ontario Ministry of Natural Resources (OMNR) effort. The report is prepared to summarize numbers of fish planted into Lake Ontario and identifying marks used by both agencies.[1]

Results

Tables 1 and 2 provide statistics on numbers of fish stocked in 1990 and 1991 and numbers of fish proposed for 1992 stocking. Tables 3(a,b) and 4(a,b) provide information on numbers of fish stocked into Lake Ontario from 1968 through 1991 by both agencies. Table 5 identifies the deviations from the 1991 proposals and explains the reasons for the changes.

The proposed stocking of trout and salmon by OMNR and NYDEC for 1992 is presented as numbers of fish by species, expected age, and proposed stocking sites in Tables 6 and 7. Appendix A and B contain detailed information about the areas of Lake Ontario that received hatchery fish in 1991. These appendices contain species information including strain, hatchery or origin, age and size at stocking, and marks applied.

Comparison of the OMNR and the NYDEC Lake Ontario stocking is shown as relative abundance of each species by percent in Fig. 1 and as actual numbers by age

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[1] Most fish were raised in provincial fish culture stations or State fish hatcheries. Exceptions in 1991 included: lake trout provided by United States Fish and Wildlife Service from the Allegheny National Fish Hatchery. Private groups raised walleye fry provided by the NYDEC and stocked them as fingerlings. Sir Sanford Fleming College in Lindsay Ontario, collected chinook salmon eggs from the Credit River and stocked fingerlings into Cobourg Creek.

group in Fig. 2. Trends in the total number of fish planted by both agencies are shown in Fig. 3 and trends by species, of fish stocked by both agencies combined, is depicted in Fig. 4.

The 1991 Lake Ontario fish stocking by government agencies consisted of salmon and trout only. Private groups in New York raised and stocked walleye from fry provided by NYDEC's Oneida Hatchery. The total number of salmon and trout stocked in all Lake Ontario waters combined was 8,184,525. The stocking of 2,706,055 salmonids in Province of Ontario waters was approximately the number proposed. The New York stocking of 5,478,470 salmon and trout was slightly above the proposed target. The 121,817 walleye stocked by private groups in New York was slightly below the record number of walleye planted in 1990.

The NYDEC stocking total of salmon and trout remained virtually the same (- 3,130 fish) from 1990 to 1991. There were however, several changes in the stocked species mix. The positive aspect of species changes included increases in Washington steelhead yearlings (+ 107,000) and fingerlings (+ 158,500), and chinook salmon spring fingerlings (+ 115,000). These excesses were all from better than expected survival at the Salmon River Hatchery. Species that were down, such as lake trout, (+ 22,490 yearling and - 150,000 fall fingerling) are expected to improve in the near future.

The OMNR stocking total increased by 472,512 (21%) from 1990 to 1991. There were OMNR stocking increases for all salmonids with the exception of Atlantic salmon. Most of these increases were the result of fall fingerling stocking of brown, lake and rainbow trout. In February of 1991, the OMNR announced the closure of three older provincial hatcheries and the termination of the coho salmon rearing program. The coho salmon on hand at the Ringwood Fish Culture Station were stocked as fry in order to accommodate rainbow and brown trout being transferred from hatcheries which were closing. As a result of the restructuring of the provincial fish culture system we have suggested interim stocking levels for 1992 (Tables 1 and 6). The OMNR Lake Ontario Manager will be reviewing the long-term stocking priorities and targets during 1992.

The 1991 stocking, by American and Canadian agencies combined, was 157,525 fish (2%) above the proposed targets for 1991 and only 15,475 (<1%) below the agreed 8.2 million (+/- 5%) stocking cap for Lake Ontario. The stocking of walleye by private groups in New York, brought the grand total of fish stocked to 1.3% over the cap.

Discussion

Since 1984, New York and Ontario fisheries managers have been adhering to a stocking cap of 8.2 million fish (+/- 5%) for Lake Ontario (Fig. 3).

As stocking numbers of various species have been modified in recent years, some developments require clarification. Changes by each agency are as follows:

NYDEC

Lake Trout

The Allegheny National fish hatchery (NFH) has been producing lake trout for New York since 1978. The target is 1,020,000 yearlings and 180,000 fall fingerlings but that number has been unreachable in recent years. The shortfall was caused by changes in program direction and hatchery equipment malfunctions.

The New York DEC Great Lakes Fisheries Section modified the request for various strains after developing brood stocks for strains that did not survive well in Lake Ontario. These changes were requested due to the exceptional success of Seneca strain and less than desirable results with progeny of other brood stock strains. This resulted in not meeting yearling goals for several years.

In 1990 and 1991 well water quantity and quality problems at Allegheny NFH were identified and have progressively gotten worse. This resulted in stocking fish early in 1991 and not obtaining adequate growth from some raceways of fish, and even the transfer of 200,000 sickly fish to Caledonia hatchery for rehabilitation. The Allegheny problems are under study and are expected to be repaired promptly.

Atlantic Salmon

The target is for 200,000 yearling Atlantic salmon for Lake Ontario. These numbers have not been available and this species was grossly understocked until 1991 (Table 2). This year the upgraded Adirondack hatchery produced nearly enough yearling to meet the Lake Ontario demand. Reaching the NYDEC goal of 200,000 yearling Atlantic salmon should be a routine occurrence from this point on.

Chinook Salmon

Management efforts in recent years have been aimed at reducing numbers of chinook salmon returning to the Black River. This process is aimed at reducing snatching while upgrading steelhead and Atlantic salmon angling opportunity in the Black River. The targeted number of 2.7 million chinook are still stocked but have all been moved west, out of the eastern basin of Lake Ontario.

Management techniques have been used to produce a small lot of triploid chinook salmon (35,000) at the Salmon River Hatchery. Triploidy is a condition where there is an extra chromosome in the cell nucleus that results in sterile fish. Experimentation is being conducted to determine if triploid fish will refrain from migrating upstream at spawning time. This technique could produce some fish that remain in the lake for extended periods of time and grow very large.

Coho Salmon

Efforts to maintain a brood stock of coho salmon at the Salmon River Hatchery have been successful. However, hatchery water temperature problems have resulted in less than desirable coho for stocking. The majority of coho have been stocked as fingerlings to avoid overwintering losses in 1991.

In 1991 a pipeline from the Salmon River reservoir upgraded the summer and winter water quality at the hatchery and the stocking policy will revert to all coho being stocked as yearlings.

Brown Trout and Steelhead
The NYDEC, Great Lakes Section staff are always striving to improve angling. As part of this approach we have experimented with stocking Seeforellen brown trout and Skamania steelhead. The Seeforellen brown trout have been finclipped and stocked at 2 sites (Shore Oaska and Oswego) annually to determine if we can produce some very large brown trout. The Skamania program is also experimental and is planned for stocking 4 sites with marked fish each year. Due to the lack of adequate brood stock only 1 site (Beaverdam Brook) has been stocked to date. The purpose of Skamania stocking is to increase nearshore summer angling opportunities. Results of both experimental strain stocking programs are not expected until at least 1994.

OMNR

The OMNR's fish culture program has undergone significant changes recently. Following an extensive review of priorities within the provincial fisheries program, the OMNR announced the closure of three older fish culture stations (FCS) in February of 1991. Two of the stations (Deer Lake and Codrington) had been supplying fish to Lake Ontario. The OMNR has also discontinued the coho salmon stocking program.

The closure of three fish culture stations represents a decrease in fish production capabilities, which in turn requires a province wide review of the Five Year Fish Stocking Requirements Plan. The Canadian Lake Ontario stocking numbers proposed for 1992 (Tables 1 and 6) are interim suggestions only.

The following is a brief summary, by species, of the major changes to date in the provincial Lake Ontario stocking program (Table 1 and 6):

Brown Trout
Because of the space limitations caused by hatchery closures, over 145,000 brown trout were stocked as fall fingerlings. The proposed stocking for the near future is expected to be a combination of yearling and fall fingerling paired plantings. These will be distributed in smaller lots at a larger number of locations along the waterfront (Table 6). This will allow for post stocking assessment of yearling versus fingerling success and contribute to a nearshore brown trout fishery over a larger area of the waterfront.

Coho Salmon
The coho salmon on hand at the Ringwood FCS were stocked as fry in 1991 in order to accommodate rainbow and brown trout being transferred from hatcheries which were closing. The OMNR will no longer be rearing coho salmon.

Chinook Salmon
The OMNR has a proposed annual chinook stocking target of 650,000 fingerlings. The Ringwood FCS does not currently meet this target. Ringwood was exclusively a Pacific salmon rearing facility prior to the station closures. It is now rearing rainbow and brown trout in addition to chinook salmon. The Ringwood FCS has also been designated to receive Lake Ontario strain Atlantic salmon when disease testing requirements have been satisfied.

Lake Trout
The continued emphasis in the lake trout program will be on planting to achieve the rehabilitation objective. This program is guided by "A Joint Plan for the Rehabilitation of Lake Trout in Lake Ontario" (Schneider et al. 1983). Assessment data suggests that Seneca Lake (N.Y.) and Lake Superior strains have performed better in Lake Ontario (Schneider et al. 1987). The OMNR has been replacing the Lake Manitou and Killala Lake strains with Lake Superior and Seneca strains. Slate Island (Lake Superior) strain were stocked into Lake Ontario starting in 1991. Some Seneca strain fish will be stocked by the OMNR for the first time in 1992.

Rainbow Trout
Put-and-delayed-take rainbow trout stocking has been restricted to the west end of Lake Ontario. Previous paired plantings of fall fingerling/yearling coho salmon in the Credit River, Bronte Creek and at Port Dalhousie indicated that fingerlings survived equally well (Bowlby 1990). A fall fingerling/yearling paired planting experiment for rainbow trout in Bronte Creek and the Credit and Rouge Rivers began in 1991. North shore streams of Lake Ontario have very healthy runs of rainbow trout which no longer need to be supplemented by hatchery fish.

Atlantic Salmon
Atlantic salmon stocking was originally planned as a ten year rehabilitative experiment which began in 1987. The goal was to stock 50,000 yearlings annually. That target was met once, in 1989 (Table 3b). There have been recent problems in obtaining eggs from the east coast. A landlock strain was not available for the 1991 stocking and will not be stocked in 1992. The OMNR is seeking alternate sources for Atlantic salmon eggs.

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Glossary of Terms and Abbreviations

Steelhead: a migratory rainbow trout, technically, one which undergoes the parr-smolt transformation and migrates to Lake Ontario from the stream in which it was planted, or hatched in the case of wild fish.

Domestic Rainbow trout: a rainbow trout that is not known to exhibit a parr-smolt transformation and, therefore, is planted directly into the lake since it would not be expected to migrate to the lake if planted in a stream.

Atlantic salmon: includes the ocean run strain of fish generally referred to as Atlantic salmon and the lake dwelling strain called landlocked salmon.

Mark: body part removed or tag added for identification
LV: Left Ventral fin clip
Ad-LV: Adipose and Left Ventral fins clipped
RV: Right Ventral fin clip
Ad-LP: Adipose and Left Pectoral fins clipped
LV-RV: Both Ventral fins clipped
RP: Right Pectoral fin clip
LP: Left Pectoral fin clip
LV-LM: Left Ventral fin and Left Maxillary bone clip
CWT: Coded Wire Tag (60-42-14; the first two numbers are the agency code; i.e., 60, 23 and 63 are agency codes for USFWS, NYDEC and OMNR respectively, the third through sixth numbers identify individual lots of fish)

Some figures and tables use the following species name abbreviations:

Coho:	Coho salmon	Splk:	Splake
Chin:	Chinook salmon	Lake:	Lake trout
Atla:	Atlantic salmon	Brwn:	Brown trout
Rbow:	Rainbow trout	Brok:	Brook trout
Sthd:	Steelhead trout	Wall:	Walleye
Koka:	Kokanee salmon	Salm:	Salmonid salmon

TABLE 1. Salmon and trout stocked in Province of Ontario waters of Lake Ontario in 1990 and 1991 and proposed for 1992.

Species	Age	Number stocked 1990	Number stocked 1991	Number proposed 1992
Brown trout	Yearling	386,718	380,914	257,000
	Fall Fingerling	0	145,039	100,000
	Sub Total	386,718	525,953	357,000
Coho salmon	Yearling	169,289	0	0
	Fall Fingerling	65,575	2,950	0
	Fry	0	275,511	0
	Sub Total	234,864	278,461	0
Lake trout	Yearling	948,574	1,092,196	965,800
	Fall Fingerling	0	0	200,000
	Sub Total	948,574	1,092,196	1,165,800
Chinook salmon	Fingerling	541,187	497,347	650,000
Rainbow trout	Yearling	0	125,070	60,000
	Fingerling	104,994 [a]	62,249	60,000
	Sub Total	104,994	187,319	120,000
Atlantic salmon	Yearling	27,446	28,495	32,000
	Fingerling	33,600 [b]	0	0
	Sub Total	61,046	28,495	32,000
	LAKE TOTAL	2,233,543	2,706,055	2,324,800

[a] 11 month old spring fingerlings.
[b] 10 and 11 month old fingerlings, except for 1,600 six month old fish.

TABLE 2. Salmon and trout stocked in New York waters of Lake Ontario in 1990, and 1991 and proposed for 1992.

Species	Age	Number stocked 1990 [a]	Number stocked 1991 [a]	Number proposed 1992
Brown trout	Yearling	461,150	381,880	425,000
Coho salmon	Yearling	110,000	97,000	90,000
	Fingerling	331,620	131,750	155,000
	Sub Total	441,620	228,750	245,000
Lake trout	Yearling	795,600	818,090	1,020,000
	Fingerling	310,000	160,000	180,000
	Sub Total	1,105,600	978,090	1,200,000
Chinook salmon	Fingerling	2,720,000	2,835,000	2,700,000
Rainbow trout				
Washington Steelhead	Yearling	412,200	519,300	375,000
	Fingerling	180,000	215,000	0
	Sub Total	592,200	734,300	375,000
Domestic	Yearling	94,110	81,550	100,000
	Fingerling	33,600	28,900	0
	Sub Total	127,710	110,450	100,000
Skamania	Yearling	0	32,000	82,000
	Rainbow Species Total	719,910	876,750	557,000
Atlantic salmon	Yearling	33,320	178,000	200,000
	LAKE TOTAL	5,481,600	5,478,470	5,327,000

[a] Stocking in both years includes surplus fingerlings.

TABLE 3a. Number of salmon and trout (x 1000) stocked in Province of Ontario waters of Lake Ontario from 1968 through 1980.

Species	Age [a]	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Coho	Y	0	138	148	160	122	272	438	226	166	313	201	156	77
Coho	F	0	0	0	0	0	0	0	0	0	0	0	130	172
Chinook	f	0	0	0	89	190	0	225	0	0	0	393	147	18
Lake	Y	0	0	0	0	0	0	0	0	194	288	200	201	383
Rainbow	Y	12	10	10	18	107	28	30	7	108	110	114	201	149
Rainbow	F	0	0	0	0	0	30	94	0	0	0	10	0	0
Rainbow	f	0	0	0	0	0	0	0	22	0	0	0	0	180
Splake	Y	24	25	0	0	48	39	26	0	6	0	0	0	0
Kokanee	f	0	20	45	50	61	0	0	0	0	0	0	0	0
Kokanee	fry	228	334	1982	678	0	0	0	0	0	0	0	0	0
TOTALS		264	527	2185	995	528	369	813	255 [b]	474 [b]	711 [b]	918	835	979

TABLE 3b. Number of salmon and trout (x 1000) stocked in Province of Ontario waters of Lake Ontario from 1981 through 1991.

Species	Age [a]	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Coho	Y	169	112	142	106	191	183	188	207	204	169	0
Coho	F	165	0	76	0	0	90	129	104	87	66	3
Coho	f	0	0	0	0	0	0	84	76	0	0	276 [c]
Chinook	f	12	270	125	662	703	598	514	516	541	497	594
Lake	Y	387	391	372	493	729	852	1066	1024	1124	949	1092
Lake	F	0	0	0	0	0	0	56	0	0	0	0
Brown	II+	0	0	0	1	1	1	0	0 [d]	0 [d]	0	0
Brown	Y	0	0	123	122	136	283	256	387	360	387	381
Brown	F	0	48	0	0	27	14	62	0	0	0	145
Brown	f	7	0	0	0	0	0	0	0	0	0	0
Rainbow	Y	81	68	105	110	106	200	306	264	118	0	125
Rainbow	F	0	0	0	0	0	0	0	111	0	105	62
Atlantic	Y	0	0	0	0	0	0	0	27	61	27	28
Atlantic	F	0	0	0	0	0	0	1	22	15	34	0
TOTALS		821	889	943	1494	1893	2221	2662	2738	2511	2234	2706

[a] II+: Two year old fish.
Y: Yearlings, stocked between January and June usually 5" to 9".
F: Fall fingerlings, stocked between September and December usually 3-1/2" to 6".
f: Spring fingerlings, stocked May and June usually 2-1/2" to 3".
fry: 1 to 2 month old fish.

[b] Does not include stocking of 15,000 rainbow trout eggs in 1975 or lake trout eggs stocked in 1976 (90,000) and 1977 (200,000).

[c] Actually 275,511 coho fry stocked in the spring of 1991 (Canadian coho stocking discontinued).

[d] There were 346 and 275 adult brown trout stocked (spent brood stock) in 1988 and 1989, respectively.

TABLE 4a. Number of salmon and trout (x 1000) stocked in New York waters of Lake Ontario from 1968 through 1980.

Species	Age [a]	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Coho	Y	25	119	294	122	230	215	147	452	178	39	40	175	0
Coho	F	15	0	0	0	0	25	69	361	0	0	40	169	299
Chinook	f	0	70	140	100	426	691	963	920	593	0	0	222	788
Chinook	F	0	0	0	0	0	9	0	0	0	0	0	0	0
Lake	Y	0	0	0	0	0	66	128	0	63	0	505	492	1012
Lake	F	0	0	0	0	0	0	517	513	274	298	538	193	182
Brown	Y	0	0	0	0	0	60	81	108	157	163	94	219	257
Brown	F	0	0	0	0	0	0	42	113	154	195	0	0	272
Rainbow	Y	0	0	0	0	0	0	19	0	54	50	41	41	85
Rainbow	F	0	0	0	0	0	0	10	99	104	67	125	167	411
Steelhead	Y	0	0	0	0	0	0	50	0	29	27	147	117	263
Brook	F	0	0	0	0	0	0	0	0	0	8	0	0	326
TOTALS		40	189	434	222	656	1066	2026	2566	1606	847	1530	1795	3895

TABLE 4b. Number of salmon, trout and walleye (x 1000) stocked in New York waters of Lake Ontario from 1981 through 1991.

Species	Age [a]	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Coho	Y	0	307	396	289	351	194	80	300	197	110	97
Coho	F	0	60	51	454	25	268	0	176	213	187	132
Coho	af	0	0	0	0	0	0	0	0	0	144	0
Coho	f	0	0	0	0	0	85	0	80	0	0	0
Chinook	f	1468	1808	2759	3878	3022	2849	3111	2848	2752	2720	2835
Lake	Y	1031	1054	1086	1045	984	1012	818	768	778	796	818
Lake	F	112	205	11	0	202	370	367	247	232	310	160
Lake	II+	3	0	0	0	0	0	0	0	0	0	0
Brown	Y	365	503	479	408	440	442	418	404	407	461	382
Brown	F	89	153	100	0	0	0	0	46	38	0	0
Brown	f	0	98	132	0	0	0	0	0	0	0	0
Rainbow	Y	76	38	108	93	84	80	91	77	94	94	82
Rainbow	F	147	96	105	105	105	23	40	150	25	34	0
Rainbow	f	0	0	140	0	549	0	0	0	0	0	29
Steelhead	Y	260	114	112	293	334	407	443	407	384	412	551
Steelhead	F	0	5	0	0	10	55	129	308	75	180	40
Steelhead	f	0	0	0	0	0	0	0	0	0	0	175
Brook	F	106	0	0	0	0	0	0	0	0	0	0
Atlantic	Y	0	0	49	25	55	55	58	32	50	33	178
Atlantic	F	0	0	0	0	13	0	7	6	15	0	0
Walleye	af	0	0	0	0	0	20	3	63	72	125	122
SALMONIDS		3657	4441	5528	6590	6174	5840	5562	5849	5260	5482	5479
WALLEYE		0	0	0	0	0	20	3	63	72	125	122
TOTALS		3657	4441	5528	6590	6174	5860	5565	5912	5332	5607	5601

[a] II+: Two year old fish.
Y: Yearlings, stocked between January and June usually 5" to 9".
F: Fall fingerlings, stocked between September and December usually 3-1/2" to 6".
af: Advanced spring fingerlings, usually stocked after June but prior to September.
f: Spring fingerlings, stocked May and June usually 2-1/2" to 3".

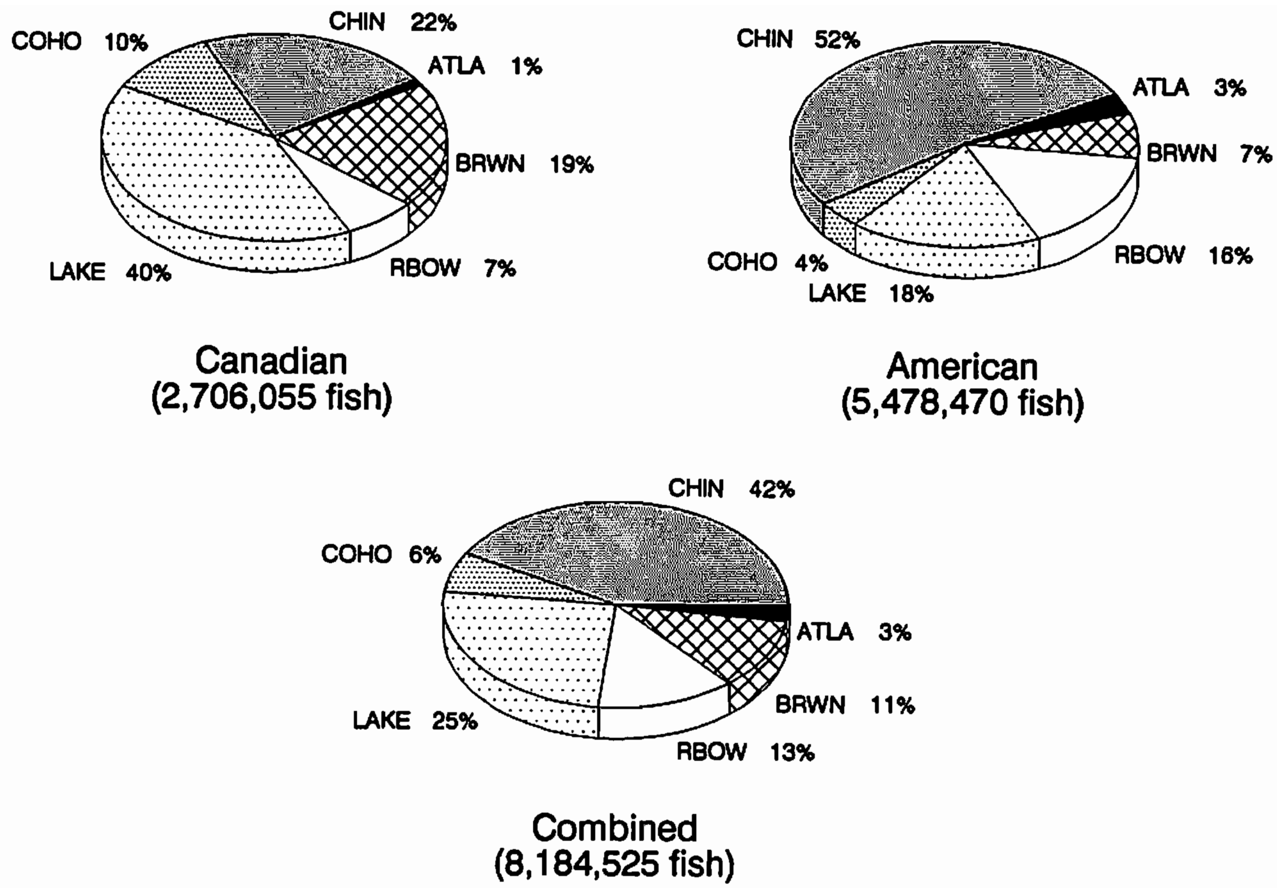

FIG. 1. Lake Ontario salmonid species mix stocked from Canadian and American sources in 1991.

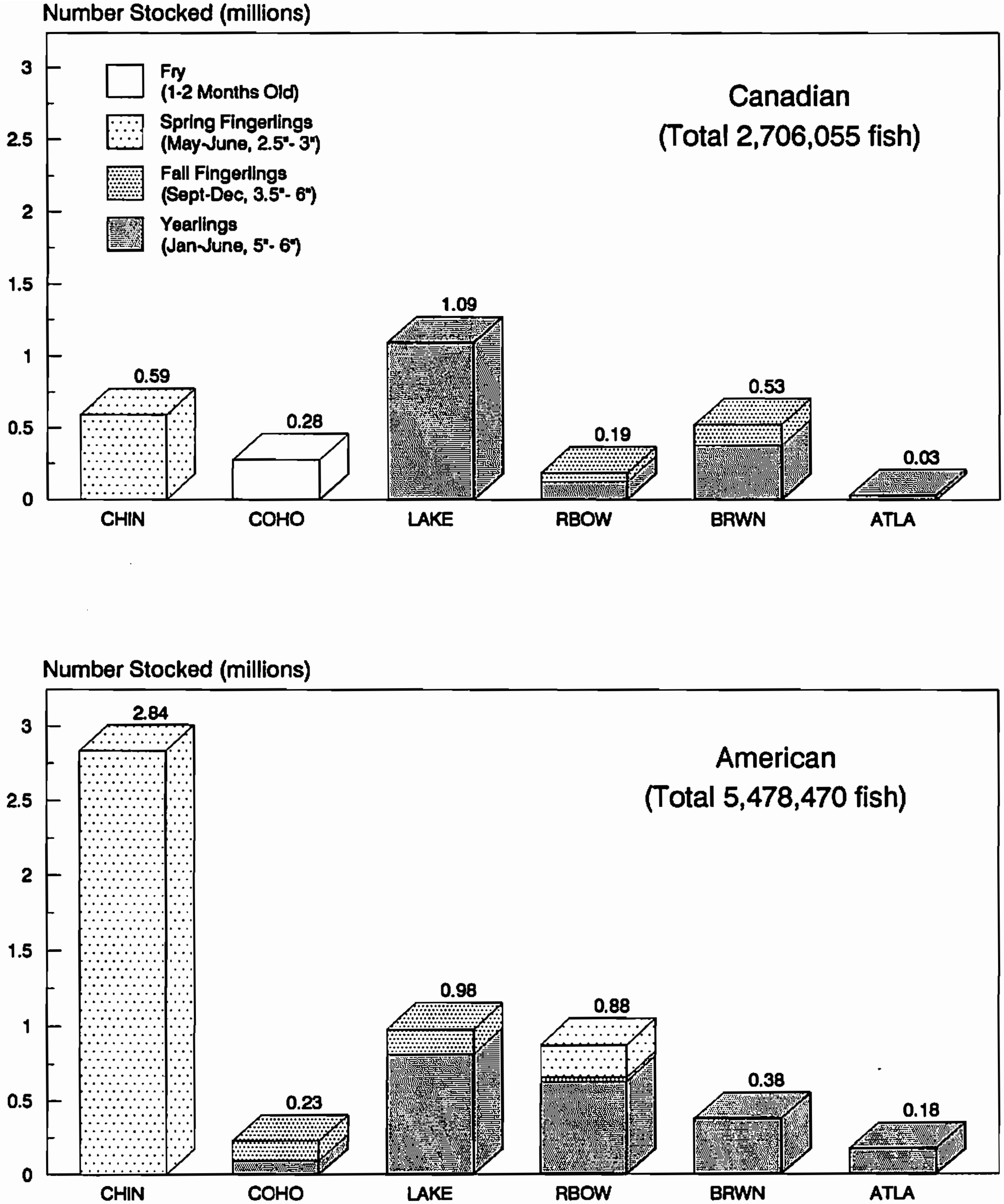

FIG. 2. Lake Ontario salmonid species mix stocked from Canadian and American sources in 1991 presented by age group.

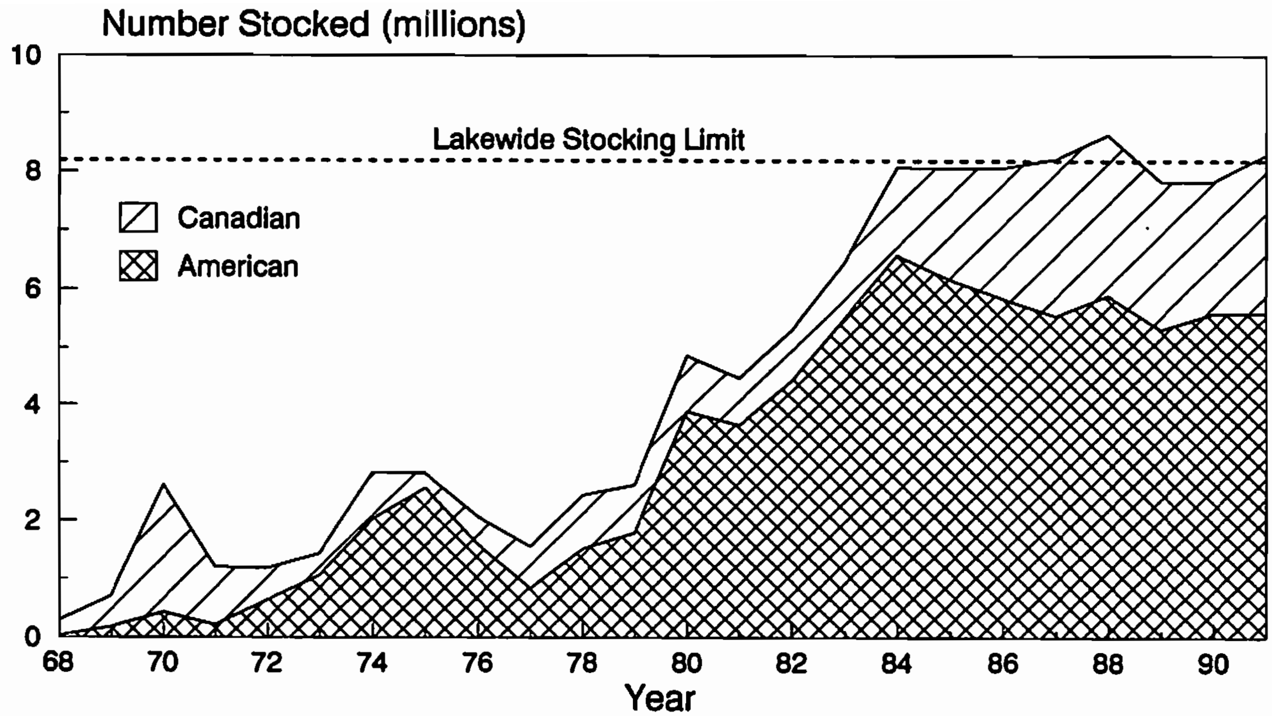

FIG. 3. Lake Ontario stocking trends (all species combined) from Canadian and American sources. Includes yearlings, all fingerlings, some fry and II+ fish. Also includes American stocked walleye beginning in 1986.

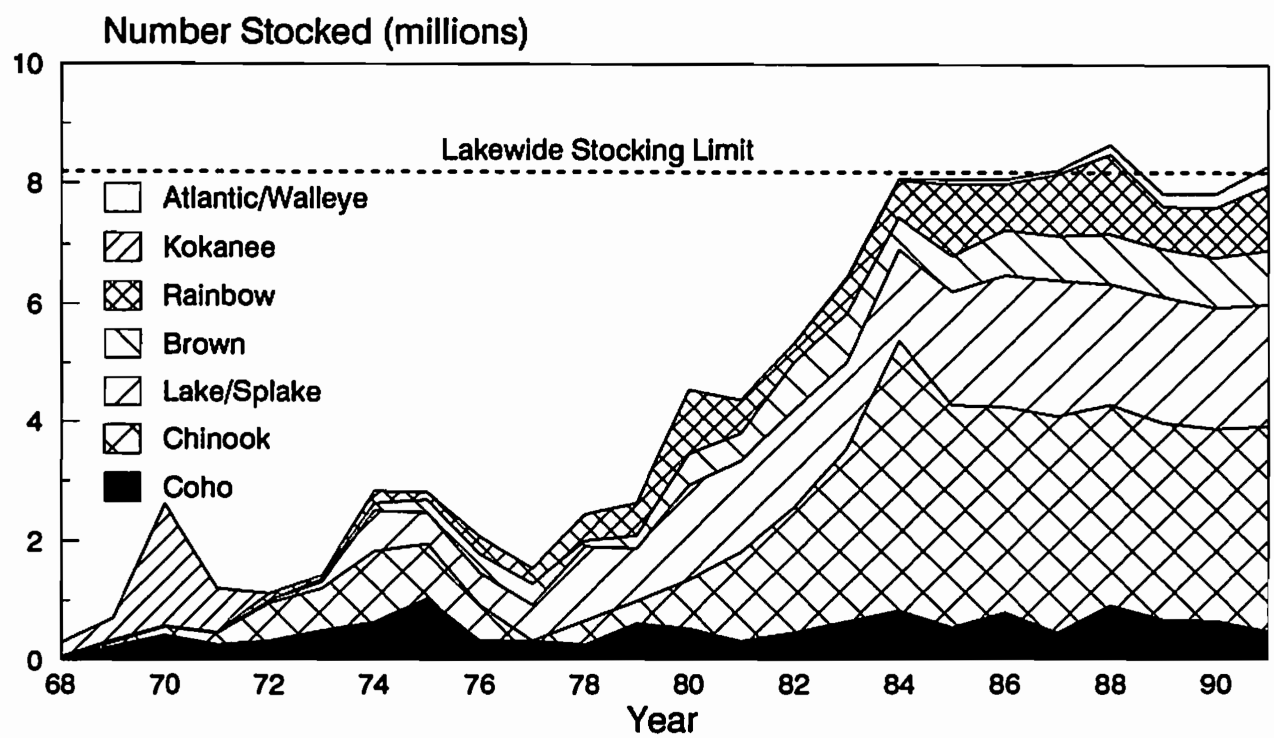

FIG. 4. Lake Ontario stocking trends, by species, for combined Canadian and American plantings. Includes all yearlings, all fingerlings, some fry and II+ fish. Canadian splake (1968-1976) are included with lake trout. Americans also stocked 326,000 and 106,000 brook trout in 1980 and 1981 respectively.

TABLE 5. Important deviations from the proposed stocking numbers by the OMNR and the NYDEC in 1991.

Species	Agency	Number (x1000)	Age [a]	Reason
Lake trout	NYDEC	- 202	Y	Attempting to produce recently required strains is taking time.
	OMNR	- 58	Y	Shortfall, due to Hills Lake Hatchery renovation and change of strains.
Coho salmon	NYDEC	+ 7 - 23	Y F	Policy for all yearling stocking was modified temporarily to include some fingerlings. Policy was restored now that Salmon River waterline has been completed.
	OMNR	+ 3 + 276	F fry	Coho stocking program has been terminated. All coho at Ringwood FCS were stocked as fry.
Chinook salmon	NYDEC	+ 135	f	Better than anticipated survival.
	OMNR	- 56	f	Hatchery (Ringwood) does not meet the 650,000 chinook fingerling target due to water supply and space limitations.
Rainbow trout	NYDEC	- 19 + 29	Y F	Statewide shortage of yearlings. Extra fingerlings stocked to replace shortfall.
	OMNR	- 50 + 62	Y F	Production shortfall due to hatchery closures. Start of fall fingerling experiment.
Steelhead trout	NYDEC	+ 144 + 215	Y F	Better than anticipated survival of all year classes.
Skamania trout	NYDEC	- 50	F	Rebuilding brood stock.
Brown trout	NYDEC	- 43	Y	Statewide shortage of yearlings.
	OMNR	- 54 + 145	Y F	Production shortfall due to hatchery closures. Stocked fall fingerlings due to hatchery space limitations.
Atlantic salmon	NYDEC	- 22	Y	Hatchery renovation completed and required numbers are anticipated by 1992.
	OMNR	- 22	Y	Shortfall due to problems with obtaining sufficient number of eggs.

[a] Y: Yearlings, stocked between January and June, usually 5" to 9".
F: Fall fingerlings, stocked between September and December usually 3-1/2" to 6".
f: Spring fingerlings, stocked May and June usually 2-1/2" to 3".
fry: 1 to 2 month old fish.

TABLE 6. Proposed 1992 stocking in Province of Ontario waters of Lake Ontario.

Species	Location	Quantity	Age
Brown trout	Port Dalhousie	25,000	Yearling
	Port Dalhousie	6,250	Fall Fingerling
	Jordan Harbour	25,000	Yearling
	Jordan Harbour	6,250	Fall Fingerling
	Grimsby	6,250	Fall Fingerling
	Fifty Point	14,600	Yearling
	Fifty Point	6,250	Fall Fingerling
	Burlinton Canal	14,600	Yearling
	Burlinton Canal	6,250	Fall Fingerling
	Spence Smith Park	14,600	Yearling
	Spence Smith Park	6,250	Fall Fingerling
	Bronte Harbour	14,600	Yearling
	Bronte Harbour	6,250	Fall Fingerling
	Oakville Harbour	14,600	Yearling
	Oakville Harbour	6,250	Fall Fingerling
	Port Credit	6,250	Fall Fingerling
	Marie Curtis Park	6,250	Fall Fingerling
	Col. Sam Smith Park	6,250	Fall Fingerling
	Humber Bay Park	6,250	Fall Fingerling
	Don River Mouth	6,250	Fall Fingerling
	Ashbridges Bay	9,000	Yearling
	Ashbridges Bay	6,250	Fall Fingerling
	Bluffers Park	9,000	Yearling
	Bluffers Park	6,250	Fall Fingerling
	Rouge River	13,000	Yearling
	Rouge River	6,250	Fall Fingerling
	Duffins Creek	9,000	Yearling
	Ganaraska River	9,000	Yearling
	Humber River	9,000	Yearling
	Oshawa Creek	9,000	Yearling
	Collins Bay	22,300	Yearling
	Millhaven	44,700	Yearling
	Total Yearling Brown	257,000	Yearling
	Total Fall Fing. Brown	100,000	Fall Fingerling
	Total Brown Trout	357,000	
Coho salmon	None	Nil	N/A

TABLE 6. (Continued)

Species	Location	Quantity	Age
Chinook salmon	Ashbridges Bay	35,000	Spring Fingerling
	Bluffers Park	35,000	Spring Fingerling
	Credit River	140,000	Spring Fingerling
	Burlington Canal	75,000	Spring Fingerling
	Bronte Creek	75,000	Spring Fingerling
	Port Dalhousie	150,000	Spring Fingerling
	Cobourg Creek	30,000 [a]	Spring Fingerling
	Oshawa Creek	30,000	Spring Fingerling
	Bowmanville Creek	30,000	Spring Fingerling
	Wellington Harbour	50,000	Spring Fingerling
	Total Chinook Salm.	650,000	Spring Fingerling
Lake trout	Burlington Canal	43,800	Yearling
	50 Mile Point	260,000	Yearling
	50 Mile Point	100,000	Fall Fingerling
	Cobourg	260,000	Yearling
	Cobourg	100,000	Fall Fingerling
	Point Traverse	402,000	Yearling
	Total Yearling Lake	965,800	Yearling
	Total Fall Fing. Lake	200,000	Fall Fingerling
	Total Lake Trout	1,165,800	
Rainbow trout	Bronte Creek	23,800	Yearling
	Bronte Creek	25,000	Fall Fingerling
	Credit River	23,800	Yearling
	Credit River	25,000	Fall Fingerling
	Rouge River	12,400	Yearling
	Rouge River	10,000	Fall Fingerling
	Total Yearling Rainbow	60,000	Yearling
	Total Fall Fing. Rainbow	60,000	Fall Fingerling
	Total Rainbow Trout	120,000	
Atlantic salmon	Credit River	22,000	Yearling
	Wilmot Creek	10,000	Yearling
	Total Atlantic Salmon	32,000	Yearling
CANADIAN PROPOSED TOTAL ALL SPECIES		2,324,800	

[a] Sir Sanford College expects to stock an additional 4,000 fry and 3,000 spring fingerling chinook salmon into Cobourg Creek in 1992.

TABLE 7. Proposed 1992 stocking of New York waters in Lake Ontario.

Region	Location	Key	Number	Age
Chinook salmon				
6	Southwicks Beach	523	50,000	4 months
6	Associated Island	423	60,000	4 months
6	Stony Creek	0.40	35,000	4 months
6	North Sandy Creek	0.45	90,000	4 months
6	South Sandy Creek	0.45	90,000	4 months
7	Salmon River	0.53	300,000	4 months
7	Lower Salmon River	0.53	270,000	4 months
7	Oswego River	0.66	225,000	4 months
7	Little Sodus Bay	0.73	180,000	4 months
8	Sodus Bay	0.84	180,000	4 months
8	Genesee River	0.117	270,000	4 months
8	Sandy Creek	0.130	180,000	4 months
8	Oak Orchard Creek	0.138	270,000	4 months
9	Eighteen Mile Creek	0.148	180,000	4 months
9	Twelve Mile Creek	0.152	60,000	4 months
9	Lower Niagara River	0.157	260,000	4 months
	Total chinook salmon		2,700,000	
Coho salmon				
7	Salmon River	0.53	90,000	Yearling
8	Sodus Point	0.84	26,000	Fingerling
8	Genesee River	0.117	22,000	Fingerling
8	Sandy Creek	0.130	26,000	Fingerling
8	Oak Orchard Creek	0.138	26,000	Fingerling
9	Eighteen Mile Creek	0.148	30,000	Fingerling
9	Niagara River	0.157	25,000	Fingerling
	Total coho salmon yearling		90,000	Yearling
	Total coho salmon fingerling		155,000	Fingerling
	Total coho salmon		245,000	
Atlantic salmon				
6	Black River	0.19	75,000	Yearling
7	Oswego River	0.66	35,000	Yearling
8	Hamlin Beach	713	20,000	Yearling
8	Irondequoit Bay	815	20,000	Yearling
8	Sodus Point	0.84	20,000	Yearling
9	Niagara River	0.157	30,000	Yearling
	Total Atlantic salmon		200,000	

TABLE 7. (Continued)

Region	Location	Key	Number	Age
Domestic brown trout				
6	Montario Point	523	19,000	Yearling
6	Ray Bay	523	19,000	Yearling
7	Fairhaven Beach St. Pk.	720	35,000	Yearling
7	Oswego Harbour	721	16,500	Yearling
7	Selkirk Shores St. Pk.	623	16,500	Yearling
8	Hamlin Beach St. Pk.	713	36,000	Yearling
8	Irondequoit	815	23,000	Yearling
8	Rochester at Kodak	815	30,000	Yearling
8	Braddocks	815	23,000	Yearling
8	Webster	816	23,000	Yearling
8	Point Breeze	711	38,000	Yearling
8	Sodus Point	819	32,000	Yearling
8	Pultneyville	817	24,000	Yearling
9	Wilson	707	25,000	Yearling
9	Olcott	708	25,000	Yearling
	Total domestic browns		385,000	
Seeforellen brown trout				
7	Oswego Harbor	721	20,000	Yearling
7	Selkirk Shores St. Pk.	623	20,000	Yearling
	Total Seeforellen browns		40,000	
	Total brown trout		425,000	
Lake trout				
6	Dablon Point	322-323	120,000	Yearling
6	Dablon Point	322-323	50,000	Yearling
6	Stony Point	422-423	120,000	Yearling
6	Stony Point	422-423	50,000	Yearling
6	Stony Point	422-423	60,000	Fingerling
7	Selkirk	623	120,000	Yearling
7	Selkirk	623	50,000	Yearling
7	Selkirk	623	30,000	Fingerling
8	Hamlin Beach	713	120,000	Yearling
8	Hamlin Beach	713	50,000	Yearling
8	Hamlin Beach	713	30,000	Fingerling
8	Sodus	819	120,000	Yearling
8	Sodus	819	50,000	Yearling
8	Sodus	819	30,000	Fingerling
9	Niagara	806	120,000	Yearling
9	Niagara	806	50,000	Yearling
9	Niagara	806	30,000	Fingerling
	Total lake trout yearling		1,020,000	Yearling
	Total lake trout fingerling		180,000	Fingerling
	Total lake trout		1,200,000	

TABLE 7. (Continued)

Region	Location	Key	Number	Age
Washington steelhead				
6	Black River	0.19	47,000	Yearling
6	Stony Creek	0.40	18,000	Yearling
6	South Sandy Creek	0.45	25,000	Yearling
7	Salmon River	0.53	120,000	Yearling
7	Oswego River	0.66	15,000	Yearling
8	Genesee River	0.117	20,000	Yearling
8	Irondequoit Creek	0.108	24,000	Yearling
8	Salmon Creek	0.125	10,000	Yearling
8	Sandy Creek	0.130	13,300	Yearling
8	Oak Orchard Creek	0.138	20,000	Yearling
9	Keg Creek	0.146	11,100	Yearling
9	E. Br. Twelve Mile Creek	0.152	13,300	Yearling
9	Twelve Mile Creek	0.152A	13,300	Yearling
9	Lower Niagara River	0.157	25,000	Yearling
	Total Washington steelhead		375,000	
Skamania steelhead				
6	Black River	0.19	18,000	Yearling
7	Salmon River	0.53	28,000	Yearling
8	Maxwell Creek	0.85	18,000	Yearling
9	Niagara River	0.157	18,000	Yearling
	Total Skamania steelhead		82,000	
Domestic rainbow trout				
7	Selkirk Shores St. Pk.	623	25,000	Yearling
8	Hamlin Beach St. Pk.	713	20,000	Yearling
8	Webster	816	10,000	Yearling
8	Sodus	819	20,000	Yearling
9	Wilson	707	12,500	Yearling
9	Olcott	708	12,500	Yearling
	Total domestic rainbow		100,000	
	Total rainbow trout species		557,000	
AMERICAN PROPOSED TOTAL ALL SPECIES			5,327,000	

APPENDIX A
Salmon and trout stocked in Province of Ontario waters of Lake Ontario in 1991.

Location	Month Stocked	Year Class	Hatchery Reared	Strain or Egg Source	Age Months	#Fish/ Pound	Mark	Number Stocked
				COHO SALMON				
16 Mile Creek	11	90	Guelph University	Lake Ontario	09	304	none	2,950
Bronte Creek	03	90	Ringwood	Lake Ontario	01	988	none	51,176
Credit River	03	90	Ringwood	Lake Ontario	01	732	none	148,553
	04	90	Ringwood	Lake Ontario	02	895	none	14,607
SUB-TOTAL CREDIT RIVER								163,160
Port Dalhousie	03	90	Ringwood	Lake Ontario	01	984	none	61,175
TOTAL FALL FINGERLING COHO								**2,950**
TOTAL COHO FRY								**275,511**
TOTAL COHO SALMON								**278,461**
				CHINOOK SALMON				
Burlington Canal (Hamilton Harbour)	05	90	Ringwood	Lake Ontario	06	96	none	44,942
Bronte Creek	05	90	Ringwood	Lake Ontario	06	98	none	89,843
Cobourg Creek	02	90	Sir Sanford [a]	Lake Ontario	04	301	none	5,907
	04	90	Sir Sanford [a]	Lake Ontario	06	65	none	3,000
	05	90	Ringwood	Lake Ontario	06	88	none	39,500
SUB-TOTAL COBOURG CREEK								48,407
Credit River	05	09	Ringwood	Lake Ontario	06	90	none	180,267
Oshawa Creek	05	90	Ringwood	Lake Ontario	06	86	none	49,491
Port Dalhousie	05	90	Ringwood	Lake Ontario	06	101	none	135,138
Wellington Harbour	05	90	Ringwood	Lake Ontario	06	87	none	45,543
TOTAL FINGERLING CHINOOK								**593,631**
				RAINBOW TROUT				
Bronte Creek	10	91	Ringwood	Ganaraska/ Normandale	07	43	Ad	24,702
	04	90	Deer Lake	Ganaraska/ Normandale	12	43	Ad	50,000
SUB-TOTAL BRONTE CREEK								74,702
Credit River	10	91	Ringwood	Ganaraska/ Normandale	07	41	Ad	24,702
	04	90	Deer Lake	Ganaraska/ Normandale	12	27	Ad	36,000
SUB-TOTAL CREDIT RIVER								60,702

[a] Sir Sanford Fleming College, Lindsay, Ontario

Location	Month Stocked	Year Class	Hatchery Reared	Strain or Egg Source	Age Months	#Fish/ Pound	Mark	Number Stocked
				RAINBOW TROUT (Cont'd)				
Duffins Creek	04	90	Deer Lake	Ganaraska/ Normandale	12	31	Ad	18,000
Little Rouge River	10	91	Ringwood	Ganaraska/ Normandale	07	41	Ad	12,845
Rouge River	04	90	Deer Lake	Ganaraska/ Normandale	12	32	Ad	21,070
TOTAL YEARLING RAINBOW TROUT								**125,070**
TOTAL FALL FINGERLING RAINBOW TROUT								**62,249**
TOTAL RAINBOW TROUT								**187,319**
				ATLANTIC SALMON				
Credit River	04	89	Normandale	Anadromous LeHave, N.S.	15	9	AdLV	20,915
	05	89	Normandale	Anadromous LeHave, N.S.	16	15	AdLV	1,580
SUB-TOTAL CREDIT RIVER								22,495
Wilmot Creek	04	89	Normandale	Anadromous LeHave, N.S.	15	11	AdLV	6,000
TOTAL YEARLING ATLANTIC SALMON								**28,495**
				BROWN TROUT				
Ashbridges Bay	10	90	Harwood	Ganaraska/ Codrington	10	28	Ad	10,024
	02	89	Harwood	Ganaraska/ Codrington	15	10	RP	14,116
	05	89	Harwood	Ganaraska/ Codrington	17	6	RP	11,505
SUB-TOTAL ASHBRIDGES BAY								35,645
Bluffer's Park	10	90	Harwood	Ganaraska/ Codrington	10	28	Ad	10,398
	02	89	Harwood	Ganaraska/ Codrington	15	11	RP	14,533
	05	89	Harwood	Ganaraska/ Codrington	18	5	RP	6,848
SUB-TOTAL BLUFFER'S PARK								31,779
Bronte Creek	02	89	Harwood	Ganaraska/ Codrington	15	11	RP	7,183
	05	89	Harwood	Ganaraska/ Codrington	18	5	RP	7,774
SUB-TOTAL BRONTE CREEK								14,957

Location	Month Stocked	Year Class	Hatchery Reared	Strain or Egg Source	Age Months	#Fish/ Pound	Mark	Number Stocked
				BROWN TROUT (Cont'd)				
Burlington Canal (Hamilton Harbour)	03	89	Harwood	Ganaraska/ Codrington	16	11	RP	17,158
	05	89	Harwood	Ganaraska/ Codrington	18	5	RP	11,307
SUB-TOTAL BURLINGTON CANAL								28,465
Collins Bay	10	90	Harwood	Ganaraska/ Codrington	10	29	Ad	17,724
Duffins Creek	10	90	Harwood	Ganaraska/ Codrington	10	27	Ad	10,441
	02	89	Harwood	Ganaraska/ Codrington	15	10	RP	6,871
	03	89	Harwood	Ganaraska/ Codrington	16	10	RP	6,548
	05	89	Harwood	Ganaraska/ Codrington	18	6	RP	4,650
SUB-TOTAL DUFFINS CREEK								28,510
Etobicoke Creek (Marie Curtis)	02	89	Harwood	Ganaraska/ Codrington	15	10	RP	7,251
	05	89	Harwood	Ganaraska/ Codrington	18	5	RP	7,386
SUB-TOTAL ETOBICOKE CREEK								14,637
Fifty Point	03	89	Harwood	Ganaraska/ Codrington	16	12	RP	9,084
	05	89	Harwood	Ganaraska/ Codrington	18	6	RP	7,417
SUB-TOTAL FIFTY POINT								16,501
Ganaraska River	10	90	Harwood	Ganaraska/ Codrington	10	31	Ad	10,102
	02	89	Harwood	Ganaraska Codrington	15	12	RP	16,309
	04	89	Harwood	Ganaraska/ Codrington	17	9	RP	5,440
SUB-TOTAL GANARASKA RIVER								31,851
Humber River	10	90	Harwood	Ganaraska/ Codrington	10	31	Ad	10,006
	05	89	Harwood	Ganaraska/ Codrington	18	5	RP	16,177
SUB-TOTAL HUMBER RIVER								26,183

Location	Month Stocked	Year Class	Hatchery Reared	Strain or Egg Source	Age Months	#Fish/ Pound	Mark	Number Stocked
				BROWN TROUT (Cont'd)				
Jordan Harbour	05	89	Harwood	Ganaraska/ Codrington	18	7	RP	12,845
	05	89	Chatsworth	Ganaraska/ Codrington	16	11	RP	17,229
SUB-TOTAL JORDAN HARBOUR								30,074
Millhaven	10	90	Harwood	Ganaraska/ Codrington	10	27	Ad	54,304
	04	89	Codrington	Ganaraska/ Codrington	15	12	RP	88,892
	05	89	Codrington	Ganaraska/ Codrington	16	8	RP	20,859
SUB-TOTAL MILLHAVEN								164,055
Oshawa Creek	10	90	Harwood	Ganaraska/ Codrington	10	30	Ad	10,102
	04	89	Codrington	Ganaraska/ Codrington	15	12	RP	14,000
	04	89	Harwood	Ganaraska/ Codrington	17	9	RP	4,630
	05	89	Harwood	Ganaraska/ Codrington	18	5	RP	3,312
SUB-TOTAL OSHAWA CREEK								32,044
Port Dalhousie	04	89	Chatsworth	Ganaraska/ Codrington	15	12	RP	17,187
	05	89	Chatsworth	Ganaraska/ Codrington	16	11	RP	4,762
SUB-TOTAL PORT DALHOUSIE								21,949
Rouge River	10	90	Harwood	Ganaraska/ Codrington	10	27	Ad	11,938
	03	89	Harwood	Ganaraska/ Codrington	16	10	RP	7,000
	05	89	Harwood	Ganaraska/ Codrington	18	6	RP	12,641
SUB-TOTAL ROUGE RIVER								31,579
TOTAL FALL FINGERLING BROWN TROUT								**145,039**
TOTAL YEARLING BROWN TROUT								**380,914**
TOTAL BROWN TROUT								**525,953**

APPENDIX A (Continued)

Location	Month Stocked	Year Class	Hatchery Reared	Strain or Egg Source	Age Months	#Fish/ Pound	Mark [a]	Number Stocked
				LAKE TROUT				
Cobourg Harbour	04	89	Skeleton Lake	Killala Lake/ Hills Lake	14	34	63-16-04 to-07	70,545
	04	89	Skeleton Lake	Killala Lake/ Hills Lake	15	48	63-16-33 to 40	150,483
	02	89	Harwood	Slate Island Dorion	15	15	63-16-41 to 50	216,579
SUB-TOTAL COBOURG HARBOUR								437,607
Fifty Point	04	89	Deer Lake	Killala Lake/ Hills Lake	17	45	63-16-13 to 22	76,053
Main Duck Island	04	89	Pembrook	Slate Island Dorion	14	25	63-16-08 to 12	85,525
	04	89	Deer Lake	Killala Lake/ Hills Lake	17	57	63-16-13 to 32	241,050
	04	89	Harwood	Slate Island Dorion	17	10	63-16-51 to 60	201,961
SUB-TOTAL MAIN DUCK ISLAND								528,536
Whitby Harbour	04	89	Deer Lake	Killala Lake/ Hills Lake	17	45	63-16-13 to 22	50,000
TOTAL YEARLING LAKE TROUT								**1,092,196**
GRAND TOTAL ALL SPECIES								**2,706,055**

[a] Lake trout have an adipose clip in addition to coded wire tags.

APPENDIX B
Salmon, trout and walleye stocked in New York State Lake Ontario waters in 1991.

Area Stocked	Location	Date Stocked	Year Class	Hatchery Reared	Strain or Egg Source	Age Months	#Fish/ Pound	Mark[a]	Number Stocked
				LAKE TROUT YEARLINGS					
Lake Ont.	Olcott	5/9	90	Allegheny	Seneca	17	12.4	60-46-30	39,100
Lake Ont.	Olcott	5/9	90	Allegheny	Seneca	17	13.0	60-46-29	36,120
Lake Ont.	Olcott	5/10	90	Allegheny	Ontario	17	12.1	60-46-9	49,260
SUB-TOTAL OLCOTT									124,480
Lake Ont.	Hamlin	5/14	90	Allegheny	Ontario	17	15.6	60-46-7	45,280
Lake Ont.	Hamlin	5/14	90	Allegheny	Superior	17	16.4	60-46-33	34,870
Lake Ont.	Hamlin	5/30	90	Allegheny	Seneca	17	10.1	60-46-21	40,160
Lake Ont.	Hamlin	5/30	90	Allegheny	Seneca	17	12.0	60-46-32	39,300
SUB-TOTAL HAMLIN									159,610
Lake Ont.	Sodus	5/14	90	Allegheny	Ontario	17	15.7	60-46-10	51,670
Lake Ont.	Sodus	5/14	90	Allegheny	Superior	17	12.8	60-46-19	37,030
Lake Ont.	Sodus	5/29	90	Allegheny	Seneca	17	10.0	60-46-22	40,000
Lake Ont.	Sodus	5/29	90	Allegheny	Seneca	17	12.6	60-46-18	39,910
SUB-TOTAL SODUS									168,610
Lake Ont.	Selkirk	5/16	90	Allegheny	Seneca	17	11.8	60-46-28	40,120
Lake Ont.	Selkirk	5/16	90	Allegheny	Seneca	17	10.1	60-46-26	40,400
Lake Ont.	Selkirk	5/16	90	Allegheny	Ontario	17	14.1	60-46-8	50,970
SUB-TOTAL SELKIRK									131,490
Lake Ont.	Stony	5/24	90	Allegheny	Seneca	17	8.9	60-46-20	22,400
Lake Ont.	Stony	5/24	90	Allegheny	Seneca	17	12.4	60-46-25	40,300
Lake Ont.	Stony	5/24	90	Allegheny	Ontario	17	12.9	60-46-5	39,350
Lake Ont.	Stony	5/21, 22, 24	90	Allegheny	Ontario	17	15.2	60-46-6	49,120
SUB-TOTAL STONY									151,170
Lake Ont.	Charity	5/21	90	Allegheny	Ontario	17	12.1	60-46-17	41,350
Lake Ont.	Charity	5/22	90	Allegheny	Ontario	17	11.3	60-46-16	41,380
SUB-TOTAL CHARITY									82,730
TOTAL YEARLING LAKE TROUT									**818,090**
				LAKE TROUT FINGERLINGS					
Lake Ont.	Wilson	11/21	91	Allegheny	Ontario	11	37	60-46-51	40,000
Lake Ont.	Wilson	12/20	91	Allegheny	Ontario X Seneca	10	40	60-46-39	40,000
Lake Ont.	Hamlin	12/20	91	Allegheny	Lewis Lake	10	23	60-46-41	40,000
Lake Ont.	Hamlin	12/20	91	Allegheny	Lewis Lake	10	18	60-46-42	24,300
Lake Ont.	Hamlin	12/20	91	Allegheny	Lewis Lake	10	18	60-46-42	15,700
TOTAL FINGERLING LAKE TROUT									**160,000**
TOTAL YEARLING LAKE TROUT									**818,090**
TOTAL LAKE TROUT									**978,090**

[a] Lake trout have an adipose clip in addition to coded wire tags.

Area Stocked	Location	Date Stocked	Year Class	Hatchery Reared	Strain or Egg Source	Age Months	#Fish/ Pound	Mark	Number Stocked
				ATLANTIC SALMON YEARLINGS					
Lake Ont.	Irondequoit off Peter Franks	5/8	90	Adirondack	Little Clear	16	12.6	none	17,800
Lake Ont.	Hamlin Beach	5/24	90	Adirondack	Little Clear	16	12.0	none	17,800
Lake Ont.	Sodus Point	4/25	90	Adirondack	Little Clear	15	13.2	none	8,900
Lake Ont.	Sodus Point	5/8	90	Adirondack	Little Clear	16	12.6	none	8,900
Black River	Dexter	4/15	90	Salmon R.	Little Clear	15	15.0	none	97,900
Lower Niagara R.	Lewiston Sand Docks	4/17	90	Salmon R.	Little Clear	15	15.0	none	26,700
TOTAL ATLANTIC SALMON YEARLINGS									**178,000**
				BROWN TROUT YEARLINGS					
Lake Ont.	Ray Bay	5/3	90	Salmon R.	Rome Lab	16.5	5.0	none	15,660
Lake Ont.	Montario Pt.	5/6	90	Salmon R.	Rome Lab	16.5	4.8	none	15,660
Lake Ont.	Shore Oaks	5/2	90	Salmon R.	Rome Lab	16.5	6.3	LV-Ad	16,500
Lake Ont.	Shore Oaks	5/2	90	Caledonia	Seeforellen/ Caledonia	13	7.8	LV	18,400
SUB-TOTAL SHORE OAKS									34,900
Lake Ont.	Oswego	5/2	90	Salmon R.	Rome Lab	16.5	6.3	LV-Ad	16,500
Lake Ont.	Oswego	5/2	90	Caledonia	Seeforellen/ Caledonia	13	8.9	LV	18,400
Lake Ont.	Oswego	6/4	90	Salmon R.	Rome Lab	17.5	3.0	none	6,000
SUB-TOTAL OSWEGO									40,900
Lake Ont.	Fair Haven	4/29& 4/30	90	Salmon R.	Rome Lab	16.5	6.0	none	28,800
Lake Ont.	Sodus	4/23	90	Salmon R.	Rome Lab	16.5	5.0	none	26,350
Lake Ont.	Pultneyville	4/25	90	Salmon R.	Rome Lab	16.5	5.3	none	19,800
Lake Ont.	Webster	4/29	90	Salmon R.	Rome Lab	16.5	7.2	none	18,950
Lake Ont.	Webster	6/4 & 6/6	90	Caledonia	Rome Lab	16.5	3.3	none	8,030
SUB-TOTAL WEBSTER									26,980
Lake Ont.	Irondequoit	4/26	90	Salmon R.	Rome Lab	16.5	6.0	none	18,950
Lake Ont.	Rochester	5/1	90	Salmon R.	Rome Lab	16.5	6.9	none	24,700
Lake Ont.	Braddock's Point	4/25	90	Salmon R.	Rome Lab	16.5	5.3	none	18,950
Lake Ont.	Hamlin	4/3	90	Caledonia	Rome Lab	14.5	4.6	none	29,700
Lake Ont.	Hamlin	6/5 & 6/6	90	Caledonia	Rome Lab	16.5	3.2	none	8,030
SUB-TOTAL HAMLIN									37,730
Lake Ont.	Point Breeze	4/3 & 4/4	90	Caledonia	Rome Lab	14.5	4.6	none	31,300
Lake Ont.	Olcott	4/2	90	Caledonia	Rome Lab	14.5	4.6	none	20,600
Lake Ont.	Wilson	4/22	90	Salmon R.	Rome Lab	16	5.0	none	20,600
TOTAL BROWN TROUT YEARLINGS									**381,880**

Area Stocked	Location	Date Stocked	Year Class	Hatchery Reared	Strain or Egg Source	Age Months	#Fish/ Pound	Mark	Number Stocked
				COHO SALMON YEARLINGS					
Beaverdam Brook	Smolt Release Pond	3/4 to 4/30[a]	90	Salmon R.	Salmon R.	15	15.0[b]	none	97,000
				COHO SALMON FINGERLINGS					
Sodus Bay	West Pier	9/24	91	Salmon R.	Salmon R.	9.5	25.0	none	22,100
Genesee River	Naval Militia Boat Ramp	9/25	91	Salmon R.	Salmon R.	9.5	25.0	none	18,700
Sandy Creek	Parkway Bridge	9/24	91	Salmon R.	Salmon R.	9.5	25.0	none	22,100
Oak Orchard Creek	Twin Bridges	9/24	91	Salmon R.	Salmon R.	9.5	25.0	none	22,100
Eighteen Mile Creek	Olcott Harbour	9/24	91	Salmon R.	Salmon R.	9.5	25.0	none	25,500
Niagara River	Lewiston Sand Docks	9/24	91	Salmon R.	Salmon R.	9.5	25.0	none	21,250
TOTAL FALL FINGERLING COHO SALMON									**131,750**
TOTAL YEARLING COHO SALMON									**97,000**
TOTAL COHO SALMON									**228,750**
				CHINOOK SALMON FINGERLINGS					
Henderson Bay	Association Island Cut	5/7	91	Salmon R.	Salmon R.	4	110	RP	41,000
Henderson Bay	Association Island Cut	5/7	91	Salmon R.	Salmon R.	4	110	none	22,000
SUB-TOTAL HENDERSON BAY									63,000
Lake Ont.	Stony Creek Boat Launch	5/7	91	Salmon R.	Salmon R.	4	100	none	36,800
Lake Ont.	Southwick Beach St. Pk.	5/9	91	Salmon R.	Salmon R.	4	110	none	52,500
N. Sandy Creek	NY Rt. 3	5/14	91	Salmon R.	Salmon R.	4	100	none	94,500
S. Sandy Creek	NY Rt. 3	5/14	91	Salmon R.	Salmon R.	4	100	none	94,500
Beaverdam Brook	Salmon River Hatchery	6/10	91	Salmon R.	Salmon R.	5	58	none	472,500
Salmon R.	NY Rt. 3	6/11	91	Salmon R.	Salmon R.	5	63	none	126,000
SUB-TOTAL SALMON RIVER									598,500

[a] Coho salmon were stocked in the hatchery smolt release pond on March 4 and were allowed to voluntarily migrate until April 30 when the pond was drained. Hatchery personnel estimated that approximately 85 percent had voluntarily migrated by April 30, most during the month of April.

[b] Average size was 22.9/lb when initially stocked in the smolt release pond. The value of 15/lb is an estimate of average size at the time of migration from the pond.

Area Stocked	Location	Date Stocked	Year Class	Hatchery Reared	Strain or Egg Source	Age Months	#Fish/ Pound	Mark	Number Stocked
				CHINOOK SALMON FINGERLINGS (Cont'd)					
Oswego R.	Oswego Harbour	5/28	91	Salmon R.	Salmon R.	4	100	none	236,200
Little Sodus Bay	State Park Boat Launch	5/14	91	Salmon R.	Salmon R.	4	100	none	189,000
Sodus Bay	Outlet Channel	5/31	91	Salmon R.	Salmon R.	4	100	none	189,000
Genesee R.	Naval Militia Boat Ramp	5/31	91	Salmon R.	Salmon R.	4	120	none	283,500
Sandy Creek	DEC Boat Ramp	5/31	91	Salmon R.	Salmon R.	4	100	none	189,000
Oak Orchard Creek	Twin Bridges	5/28	91	Salmon R.	Salmon R.	4	100	none	283,500
Eighteen Mile Creek	Olcott Harbour	5/28	91	Salmon R.	Salmon R.	4	100	none	154,000
Eighteen Mile Creek	Olcott Harbour	5/28	91	Salmon R.	Salmon R.	4	100	LV	35,000[a]
Twelve Mile Creek	Wilson Harbour	5/28	91	Salmon R.	Salmon R.	4	100	none	63,000
Niagara R.	Lewiston Sand Docks	5/30	91	Salmon R.	Salmon R.	4	100	none	273,000
TOTAL CHINOOK SALMON									**2,835,000**
				RAINBOW TROUT YEARLINGS					
Lake Ont.	Selkirk Shores State Park	4/29	90	Caledonia	Nashua	13	4.4	none	20,400
Lake Ont.	Sodus Point	4/11	90	Caledonia	Nashua	13	4.2	none	16,300
Lake Ont.	Webster	4/12	90	Caledonia	Nashua	13	5.1	none	8,150
Lake Ont.	Hamlin Beach State Park	4/8	90	Caledonia	Nashua	13	5.6	none	16,300
Lake Ont.	Olcott Harbour	3/29	90	Caledonia	Nashua	12	5.0	none	10,200
Lake Ont.	Wilson Harbour	3/29	90	Caledonia	Nashua	12	5.0	none	10,200
TOTAL YEARLING RAINBOW TROUT									**81,550**
				RAINBOW TROUT FINGERLINGS					
Lake Ont.	Hamlin Beach State Park	6/25	91	Caledonia	Utah	6	499	none	28,900
TOTAL FINGERLING RAINBOW TROUT									**28,900**
TOTAL YEARLING RAINBOW TROUT									**81,550**
TOTAL RAINBOW TROUT									**110,450**

[a] triploids

Area Stocked	Location	Date Stocked	Year Class	Hatchery Reared	Strain or Egg Source	Age Months	#Fish/ Pound	Mark	Number Stocked
					STEELHEAD YEARLINGS				
Black R.	Dexter Boat Lauch	4/30	90	Salmon R.	Washington-Salmon R.	11	15.0	none	30,000
Black R.	Dexter Boat Lauch	6/3	90	Salmon R.	Washington-Salmon R.	12	15.0	none	19,000
SUB-TOTAL BLACK RIVER									49,000
Stony Ck.	State Park Boat Lauch	5/6	90	Salmon R.	Washington-Salmon R.	11	15.0	none	18,000
South Sandy Ck.	NY Rt. 3	4/30	90	Salmon R.	Washington-Salmon R.	11	15.0	none	25,000
Beaverdam Brook	Salmon R. Hatchery	4/30	90	Caledonia	Skamania	13	11.0	LP-Ad	32,000
Beaverdam Brook	Salmon R. Hatchery	4/30	90	Salmon R.	Washington-Salmon R.	14	8.9	LV	45,000
Beaverdam Brook	Salmon R. Hatchery	4/30	90	Salmon R.	Washington-Salmon R.	11	15.0	LV	45,000
SUB-TOTAL BEAVERDAM BROOK									122,000
Orwell Brook	Tubbs Road	4/24	90	Salmon R.	Washington-Salmon R.	10	15.0	LV	17,500
Trout Brook	Mattison Road and Co. Rt. 22	4/24	90	Salmon R.	Washington-Salmon R.	10	15.0	LV	17,500
Spring Bk. Reservoir	Reservoir	3/14	90	Salmon R.	Washington-Salmon R.	12	11.0	LV	25,000
Salmon R.	NY Rt. 3	5/17	90	Salmon R.	Washington-Salmon R.	11	15.0	none	55,000 [a]
SUB-TOTAL SALMON RIVER SYSTEM									237,000
Oswego R.	Below Rt. 104	5/13	90	Salmon R.	Washington-Salmon R.	11	15.0	none	15,000
Maxwell Ck.	Mouth to Trib. 2	6/3	90	Salmon R.	Washington-Salmon R.	12	15.0	none	18,000
Irondequoit Creek	Audubon Property	5/10	90	Salmon R.	Washington-Salmon R.	11	15.0	none	24,000
Genesee River	Naval Militia Boat Ramp	5/10	90	Salmon R.	Washington-Salmon R.	11	15.0	none	20,000
Salmon Ck.	Near Hilton High School	5/7	90	Salmon R.	Washington-Salmon R.	11	15.0	none	6,600
Sandy Ck.	DEC Boat Launch	5/8	90	Salmon R.	Washington-Salmon R.	11	15.0	none	13,300
Oak Orchard Creek	Twin Bridges	5/6	90	Salmon R.	Washington-Salmon R.	11	15.0	none	20,000
Johnson Ck.	Kuckville to Lyndonville	5/6	90	Salmon R.	Washington-Salmon R.	11	15.0	none	6,700
Keg Creek	Rt. 18	5/14	90	Salmon R.	Washington-Salmon R.	11	15.0	none	11,100

[a] Surplus stocking

Area Stocked	Location	Date Stocked	Year Class	Hatchery Reared	Strain or Egg Source	Age Months	#Fish/ Pound	Mark	Number Stocked
				STEELHEAD YEARLINGS (Cont'd)					
E. Branch 12 Mile Ck.	Near Mouth	5/8	90	Salmon R.	Washington-Salmon R.	11	15.0	none	13,300
Twelve Mile Creek	Rt. 18 and Youngstown Rd.	5/8	90	Salmon R.	Washington-Salmon R.	11	15.0	none	13,300
Niagara R.	Lewiston Sand Docks	5/13	90	Salmon R.	Washington-Salmon R.	11	15.0	none	43,000
Niagara R.	Lewiston Sand Docks	6/3	90	Salmon R.	Washington-Salmon R.	12	15.0	none	18,000 [a]
SUB-TOTAL LOWER NIAGARA RIVER									61,000
TOTAL SCHEDULED WASHINGTON STEELHEAD YEARLINGS									**446,300**
TOTAL SURPLUS WASHINGTON STEELHEAD YEARLINGS									**73,000**
TOTAL WASHINGTON STEELHEAD YEARLINGS									**519,300**
TOTAL SKAMANIA STEELHEAD YEARLINGS									**32,000**
TOTAL STEELHEAD YEARLINGS									**551,300**
				STEELHEAD FINGERLINGS					
Black R.	Dexter Boat Launch	6/25	91	Salmon R.	Washington-Salmon R.	1	400.0	none	175,000 [a]
Salmon R.	NY Rt. 3	11/4	91	Salmon R.	Washington-Salmon R.	5	25.0	none	40,000 [a]
TOTAL SURPLUS FINGERLING STEELHEAD									**215,000**
TOTAL YEARLING STEELHEAD									**551,300**
TOTAL STEELHEAD									**766,300**
				WALLEYE FINGERLINGS					
Niagara R.	Lewiston	2nd week of July	91	NRAA [b] Ponds	Constantia	2.5	1.5"-3"	none	6,167
Lake Ont.	Fairhaven	2nd & 3rd week of June	91	Sanford [c] Bait Farms	Constantia	2	2"	none	12,000
Lake Ont.	Fairhaven	August	91	Sanford Bait Farms	Constantia	3.5	6"	none	1,000
Lake Ont.	Blind Sodus	2nd & 3rd week of June	91	Sanford Bait Farms	Constantia	2	2"	none	8,000
Lake Ont.	Blind Sodus	October	91	Sanford Bait Farms	Constantia	5.5	6"-10"	none	50

[a] Surplus stocking.
[b] Niagara River Anglers Association - 10 ponds, 1/2 acre each.
[c] Sanford Bait Farms - 11 ponds, 1/4 acre to 1 acre, total of 9-1/2 acres.

Area Stocked	Location	Date Stocked	Year Class	Hatchery Reared	Strain or Egg Source	Age Months	#Fish/ Pound	Mark	Number Stocked
				WALLEYE FINGERLINGS (Cont'd)					
Lake Ont.	Port Bay	2nd & 3rd week of June	91	Sanford Bait Farms	Constantia	2	2"	none	14,000
Lake Ont.	Port Bay	August	91	Sanford Bait Farms	Constantia	3.5	4"	none	3,000
Lake Ont.	Sodus Bay	2nd & 3rd week of June	91	Sanford Bait Farms	Constantia	2	2"	none	76,000
Lake Ont.	Sodus Bay	August	91	Sanford Bait Farms	Constantia	3.5	6"	none	1,100
Lake Ont.	Sodus Bay	October	91	Sanford Bait Farms	Constantia	5.5	6"-10"	none	500
TOTAL WALLEYE									**121,817**
TOTAL SALMONIDS									**5,478,470**
GRAND TOTAL ALL SPECIES									**5,600,287**

Preliminary Report of the Lake Ontario Fall Shore Angler Survey, 1991

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Lake Ontario Fisheries Unit, 1991 Annual Report, Section 16

This fall shore angler survey covered all significant Lake Ontario waterfront angling locations from Niagara Falls to Kingston, Ontario. The total angling effort from September 7 to November 22, 1991 was estimated at 342,207 angler-hours. Four sites accounted for 51% of the effort in this fishery. These were Port Credit (18%), Bronte Harbour (13%), the Ganaraska River mouth (12%) and the Niagara Gorge (8%). The harvest consisted of 17,184 salmonines and 23,307 non-salmonines. The salmonine catch rate (CUE) was 0.132 fish per angler-hour and the non-salmonine CUE was 0.171. The salmonine component of this fall waterfront fishery was predominantly chinook salmon (40% by number) and rainbow trout (31%). Brown trout comprised 19% of the salmonine harvest. The performance of stocked brown trout was far better than previously indicated from assessment of the boat fishery. Over 57% of the harvest was comprised of non-salmonine species. Most of the busiest sites in this survey received stocked fish. We project that the spring and fall shore fisheries may be as large as the launch daily boat fishery.

Recommendations

1. Conduct lake shore angler surveys on a five year rotational basis.
2. Ensure that lake shore angler surveys are conducted for spring and fall seasons of the same calendar year.
3. Extend the shore angler survey to cover the winter season at selected sites.

Introduction

In 1990, as part of a Lake Ontario fisheries management planning exercise, we attempted to determine the significance of Lake Ontario shore angling fishery (Savoie and Bowlby 1991). This exercise was based on a few localized historical surveys of shore anglers, the size of migratory salmonine spawning runs, fish stocking trends and anecdotal information from OMNR field staff. Stream and lakeshore fisheries were estimated to have been as large as the entire recreational boat fishery. During the summer of 1990 we conducted a pilot shore angler survey from Niagara Falls to Colborne. This preliminary report summarizes the results of the fall waterfront survey. We felt that the magnitude and the distinct species mix of this fall shore fishery should be communicated to the managers in a timely manner. We will be producing a more detailed report of the combined summer of 1990, fall of 1991 and spring of 1992 shore angler surveys in 1993. This synthesis will also include data from a re-analysis of a Niagara District shore creel conducted during the spring of 1988.

Methods

The shore angler survey during the fall of 1991 covered all significant Lake Ontario lakeshore angling locations from Niagara Falls to Kingston. Sixty-seven sites were monitored (Table 1). These sites included piers, river mouths, harbours and points of land. This survey occasionally extended a few hundred meters upstream of a river mouth, and further at the Niagara, Trent, Moira and Napanee Rivers. For logistical reasons, the waterfront was divided into four sectors and each sector comprised of two survey routes (Fig. 1, 2, 3 and 4). One technician surveyed each sector. To ensure that a given site was surveyed at different times of the day, four separate route patterns were scheduled.

All weekend days were surveyed from September 7 to November 17, 1991. Two weekdays per week were surveyed from September 9 to October 31, 1991. November weekday fishing activity was estimated by using the ratio of weekend to weekday activity from the previous month. The fishing day was divided into two time periods: a morning shift from 06:00 to 13:00 and an afternoon shift from 13:00 to 20:00.

Creel technicians followed a given route pattern and timetable. At each site, they obtained a count of all anglers and interviewed as many of them as the timetable permitted before moving on to the next site.

Field work and most data entry were done by independent contractors. Data entry and the estimating of angler effort, catch and harvest was done using CREESYS software (Lester and Trippel 1985). Detailed protocol manuals are

TABLE 1. Shore angler survey sites by Sector and Route (Fig. 1, 2, 3, and 4).

Sector	Route	Site code	Location name
I	1	00	Maid-of-the-Mist Access (Niagara Falls)
		01	Niagara Gorge (Whirlpool to Glen)
	2	02	Sir Adam Beck Hydro Dam (Lower Niagara River)
		03	Queenston Sand Docks
		04	Niagara-on-the-Lake
		05	Port Weller (Welland Canal Lock #1)
		06	Port Dalhousie Harbour and Piers
		07	Fifteen Mile Creek
		08	Charles Daley Park
		09	Sixteen Mile Creek
		10	Beacon Motor Inn (Twenty Mile Creek)
		11	Victoria Avenue
		12	Martin's Pier
		13	Grimsby Harbour and Pier
II	3	14	50 Mile Point Waterfront Park (HRCA) [a]
		15	Fifty Road
		16	Confederation Park (HRCA)
		17	Burlington Canal (Fisherman's Pier)
		18	Spencer Smith Waterfront Park (Burlington)
		19	Shell Refinery Pier
		20	Bronte Harbour and Piers
		21	Coronation Park
		22	Oakville Harbour and Piers
	4	23	Jack Darling Waterfront Park (Mississauga)
		24	Port Credit Harbour and Piers
		25	Lakefront Promenade Park
		26	Marie Curtis Waterfront Park (MTRCA) [b]
		27	Colonel Samuel Smith Waterfront Park (MTRCA)
		28	Humber Bay Waterfront Park (MTRCA)
		29	Humber River Mouth
		30	Clark Beach Park (Eastern Gap, Toronto Harbour)
		31	Ashbridges Bay Waterfront Park (MTRCA)
III	5	32	Bluffers Waterfront Park (MTRCA)
		33	Rouge River Mouth
		34	Liverpool Road (Frenchman's Bay East)
		35	Duffins Creek Mouth (Rotary Park)
		36	Lynde Creek Mouth
		37	Whitby Harbour and Pier
		38	Oshawa Harbour and Pier
	6	39	Port Darlington Harbour and Pier
		40	Wilmot Creek Mouth
		41	Newcastle Ramp
		42	Ganaraska River Mouth
		43	Gage Creek Mouth
		44	Cobourg Harbour and Piers
		45	Barnum House Creek Mouth
		46	Shelter Valley Creek Mouth
		47	Colborne Creek Mouth

[a] HRCA = Hamilton Region Conservation Authority
[b] MTRCA = Metro Toronto and Region Conservation Authority

TABLE 1. (Continued)

Sector	Route	Site code	Location name
IV	7	48	Brighton (Marina, Ontario St. Ramp, Gosport)
		49	Murray Canal
		54	Trent River Mouth
		55	Trent River, Dam #1
		56	Meyers Pier (Belleville)
		57	Moira River (Belleville)
		53	Belleville Bridge
		50	Wellington Harbour and Pier
	8	69	Macfarland Conservation Area (Picton Bay)
		52	Picton Bay (Picton)
		59	Deseronto Bridge
		60	Napanee River (Napanee)
		61	Lennox Generating Station (North Channel)
		70	Bath Shoreline (North Channel)
		62	Millhaven Waterfront
		63	Celanese Plant
		64	Parrot Bay
		65	Collins Bay
		66	Little Cataraqui River Mouth

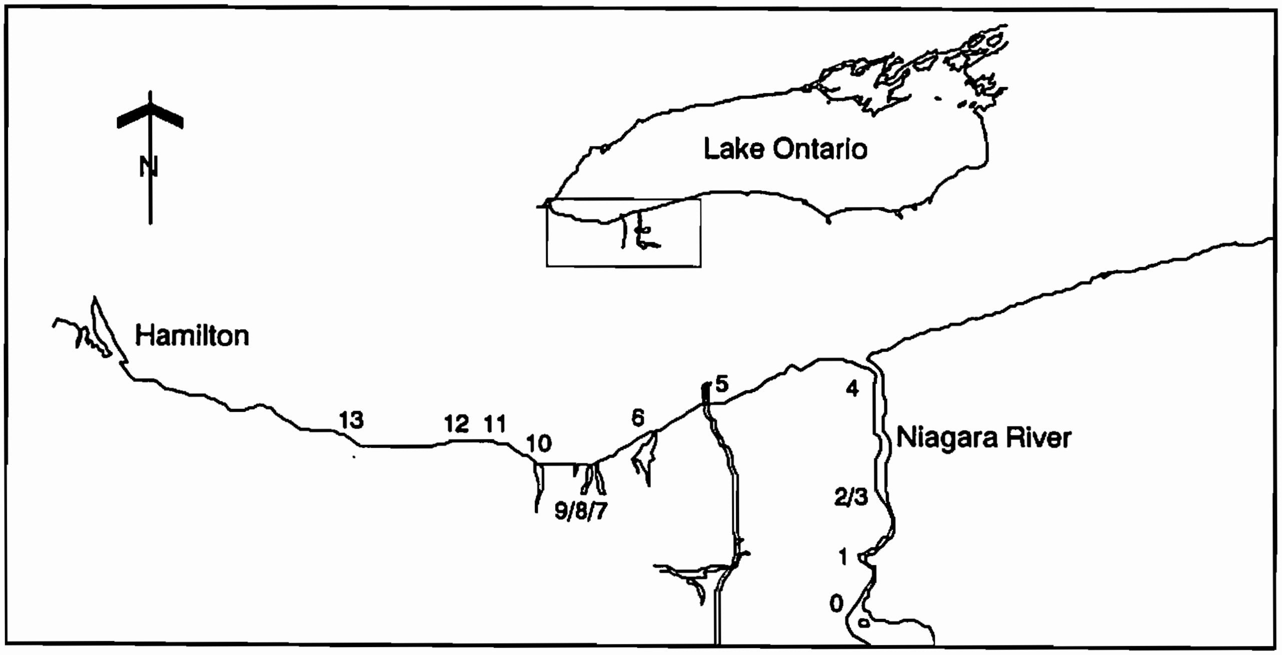

FIG. 1. Fall shore angling survey sites within Sector I, Routes 1 and 2 (Table 1).

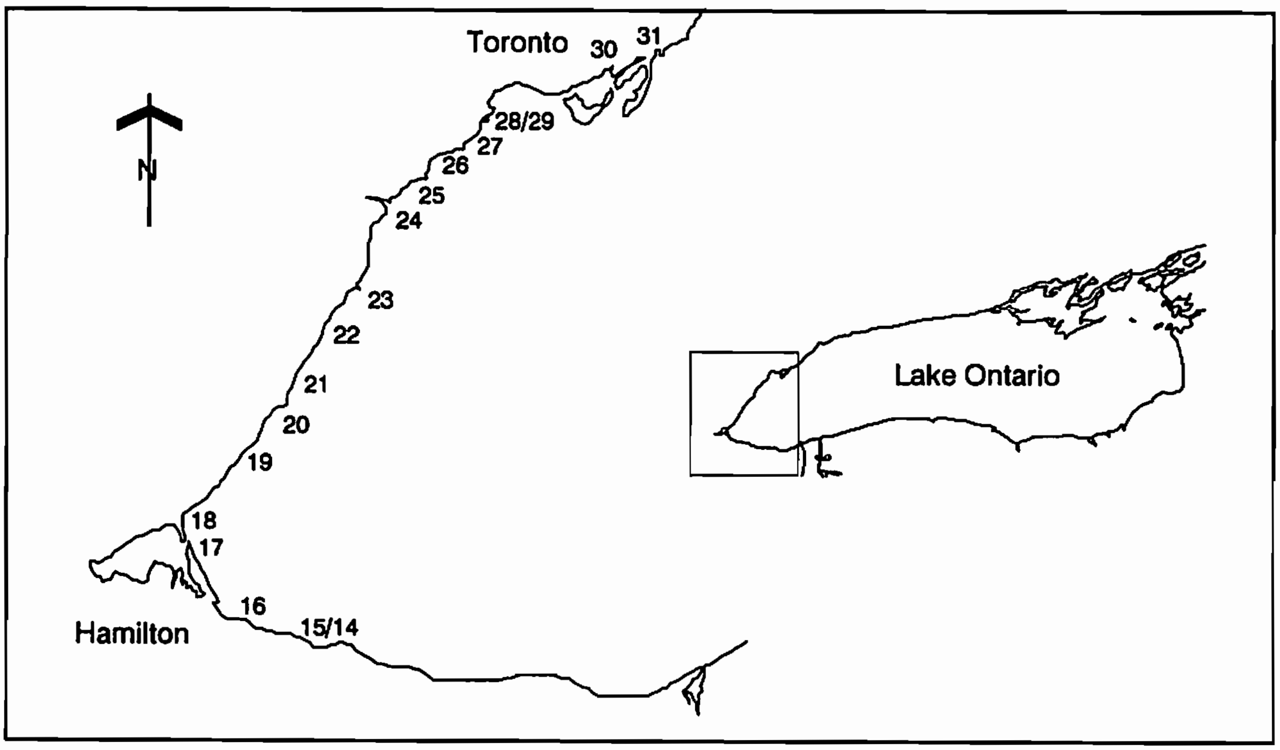

FIG. 2. Fall shore angling survey sites within Sector II, Routes 3 and 4 (Table 1).

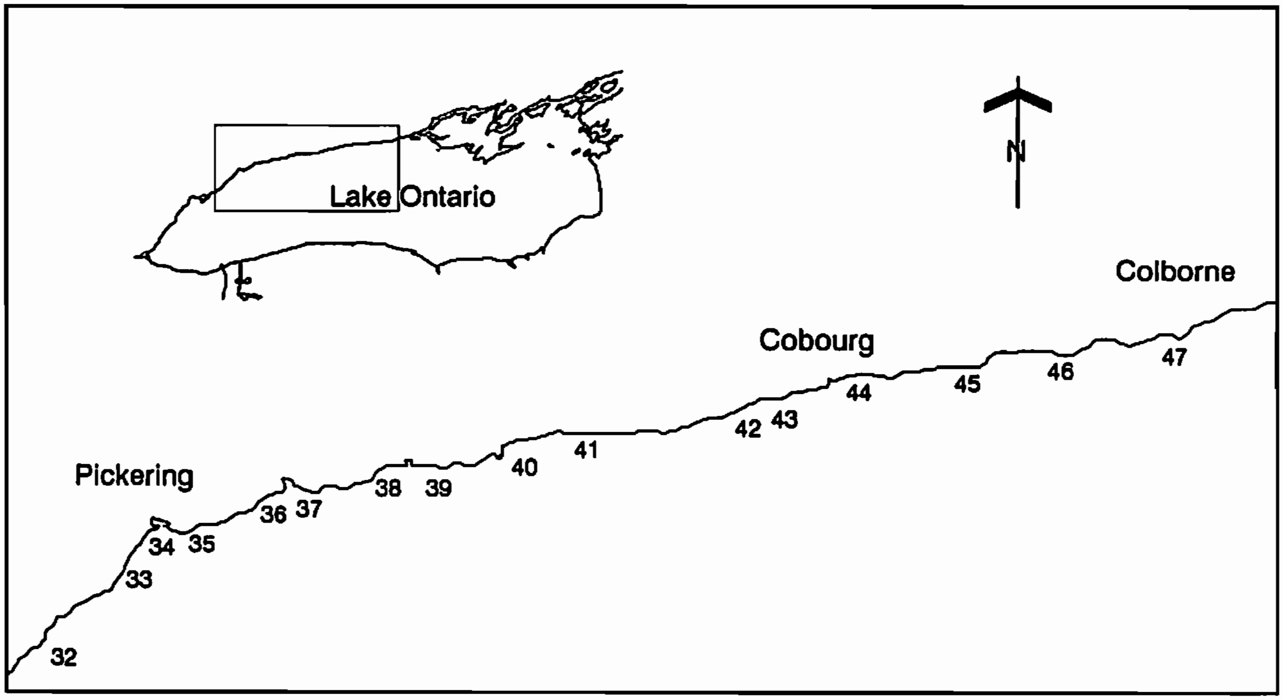

FIG. 3. Fall shore angling survey sites within Sector III, Routes 5 and 6 (Table 1).

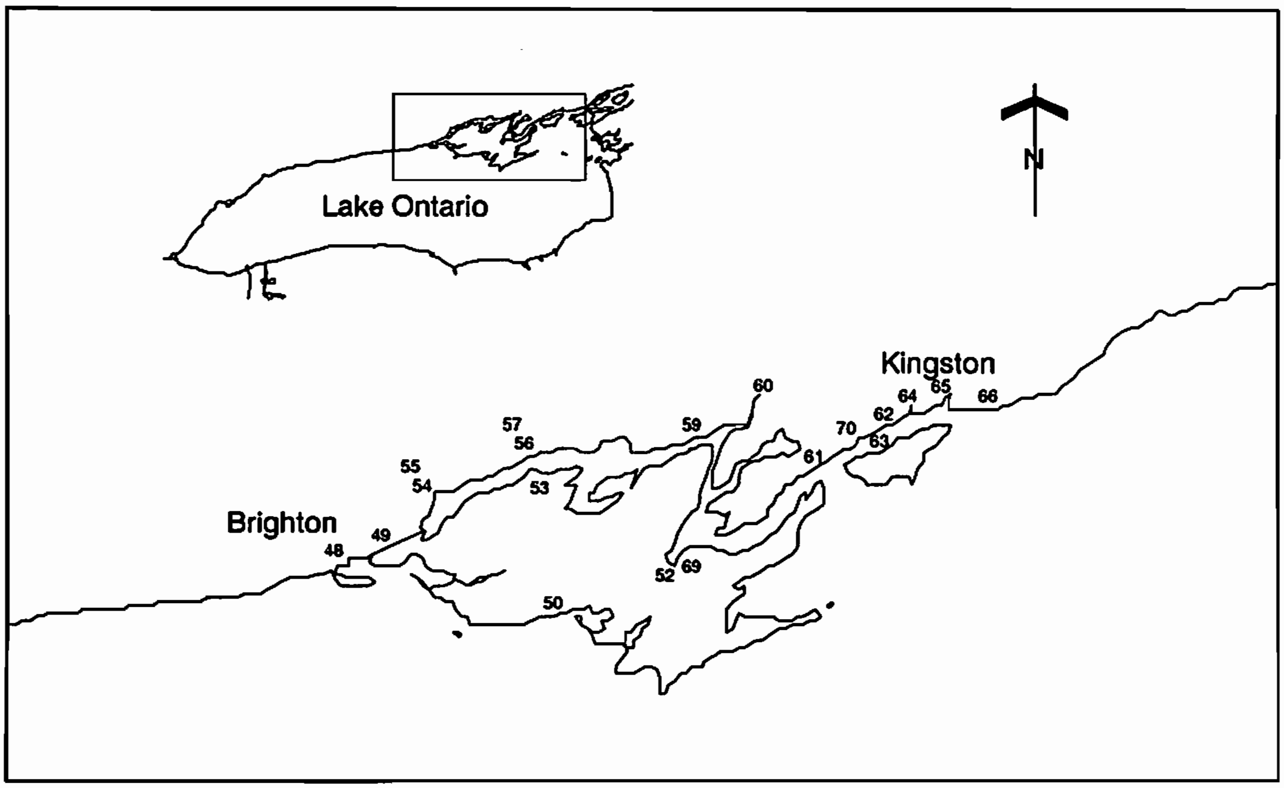

FIG. 4. Fall shore angling survey sites within Sector IV, Routes 7 and 8 (Table 1).

available for each sector of this survey at the OMNR office in Aurora, Ontario.

Results and Discussion

The total angling effort from September 7 to November 22, 1991 was 342,207 angler-hours (Table 2). This level of effort was equal to 26% of the entire western Lake Ontario boat fishery in 1991 (Bowlby and Savoie 1992). Port Credit, Bronte Harbour, the Ganaraska River mouth and the Niagara Gorge sites accounted for 51% of the effort in this fall shore fishery (Fig. 5). The salmonine catch rate (CUE) was 0.132 fish per angler-hour. This was less than the western Lake Ontario 1991 launch daily boat angler CUE (0.202 fish per angler-hour; Bowlby and Savoie 1992). The harvest consisted of 17,184 salmonines and 23,307 non-salmonines. This highlights a dramatic difference between the boat and shore fisheries. Over 57% of the shore harvest was comprised of non-salmonines as compared to only 3% for the 1991 western Lake Ontario boat fishery (Fig. 6). The non-salmonine shore harvest was comprised mostly of white perch and yellow perch. Another difference between the boat and shore fisheries was the species mix of the salmonine harvest (Fig. 7). The salmonine component of the boat fishery was dominated by chinook salmon (60%), but the fall shore fishery was dominated by both chinook salmon (40%) and rainbow trout (31%). Coho salmon and lake trout played a smaller role in the fall shore fishery than in the boat fishery. In 1991, brown trout comprised 19% of the salmonine fall shore harvest compared to only 4% in the boat fishery. The harvest rate (HUE) of brown trout by shore anglers during the fall was 2.25 times that of the record 1991 harvest of brown trout by launch daily boat anglers (Bowlby and Savoie 1992). A number of winter fisheries for brown and rainbow trout at the lower Niagara River, Port Dalhousie and Lakefront Promenade Park (Mississauga), were not covered by this survey. No Atlantic salmon were observed in the shore fishery. However, some Atlantic salmon were caught at the mouth of the Credit River during August 1991 (I. Buchanan, Maple District, OMNR, pers. comm.), before this survey began.

Sector I (Niagara Falls to Grimsby)

Sector I had 26% of the overall shore angler effort. The top three sites were the Niagara Gorge, Port Dalhousie and Twenty Mile Creek. These three access points accounted for 73% of the angler effort within Sector I. Over 80% of the harvest was comprised of non-salmonines. The vast majority of these were from the lower Niagara River (from Niagara Falls to Niagara-on-the-Lake). The non-salmonine harvest in this area was dominated by white perch (63%) and yellow perch (19%). The salmonine harvest was comprised primarily of chinook salmon (43%) and brown trout (33%).

Sector II (50 Mile Point to Ashbridges Bay, Toronto)

Sector II was the busiest area, accounting for almost 43% of the overall effort. The most active sites were Port Credit, Bronte Harbour and 50 Mile Point Conservation Area. Together they accounted for almost 83% of the activity in Sector II. In contrast to Sector I, over 80% of the harvest was composed of salmonines. The salmonine harvest was again dominated by chinook salmon (60%) and brown trout (23%). Also, a night fishery for brown trout along the Toronto waterfront was not surveyed (I. Buchanan, Maple District, OMNR, pers. comm.). The non-salmonine harvest was limited.

Sector III (Bluffers Park, Toronto to Colborne Creek)

Sector III had almost 23% of the overall shore angling effort. The Ganaraska River mouth alone accounted for 53% of the activity in this area. For this sector, 99% of the harvest was comprised of salmonines. Anglers in Sector III were clearly targeting the fall runs of rainbow trout which comprised 72% of the harvest. This area had the highest salmonine CUE at 0.201 fish per angler-hour. Almost 40% of the salmonine catch in this sector was the result of incidentally hooked lake trout at the Ganaraska River mouth. This was due to the past practice of stocking lake trout in Port Hope Harbour. The vast majority of anglers fishing the Ganaraska River are seeking rainbow trout. As a result of this angler preference, and the fact that most lake trout caught during our survey were out of season, 84% of the lake trout were released. Despite all of the above, Sector III still had the highest salmonine HUE at 0.079 fish per angler-hour.

Sector IV (Brighton to the Little Cataraqui River, Kingston)

Sector IV was the least busy area, accounting for only 8% of the overall shore angling effort. The Trent River Dam #1 and the Napanee River at the town of Napanee, accounted for over 46% of the fishing effort in Sector IV. Salmon and trout comprised only 6% of the harvest which was almost exclusively chinook salmon. The non-salmonine harvest was dominated by yellow perch (42%) and lake whitefish (23%). This was the only sector in which lake whitefish and northern pike were reported in the catch. The return of the larger walleye into the Bay of Quinte was late in the fall of 1991. At Picton Bay angling activity for walleye did not start to increase until mid November (near the end of our survey). The walleye harvest for Sector IV should therefore be considered a minimum estimate. Angling activity at Wellington Harbour, Millhaven, Parrot Bay and Collins Bay was likely affected by construction and dredging activity.

TABLE 2. Summary of fall shore angler effort, catch and harvest by sector for 1991.

	Sector I		Sector II		Sector III		Sector VI		Lakewide totals			
Angler interviews	1,148		1,246		843		471		3,708			
Effort (Rd-Hrs)	90,072		146,317		77,831		27,987		342,207			
Relative effort	26.3%		42.8%		22.7%		8.2%		100.0%			
Species name	Catch	Harvest	Catch	Harvest	Catch	Harvest	Catch	Harvest	Catch	CUE[a]	Harvest	HUE[b]
Coho salmon	17	17	1,402	982	36	36	0	0	1,455	0.004	1,035	0.003
Chinook salmon	6,114	1,665	7,643	4,056	1,786	814	2,211	359	17,754	0.052	6,894	0.020
Rainbow trout	1,641	799	361	137	6,884	4,403	121	22	9,007	0.026	5,361	0.016
Brown trout	2,736	1,293	2,852	1,536	835	366	15	15	6,438	0.019	3,210	0.009
Lake trout	2,429	111	1,294	34	6,106	539	800	0	10,629	0.031	684	0.002
Unknown salmonine	13	0	0	0	0	0	0	0	13	0.000	0	0.000
Salmonine total	12,950	3,885	13,552	6,745	15,647	6,158	3,147	396	45,296	–	17,184	–
Salmonine CUE/HUE	0.144	0.043	0.093	0.046	0.201	0.079	0.112	0.014	0.132	–	0.050	–
Lake whitefish	0	0	0	0	0	0	6,925	1,364	6,925	0.020	1,364	0.004
Northern pike	0	0	0	0	0	0	249	54	249	0.001	54	0.000
Suckers	703	511	134	86	52	0	67	67	956	0.003	664	0.002
Common carp	14	0	151	151	181	0	22	0	368	0.001	151	0.000
Creek chub	0	0	0	0	20	0	0	0	20	0.000	0	0.000
Brown bullhead	38	38	402	0	1,169	0	148	148	1,757	0.005	186	0.001
Channel catfish	233	83	67	25	0	0	21	0	321	0.001	108	0.000
American eel	24	24	0	0	0	0	0	0	24	0.000	24	0.000
White perch	9,881	9,881	1,220	650	0	0	0	0	11,101	0.032	10,531	0.031
White bass	73	73	0	0	136	0	31	31	240	0.001	104	0.000
Rock bass	1,239	898	423	254	0	0	2,449	461	4,111	0.012	1,613	0.005
Pumpkinseed	496	364	0	0	103	0	1,196	90	1,795	0.005	454	0.001
Bluegill	212	212	0	0	0	0	0	0	212	0.001	212	0.001
Smallmouth bass	1,519	370	681	169	0	0	1,388	339	3,588	0.010	878	0.003
Largemouth bass	87	87	0	0	17	0	9	9	113	0.000	96	0.000
Sunfish sp.	0	0	169	0	0	0	713	0	882	0.003	0	0.000
Crappie sp.	0	0	0	0	0	0	67	67	67	0.000	67	0.000
Yellow perch	3,530	3,018	284	0	477	84	18,677	2,429	22,968	0.067	5,531	0.016
Walleye	180	137	330	330	0	0	1,284	750	1,794	0.005	1,217	0.004
Freshwater drum	444	38	39	15	15	0	0	0	498	0.001	53	0.000
Unknown sp.	13	0	85	0	175	0	119	0	392	0.001	0	0.000
Other total	18,686	15,734	3,985	1,680	2,345	84	33,365	5,809	58,381	–	23,307	–
Other CUE/HUE	0.207	0.175	0.027	0.011	0.030	0.001	1.192	0.208	0.171	–	0.068	–
Salmonine mix	40.9%	19.8%	77.3%	80.1%	87.0%	98.7%	8.6%	6.4%	43.7%	–	42.4%	–
Other mix	59.1%	80.2%	22.7%	19.9%	13.0%	1.3%	91.4%	93.6%	56.3%	–	57.6%	–

[a] CUE = Number of fish caught per rod-hour of effort.

[b] HUE = Number of fish harvested per rod-hour of effort.

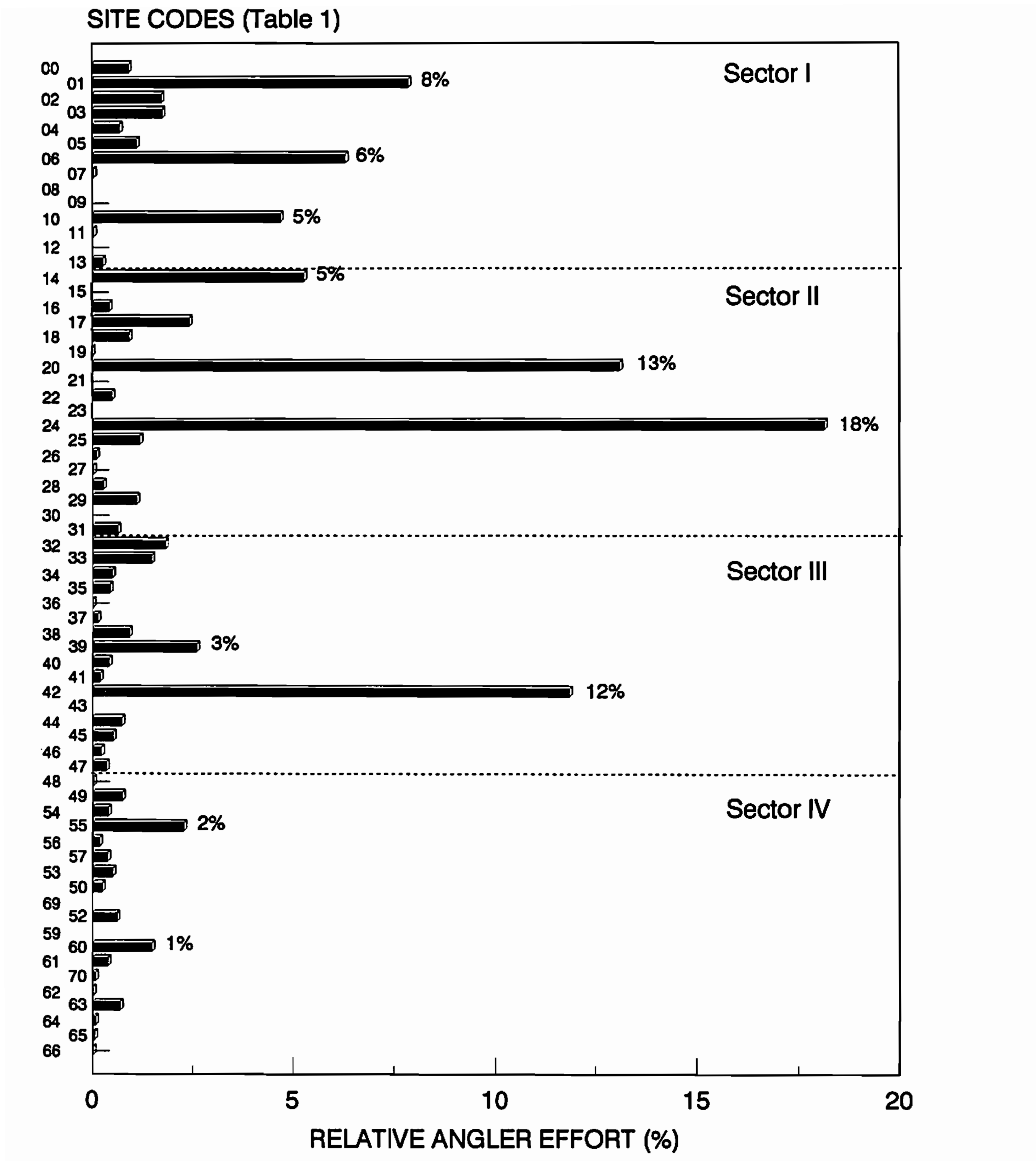

FIG. 5. Lake-wide distribution of Canadian fall shore angling effort for Lake Ontario.

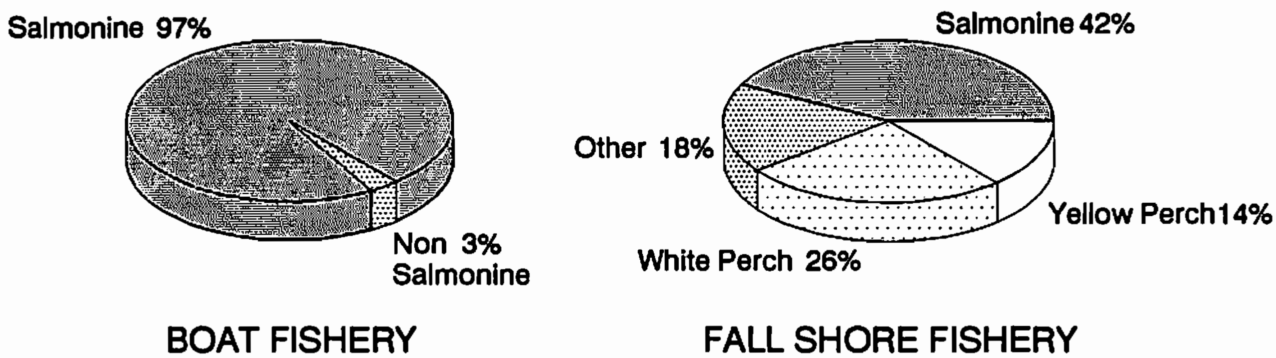

FIG. 6. Relative abundance of harvested species, in the 1991 launch daily boat fishery and fall shore fishery.

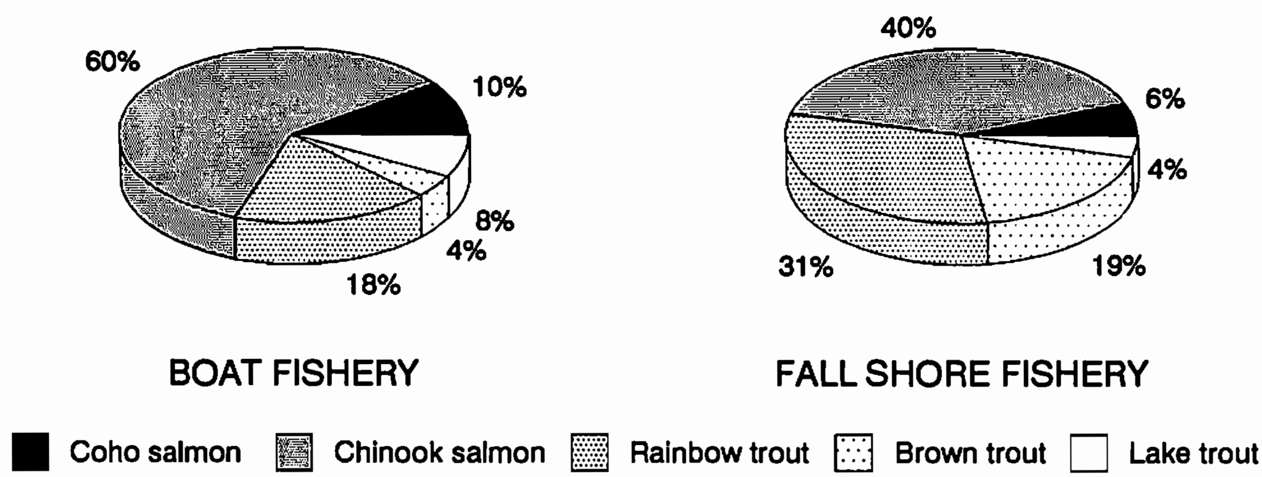

FIG. 7. Relative abundance of harvested salmonines, in the 1991 launch daily boat fishery and fall shore fishery.

Management Implications

Although we have only completed the fall component of the waterfront shore angler survey, a number of important elements of the fishery have come to light. It is obvious that the performance of brown trout was far better than previously indicated from assessment of the boat fishery (Bowlby 1991). The species mix of the harvest is also significantly different from that of the boat fishery. As well, the shore fishery is comprised of several dramatically different components varying geographically. For example, Sector III was an exclusively salmonine fishery dominated by rainbow trout, whereas, in the Niagara area there was a mixed fishery where non-salmonines were predominant. Most of the busiest sites in this survey received OMNR stocked salmon and/or trout (LeTendre and Savoie 1992). As we postulated in our 1991 report, the spring and fall shore based waterfront fisheries may in fact be as large as the launch daily boat fishery.

Acknowledgments

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Trends in Size, Condition and Spawning Time of Coho Salmon in the Credit River, 1977-1991.

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Lake Ontario Fisheries Unit, 1991 Annual Report, Section 17

Coho salmon returning to the Credit River to spawn during 1977-1991 were sampled for length, weight and sex. This time period represented five generations for each of Big Qualicum River, Capilano River, and Skagit River strains. Sample sizes were 155-433 each year. Big Qualicum strain tended to be longer, heavier, and have higher body condition than the other strains. Length and weight of Big Qualicum and Capilano strains declined significantly through the study period. Body condition declined significantly in all strains and sexes except Capilano females. The declines in size and condition correspond in time to increased salmonid stocking and are not unexpected. Current growth rates are still high relative to coho from Lake Michigan and the Pacific Ocean. The difference in length between males and females increased significantly for Skagit strain. Spawning time for the three strains has converged to mid-November.

Recommendations

1. Continue programs for monitoring predator fish growth and prey fish density in Lake Ontario.

2. Support research across the Great Lakes into the relationships between predator and prey fish species.

Introduction

The Ontario Ministry of Natural Resources (OMNR) initiated the Lake Ontario coho salmon stocking program in 1969 with the Credit River as the primary stocking site. The program provided a put and take fishery in Lake Ontario for coho salmon. In 1970, OMNR began collecting eggs for the stocking program from mature coho returning to the Credit River. Eggs were collected annually until the fall of 1990 inclusive. Fish attribute data were collected during the egg collections. In 1991, the coho salmon stocking program was discontinued due to hatchery closures.

Since 1977, all returning coho salmon returning to the Credit River have been the progeny of one of three Pacific Ocean strains of coho. The Skagit River strain was introduced in 1976, the Capilano River strain in 1977, and the Big Qualicum strain in 1978. The spawning returns of these three strains of coho have been on a three year cycle (Table 1). Each strain has completed five spawning returns.

Fish attribute data, collected over the period 1977-1991, corresponding to five spawning generations of each of three strains of coho salmon, were examined to detect changes in strain characteristics over time.

Stewart (1988, 1989) has previously analyzed the data for the years 1977 to 1988. Plante and Bowlby (1990) furthered the investigations with the addition of the 1989 data.

The objectives of this study were to: 1) summarize length and weight data for the 1990 and 1991 spawning returns, 2) further investigate changes in size and condition related to stock and spawning generation, and 3) determine if there is a trend to later spawning return dates.

Methods

Data Collection

Data were collected during November 14 to December 4 1990, and October 7 to November 25, 1991. The 1990 data were collected during egg collection, according to the methods outlined by Stewart (1989). Egg collection began when 50% of the females achieved spawning condition. In 1991, no egg collection was carried out. The Lake Ontario Fisheries Unit conducted the capture and sampling of the returning coho. In 1991, detailed sampling began when 50% of the females achieved spawning condition.

Round weight, fork length, gonad condition, lamprey marking and fin clip data were recorded for both years.

Datasets

For the trend-through-time analyses, the 1990 and 1991 data for adult coho were appended to the dataset containing the 1977-1989 data used in previous analyses (Stewart 1989, Plante and Bowlby 1990). The trend-through-time dataset was composed of 4696 records, covering the years 1977-1991. Previous monitoring information from 1977 to 1987 was reviewed by Stewart (1989) for differences in methodology and data recording. This included the removal of precocious male or female fish from the dataset, and elimination or correction of weights taken from fish stripped of gonadal material or bled prior to weighing.

Analysis

All statistical analyses were performed using the SAS System for Personal Computers (Release 6.03).

For the purpose of the current analysis, different measurements of weight were handled in the following manner. Female stripped weights were converted to round weight using a correction factor developed by Stewart (1989). Male stripped weights were considered to be equivalent to round weights. This was thought to be a consistent treatment of the data based on Stewart's (1989) observation that in most years it was difficult to determine if males were stripped before or after weighing. The amount of sperm collected was estimated to be less than 100 grams. Analysis of variance, performed to examine the effects of return sequence on weight for each strain, as well as analysis of covariance, performed to examine the effects of return sequence on condition for each strain, were carried out with and without the inclusion of male stripped weights. The results did not differ statistically, therefore all analyses included in this study were carried out with the inclusion of male stripped weights. Male stripped weights were excluded from previous investigations (Plante and Bowlby 1990).

Females belonging to the third spawning generation of the Capilano stock (1984 return) were bled prior to weighing. Based on the following, weight loss due to bleeding was considered negligible for the present analyses. The bleeding procedure was thought to result in a loss of at most 150 grams of blood for each female coho (B. Marchant , Ringwood Fish Culture Station, OMNR, and P. Savoie, Lake Ontario Fisheries Unit, OMNR, pers. comm.). Analysis of variance and analysis of covariance (as above) were performed with and without the addition of 150 grams to the recorded weights. Statistically the results were the same. However, the mean weight of females with the correction constant of 150 grams applied was found to be greater than the mean weight of males for the same year (4187 vs 4033 grams), a phenomenon not found in the other years included in this study. The addition of 150 grams was therefore thought to be an overestimation and the 1984 female bled weights were considered to be equivalent to round weight for the current analyses. Stewart (1989) reported that an adequate correction factor could not be determined for the bled female weights. The 1984 female weights therefore had not been included in previous analyses (Stewart 1989, Plante and Bowlby 1990).

All fish captured and sampled (excluding jacks and jills) were considered to be part of the returning strain of coho regardless of fin clip. For example, all 1990 coho sampled were considered to belong to the fifth generation of the Capilano strain, all 1991 coho sampled were considered to belong to the fifth generation of the Big Qualicum strain. The number of unclipped fish was low and did not differ from expected fin regeneration rates. Thus the genetic purity of the strains was thought to be high.

Two-way analysis of variance (ANOVA) was performed to examine the effects of strain and generation on length and weight. Interactions between the main effects were significant, and so separate ANOVAs were applied to determine the effects of generation for each strain and the effects of strain on each generation. The Tukey multiple comparison procedure was used to compare treatment means.

Two-way analysis of covariance (ANCOVA) was performed to determine the effects of strain and generation on weight adjusted for fork length (a measure of condition). $Log_{(10)}$ transformations were applied to the length and weight data. As above, separate ANCOVAs were applied to examine the effects of generation on condition for each strain and the effects of strain on condition for each generation. Comparison of treatment mean weights was accomplished using t-test on least square means adjusted for fork length. The least square means were untransformed for reporting purposes.

The divergence of male and female fork lengths over time for each stock was investigated using regression of the differences between male and female fork lengths versus return sequence.

Sampling began when 50% of the females were ripe. The first day of sampling was used as an indicator of spawning time.

Results

1990 and 1991

The 1990 spawning run of coho in the Credit River marked the fifth return of the Capilano strain, and 1991 marked the fifth return of the Big Qualicum strain. Table 2 provides details of recent coho stockings.

Statistics for length and weight of these fish are given in Table 3.

Size Trends

Weight and fork length for both male and female coho varied greatly over the study period (Figure 1). Two-way ANOVA's and ANOCOVA's applied to length and weight determined that the interaction of strain and generation were significant ($p < 0.0001$).

With the exception of the third generation of Skagit strain the Big Qualicum strain remained the heaviest throughout all returns (Table 4, Fig. 2). As well, Big Qualicum strain was consistently longer than Capilano, but Skagit was more variable (Table 5, Fig. 2).

The condition for females of the Big Qualicum strain remained the highest throughout all returns (Table 6). No strain had consistently higher or lower body condition in the males although Big Qualicum males were more often larger (Table 6). The differences however were not always significant.

The length and weight of males and females of Big Qualicum and Capilano strains have declined significantly through time (Tables 7, 8; Fig. 2). Skagit strain, however, shows no clear trend in either males or females.

Condition declined for all strains and sexes with the exception of Capilano females (Table 9).

Divergence of mean male and female fork length over time was found to be significant for the Skagit strain only ($p = 0.0079$) (Fig. 3). However, all three strains exhibited a positive slope for length difference (mean male length minus mean female length) versus return sequence. This suggests a possible trend to increasing differences in fork length between male and female coho.

Spawning Time

Spawning time for the three strains has converged to mid-November. (Fig. 4). The fifth generation of Skagit and Capilano strains spawned about three and two weeks later than the first generation. The spawning time of Big qualicum strain remained unchanged.

Discussion

Results from this study support the hypothesis of decreasing growth over time (Stewart 1988) although these results are inconsistent. Stewart (1989) noted that increased growth in the third spawning generation of the Skagit strain, while not consistent with the theory of decreasing size over time, might be explained by favourable growth conditions during the lake residency period of that particular generation. Similarly, a decline in size could be the result of a decline in prey abundance associated with increased salmonid stocking (Stewart 1989). Plante and Bowlby (1990) suggested the decline over time in condition was coincident with increases in salmonid stocking suggesting that condition may be density dependent.

The declines in size and condition are to be expected with increased stocking. More predators mean less prey for each predator. The mean length of these three strains of coho salmon returning to their native streams to spawn ranges from 439-496 mm (I. Fleming, University of Toronto, pers. comm.). Thus growth in Lake Ontario far exceeds that in the Pacific Ocean. In Lake Huron, coho lengths and weights (Rakoczy, 1991) are well within the ranges reported here. The weight of coho in Lake Michigan in the mid 1980s (M. Jones, Lake Ontario Fisheries Unit, OMNR, pers. comm., source unclear) appears to be at least 10% less that the smallest returning coho in the Credit River (5th generation Capilano strain). The rate of decline has decreased in recent years and growth rates may be levelling off at some steady state relative to prey numbers. However, we should continue to support salmonid growth rate and prey density monitoring in Lake Ontario and research across the Great Lakes into the relationships between predator and prey fish species.

Genetic differences account for some of the variability in the size of the returning coho. That these differences may have been maintained throughout the artificial propagation of these strains is indicated by the fact that with only one exception, the Big Qualicum strain has remained the largest strain over the study period. Thus, there is no evidence for convergence of these strains to a common size. It is difficult to make comparisons between strains as the fish of different strains are not resident in the lake at the same time.

The spawning times for all strains appears to have converged to the middle of November. The greatest change is for Skagit strain. We speculate that the delay in spawning has allowed increased growth. This in turn may have resulted in the differing growth trends in Skagit strain relative to Big Qualicum and Capilano.

The apparent trend for divergence of male and female fork lengths over time may indicate a greater response of female coho to environmental influences. Alternatively, the selection process for males by the hatchery staff may have selected for larger males.

Acknowledgements

Through the years this program has received the assistance of a large number of individuals, particularly from Maple District and Fish Culture Section of OMNR. We especially thank Brian Marchant and his staff at Ringwood Fish Culture Station for assistance in the field. Phil Smith and Tom Stewart provided valuable comments.

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TABLE 1. Return years of 3 strains of coho salmon stocked in the Credit River.

Strain	First Stocking	Generation				
		First	Second	Third	Fourth	Fifth
Skagit River (Washington)	1976	1977	1980	1983	1986	1989
Capilano River (British Columbia)	1977	1978	1981	1984	1987	1990
Big Qualicum River (British Columbia)	1978	1979	1982	1985	1988	1991

TABLE 2. Canadian stockings of coho salmon into Lake Ontario contributing to the 1990 and 1991 coho spawning returns to the Credit River.

Year of Stocking	Age Month	# Stocked	Location	Size at Stocking (#/lb)	Fin Clip	Year of Return
1988	03	63,370	Credit River	704	None	1990
	04	12,452	Credit River	254	None	1990
	08	51,977	Credit River	88	AdRp	1990
	08	12,000	Bronte Creek	40	AdRp	1990
	08	26,030	Port Dalhousie	41	AdRp	1990
1989	14	100,631	Credit River	21	RP	1990
	14	51,585	Bronte Creek	23	RV	1990
	13-14	51,413	Port Dalhousie	22	RV	1990
	08	50,596	Credit River	34	AdRV	1991
	08	13,756	Bronte Creek	44	AdRV	1991
	08	22,672	Port Dalhousie	33	AdRV	1991
1990	14	106,173	Credit River	21	Ad	1991
	14	15,778	Bronte Creek	22	RV	1991
	14	15,781	Bronte Creek	22	Ad	1991
	14	31,557	Port Dalhousie	23	RV	1991

TABLE 3. Size of male and female coho in the Credit River in fall, 1990 and 1991.

Attribute	Sex	N	Mean	Maximum	Minimum	Standard Deviation
1990						
fork length (mm)	Males	120	637	762	463	54
weight (g)	Males	120	3580	6800	1900	896
fork length (mm)	Females	107	634	703	514	33
weight (g)	Females	107	3425	4900	1700	596
1991						
fork length (mm)	Males	157	685	780	548	44
weight (g)	Males	157	4838	7100	2300	981
fork length (mm)	Females	127	661	740	557	33
weight (g)	Females	127	4498	6300	2400	657

TABLE 4. Comparison of mean weight between strains of coho salmon in the Credit River for each generation. Weights were collected 1977-1991. Weights with a common underline are not significantly different (p=0.05, Tukey's multiple comparison).

Generation	Sex	Strain/Weight(g)		
First	Males	BQ (N=133) 5654	CA (N=80) 4830	SK (N=123) 4239
	Females	BQ (N=382) 5424	CA (N=170) 4337	SK (N=200) 4120
Second	Males	BQ (N=141) 4635	CA (N=50) 4542	SK (N=115) 4426
	Females	BQ (N=376) 4615	CA (N=75) 4389	SK (N=195) 4056
Third	Males	SK (N=112) 4908	BQ (N=97) 4719	CA (N=93) 4033
	Females	SK (N=189) 4476	BQ (N=186) 4417	CA (N=228) 4037
Fourth	Males	BQ (N=132) 4544	CA (N=148) 4400	SK (N=170) 3771
	Females	BQ (N=148) 4231	CA (N=202) 4100	SK (N=159) 3458
Fifth	Males	BQ (N=157) 4838	SK (N=114) 4224	CA (N=120) 3580
	Females	BQ (N=127) 4498	SK (N=123) 3852	CA (N=107) 3425

TABLE 5. Comparison of mean fork length between strains of coho salmon in the Credit River for each generation. Lengths were collected 1977-1991. Lengths with a common underline are not significantly different (p=0.05, Tukey's multiple comparison).

Generation	Sex	Strain/Fork length (mm)		
First	Males	BQ (N=134) 714	CA (N=80) 696	SK (N=123) 671
	Females	BQ (N=382) 700	CA (N=170) 690	SK (N=200) 660
Second	Males	BQ (N=141) 689	CA (N=50) 683	SK (N=116) 671
	Females	CA (N=80) 676	BQ (N=377) 676	SK (N=196) 651
Third	Males	SK (N=112) 711	BQ (N=97) 697	CA (N=93) 659
	Females	SK (N=189) 682	BQ (N=186) 666	CA (N=228) 649
Fourth	Males	BQ (N=132) 693	CA (N=149) 685	SK (N=171) 679
	Females	BQ (N=148) 668	CA (N=202) 659	SK (N=159) 650
Fifth	Males	SK (N=114) 701	BQ (N=157) 685	CA (N=120) 637
	Females	SK (N=123) 665	BQ (N=127) 661	CA (N=107) 634

TABLE 6. Comparison of condition between strains of coho salmon in the Credit River for each generation. Least square means of the weight [1] adjusted for fork length were used as a relative measure of condition. Reported mean weights have been converted from the log values. Weights with a common underline are not significantly different (p=0.05, t-test).

Generation	Sex	Strain/Weight(g)		
First	Males	BQ 5164	CA 4656	SK 4539
	Females	BQ 5140	SK 4446	CA 4207
Second	Males	SK 4529	CA 4395	BQ 4385
	Females	BQ 4426	SK 4285	CA 4169
Third	Males	BQ 4487	CA 4467	SK 4416
	Females	BQ 4305	CA 4236	SK 4074
Fourth	Males	CA 4325	BQ 4305	SK 3776
	Females	CA 4027	BQ 4027	SK 3532
Fifth	Males	BQ 4519	CA 4064	SK 3733
	Females	BQ 4315	CA 3640	SK 3614

[1] The weight of a strain is relative to other strains within a spawning return, weights are not comparable between spawning returns.

TABLE 7. Mean weight of the three stocks of coho salmon in the Credit River by generation. Weights were collected 1977-1991. Weights with a common underline are not significantly different (p=0.05, Tukey's multiple comparison).

Strain	Sex	Generation/Weight(g)				
Big Qualicum	Males	1 (n=133)	5 (n=157)	3 (n=97)	2 (n=141)	4 (n=132)
		5654	4838	4719	4635	4544
	Females	1 (n=382)	2 (n=376)	5 (n=127)	3 (n=186)	4 (n=148)
		5424	4615	4498	4417	4231
Capilano	Males	1 (n=80)	2 (n=50)	4 (n=148)	3 (n=93)	5 (n=120)
		4830	4542	4400	4033	3580
	Females	2 (n=75)	1 (n=170)	4 (n=202)	3 (n=228)	5 (n=107)
		4389	4337	4100	4037	3425
Skagit	Males	3 (n=112)	2 (n=115)	1 (n=123)	5 (n=114)	4 (n=170)
		4908	4426	4239	4224	3771
	Females	3 (n=189)	1 (n=200)	2 (n=195)	5 (n=123)	4 (n=159)
		4476	4120	4056	3852	3458

TABLE 8. Mean fork length of the three stocks of coho salmon in the Credit River by generation. Lengths were collected 1977-1991. Lengths with a common underline are not significantly different (p=0.05, Tukey's multiple comparison).

Strain	Sex	Generation/Fork length (mm)				
Big Qualicum	Males	1 (n=134)	3 (n=97)	4 (n=132)	2 (n=141)	5 (n=157)
		714	697	693	689	685
	Females	1 (n=382)	2 (n=377)	4 (n=148)	3 (n=186)	5 (n=127)
		700	676	668	666	661
Capilano	Males	1 (n=80)	4 (n=149)	2 (n=50)	3 (n=93)	5 (n=120)
		696	685	683	659	637
	Females	1 (n=170)	2 (n=80)	4 (n=202)	3 (n=228)	5 (n=107)
		690	676	659	649	634
Skagit	Males	3 (n=112)	5 (n=114)	4 (n=171)	1 (n=123)	2 (n=116)
		711	701	679	671	671
	Females	3 (n=189)	5 (n=123)	1 (n=200)	2 (n=196)	4 (n=159)
		682	665	660	651	650

TABLE 9. Least square means of the weight per generation of coho salmon in the Credit River corrected for the fork length (a relative measure of body condition). Significance tests were carried out on the $\log_{(10)}$ wt and fork length. Reported means have been converted to their untransformed values. [1] Weights with a common underline are not significant ($p=0.05$, t-test). The weight of a generation is reative to other generations within a strain, weights are not comparable between strains.

Strain	Sex	Generation/Weight(g)				
Big Qualicum	Males	1	5	2	3	4
		5164	4920	4656	4592	4487
	Females	1	5	2	3	4
		4977	4753	4624	4560	4365
Capilano	Males	1	2	3	4	5
		4198	4178	4083	4036	4009
	Females	3	4	2	5	1
		4178	4064	4018	3811	3741
Skagit	Males	2	1	3	5	4
		4603	4426	4335	3899	3776
	Females	2	1	3	5	4
		4169	4093	4055	3733	3565

[1] The weight of a generation is relative to other generations within a strain, weights are not comparable between strains.

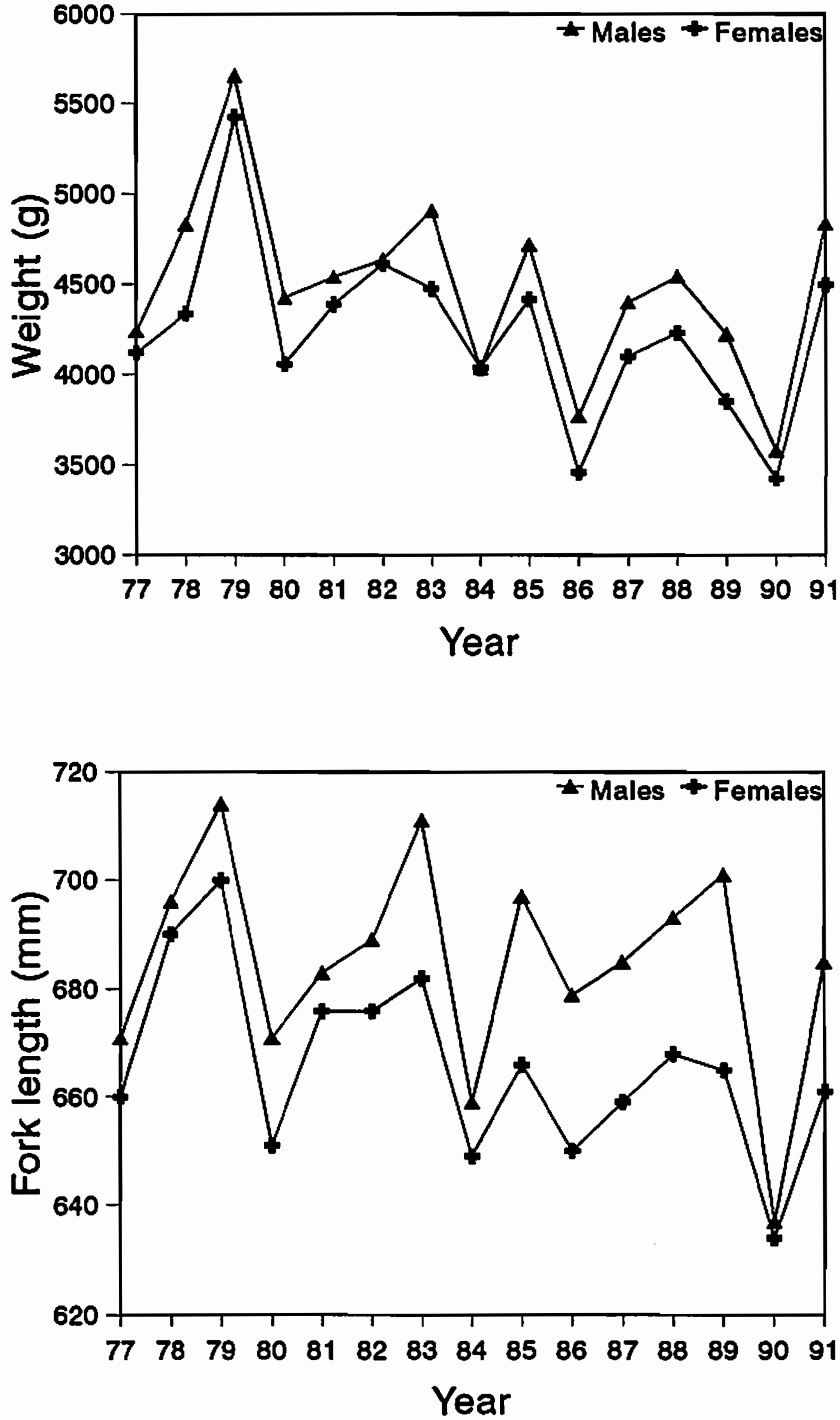

FIG. 1. Mean weight and length of adult coho salmon sampled during spawning on the Credit River from 1977-1991.

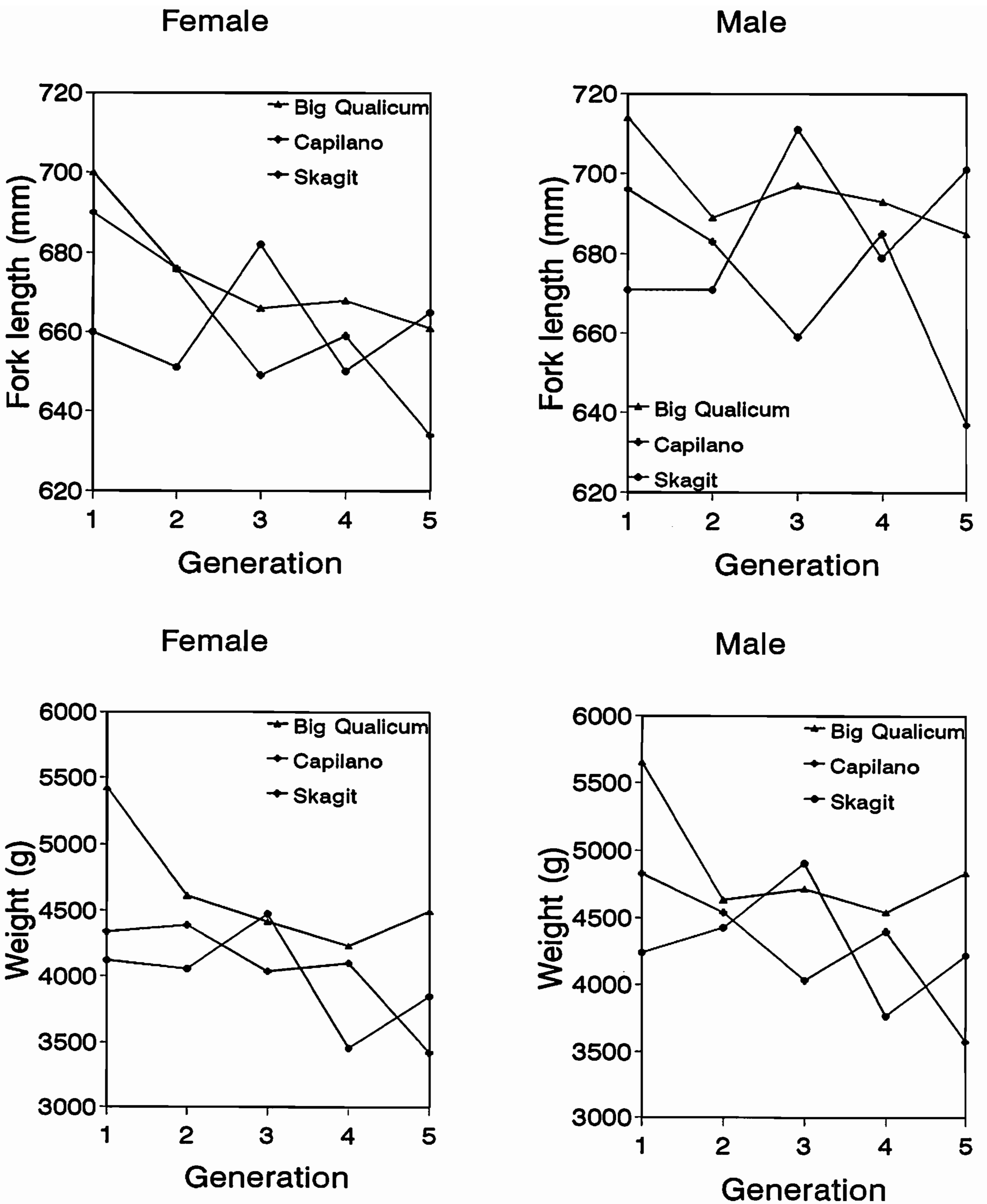

FIG. 2. Mean length and weight for each generation of coho salmon returning to the Credit River during 1977-1991.

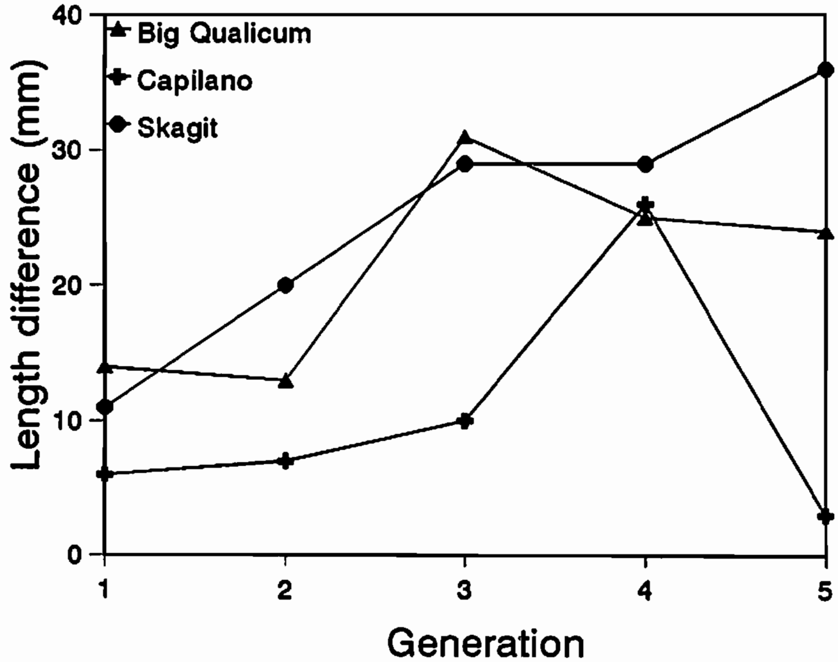

FIG. 3. Length differences between mean male fork length and mean female fork length of coho salmon in the Credit River for each generation and strain during 1977-1991.

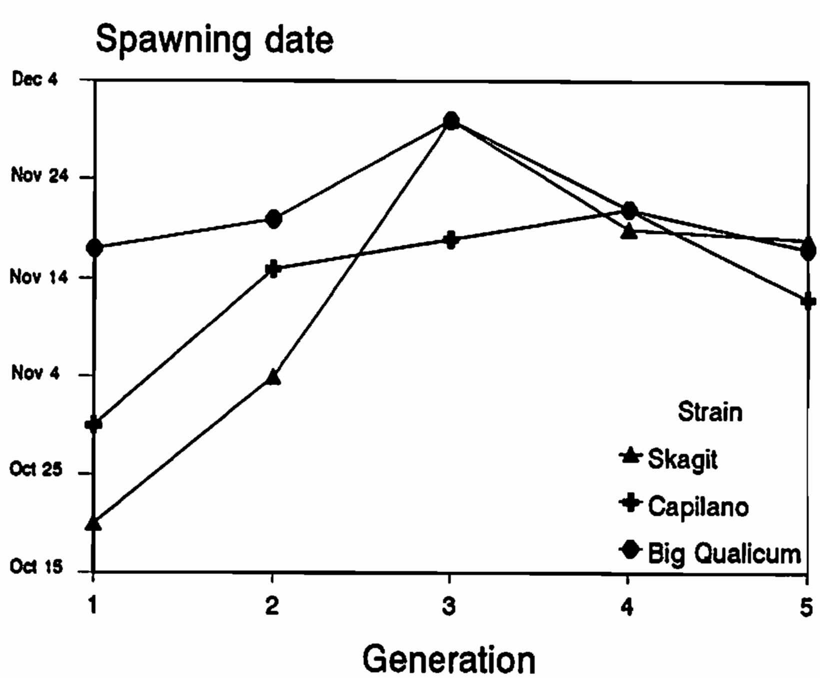

FIG. 4. Spawning date of coho salmon in the Credit River for each generation and strain during 1977-1991.

Research Project: Fish Community Dynamics of the Outlet Basin of Lake Ontario

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Lake Ontario Fisheries Unit 1991 Annual Report, Section 18

Sampling the deep-water fish community of the Outlet Basin with bottom-set gill nets and bottom trawls continued from May until August 1991. In comparison to 1989 and 1990, slightly more lake trout were taken in the gill nets, slightly fewer lake whitefish, and slightly fewer rainbow smelt and alewife; however, none of these catches were significantly different than those taken in the two previous years. Significantly more lake trout, lake whitefish, and rainbow smelt were taken in the deep waters of the middle of the Outlet Basin in mid- to late summer than were taken at other locations and other times of the year. Numbers of large alewife entangled in the coarse mesh of the experimental gill nets in 1991 were as low as have been seen since the early 1980s. The number of large rainbow smelt has increased slightly in the past few years, but catches are still quite low compared with those of the late 1970s and early 1980s. Yellow perch catches remained low, but burbot catches over the past few years have increased markedly in the deep waters of the Outlet Basin. This may signal the resurgence of the species; however, the numbers are still quite low, and the increase is mainly because of one strong year-class--1986. There has been no significant change in the trawl catches of rainbow smelt and alewife in recent years, but the confidence limits are extremely broad; they are 2.9 and 7.6 times, respectively, greater than for gill nets. Over the past 19 years, trout-perch catches have increased, while slimy sculpin catches have decreased. In 1990 and 1991, slimy sculpin catches were as low as have been observed during this period. A comparative study of multifilament and monofilament gill nets involving more than 60 paired sets indicated some differences in catch. The monofilament caught 40% more lake trout and 14% more whitefish, while the multifilament caught 40% more alewife and 5.7 times as many rainbow smelt; the differences were significant only for rainbow smelt. For the four primary species, there was a significant log-log relation between catches in these two types of nets, and variances in the catches were linearly correlated for lake trout and rainbow smelt. Studies of the relative abundance of various species, as indicated by catches in the experimental gill nets over the years, indicate some rather strong associations that no doubt reflect interaction and direct effects. Over the past 18 years, there has been an inverse relation between the catch of whitefish and the catch of rainbow smelt. Also, the catch of rainbow smelt was inversely related to the catch of lake trout four years earlier. It then follows that the size of the lake trout population in the Outlet Basin has probably had a direct effect on the size of the lake whitefish population.

Background and Objectives

For the past 31 years, Research has routinely sampled the fish community in the deep waters of the Outlet Basin of Lake Ontario. This long-term index series, initiated in 1961, has been conducted in a very consistent and standard fashion. Six fixed stations ranging in depth from 26 to 38 m have been sampled once a month with multifilament gill nets ranging in mesh size from 1.5 to 6 inches. Since 1972, trawling with a three-quarter "Yankee Standard" No. 35 bottom trawl has been conducted at six similar deep-water stations. The trawl tows were 1/2 mile (804.7 m) and, like the gill-netting, were usually conducted during each of the summer months.

Although the stations and gill nets were originally selected to assess changes in the lake whitefish population, over the years it has become a general index series used to study and monitor the deep-water fish community of the Outlet Basin of Lake Ontario.

More recently it has documented the attempt to re-introduce lake trout, the once abundant keystone predator, and to examine fish community responses to the rehabilitation process. Carried out in conjunction with concurrent community index sampling of the adjacent waters of the Bay of Quinte, it has provided the opportunity to evaluate the dynamics and movement of the fish between the east end of Lake Ontario and a large productive embayment. Gill net sampling in the deep waters of the Outlet Basin has consistently taken lake trout, lake whitefish (hereafter called whitefish), lake herring, rainbow smelt (hereafter called smelt), and alewife. Trawling has sampled the smaller species, especially the latter two, along with trout-perch, slimy sculpin, and johnny darters.

Detailed studies of species interaction are now possible because for the past three years, sampling variability has been examined and quantified. Biological data such as length, weight, age, sex, maturity, and stomach contents and calcified structures for age determination have been collected over the years but have been only sporadically analyzed. This report does not include any analysis of the biological data but simply provides a summary of the catch statistics to show general trends and to indicate the preliminary analyses that are under way and are used to verify the basic catch data in preparation for more specific analyses.

Progress

Over the years, gill netting has involved setting one or two gangs of nets at one station each month. Although there was no measure of variability, the single unit of effort was intensive. Up to 1988, only experimental gill nets were used. They were 8 ft (2.44 m) deep and were composed of two 25-yd (22.86-m) panels of 1.5- and 2.5-inch mesh and two sets of eight 50-yd (45.72-m) panels ranging from 2.5- to 6-inch stretched mesh in 0.5-inch intervals. In 1988, green monofilament gill nets were also fished at each station concurrent with the multifilament nets. In 1989 and 1990, three additional 25-yd panels of white multifilament of both 1.5- and 2.0-inch mesh nets were used. Then a total of 100 yd (91.44 m) of each mesh size was fished, with panel lengths 50 yd long. The effort was increased to assess sampling variability. With this configuration it was possible to subsample all meshes equally by 50-ft intervals and obtain six replicate subsamples of the catch, which were then used to project the estimated sampling variability associated with these large units of gill net effort.

From this study of variance by subsampling, it was concluded that replicate sampling should be routine to measure observational variability and that 50-ft units of gill net effort provided appropriate samples of fish of the Outlet Basin at present densities (Casselman 1991). Since this type of subsampling is not true replication and since the long panels of a single mesh no doubt affect variability across the net because different mesh sizes are very distant, it was decided to conduct more truly replicate sampling in 1991. So smaller multimesh nets consisting of 50-ft panels were built. One unit of experimental gill net effort now was a 500-ft (152.4-m) net with meshes ranging in size from 1.5 to 6 inches.

Prior to 1988, only one trawl drag was conducted at each station. In 1988, four replicate drags were made at each station. In 1989, trawling was not conducted because the vessels were being refitted to meet safety specifications. However, for 1989, trawl estimates were made for both smelt and alewife with relations that exist between trawl and gill net catches in the Outlet Basin series. In 1990, three replicate tows were made at each of the six stations in each of the four summer months. In 1991, trawling was replicated with six tows.

In 1991, sampling effort was changed. Fewer stations were sampled so that a comparative study could be conducted between the conventional multifilament gill nets and the new monofilament gill nets that would be used in future index sampling of Lake Ontario. Three stations were sampled--2, 4, and 6. This alteration in sampling design was an initial necessary step in the transfer to Assessment of Research's traditional role of index sampling the Outlet Basin and the Bay of Quinte.

Monofilament gill nets were used in 1991 to conduct a comparison so that future catches in monofilament gill nets can be related to those of the old traditional multifilament nets. The experimental multifilament gill nets traditionally used in this series have a hanging ratio of approximately 0.4, 25% more twine, and a more oval shape, as compared with conventional monofilament experimental gill nets, which have a hanging ratio of 0.5. To provide adequate replicates and the proper comparison between the two types of nets, three nets (multimesh, 1.5 to 6 inches, 50-ft panels) of one filament type were set consecutively, followed by three nets of the alternate filament type. The next day, nets were reset at the same location, but with the filament types switched. For a particular filament type, six replicate samples from the multimesh nets were obtained, but over two consecutive days, which no doubt added some temporal variability to the sampling design.

Gill net catches are reported as numbers per 100 m^2 of net, and for the third year, 95% confidence limits about the geometric mean catch were measured to examine changes in the relative abundance of various species. Confidence limits are now available for gill net catches in 1989, 1990, and 1991 and for trawl catches in 1988, 1990, and 1991. These were calculated for gill net catches from subsamples in 1989 and 1990 and for replicate samples in 1991. Results for each station and month were averaged to obtain an annual value for each year except 1991, when only three of the six stations were sampled. For 1991, the catches at the three stations were adjusted to reflect the estimated catch at all six stations by using the relative proportions of the catches at these stations in former years.

The catch of the large primary species in the gill nets has shown very prominent trends in recent years (Fig. 1). However, in 1991, the average catch was very similar to 1989 and 1990. Although slightly more lake trout were taken, their numbers were not significantly greater than those taken in the two previous years. The whitefish catch was slightly lower than in 1990 but has not been significantly different in the past three years. Lake herring catches were similar to 1990. Changes in the catch of lake herring may not be indicative of the actual abundance of lake herring in the Eastern Basin since they would have a temperature optimum that would be higher than that seen at the bottom of the deepest portions of the Outlet Basin. Greater catches of lake herring would be seen in the shallower inshore waters. Lake trout catches were not significantly different among the three stations sampled in 1991 (Table 1). As in previous years significantly more lake trout were taken in mid- to late summer than in early summer, but catches in August 1991 were not significantly lower than in July, as were seen in 1990 (Casselman et al. 1991). In 1991, whitefish showed a similar seasonal cycle of abundance in the deep waters of the Outlet Basin (Table 1). But significantly fewer were taken at station 4, near Main Duck Island, than at station 2, inshore, and significantly more were taken in the middle of the basin at station 6 than at the other two stations. This occurred because, like lake trout, there is an increased movement of whitefish to deep water in the Outlet Basin as temperatures increase in mid- to late summer.

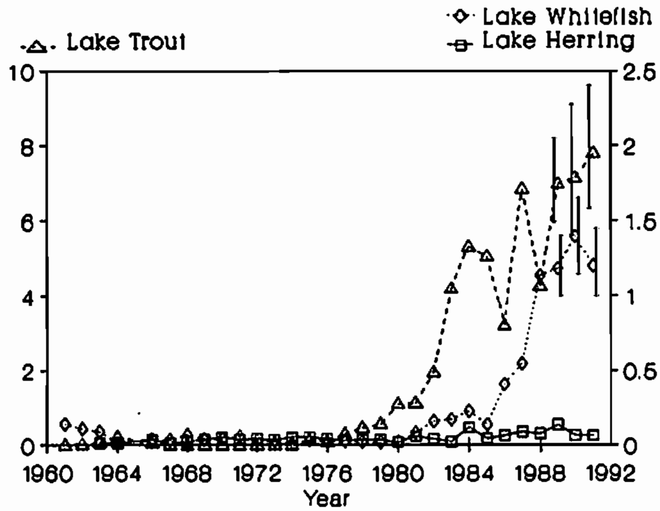

FIG. 1. Relative abundance of lake trout, lake whitefish, and lake herring in the Outlet Basin of Lake Ontario, 1961-1991, as indicated by numbers caught in experimental gill nets set 26-38 m deep. Six stations were sampled annually, once during May, June, July, and August from 1961 to 1990, with the exception of 1965. In 1991, three stations (2, 4, and 6) were sampled each month. The 1991 catches were adjusted to reflect the estimated average catch at all six stations, making them comparable to former years. For 1991, the catches at the three stations were adjusted to reflect the estimated catch at all six stations by using the relative proportions of the catches at these stations in former years. Experimental gill nets were white multifilament 8 ft (2.44 m) deep and were composed of two 25-yd (22.86-m) panels of 1.5- and 2-inch mesh and two sets of eight 50-yd (45.72-m) panels ranging from 2.5- to 6-inch stretched mesh in 0.5-inch intervals. In 1989 and 1990, all panels were 50 yards (45.72 m) long. In 1991, the same amount of effort was used with replicate multifilament multimesh (1.5- to 6-inch) nets 500 ft (152.4 m) long composed of 50-ft (15.24-m) panels. Catches are expressed as numbers per 100 m^2 of experimental net. The 95% confidence limits about the geometric mean catch, calculated for stations 2, 4, and 6, as determined by subsampling in 1989 and 1990 and replicate sampling in 1991 (N = 6), are indicated for lake trout and lake whitefish.

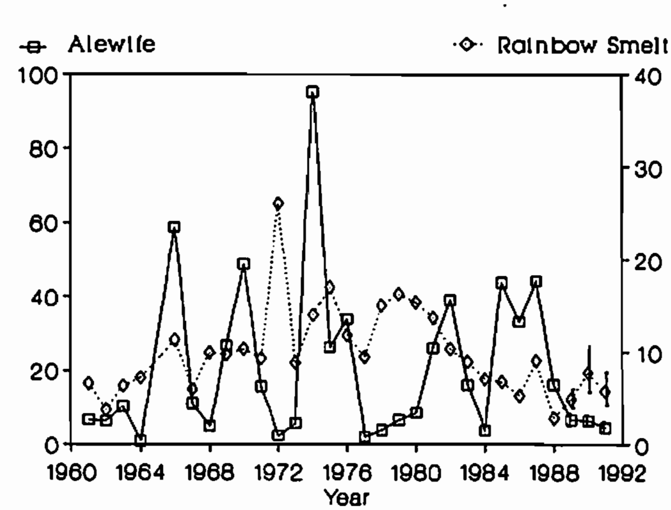

FIG. 2. Relative abundance of all sizes of alewife and rainbow smelt in the Outlet Basin of Lake Ontario, 1961-1990, as indicated by numbers entangled in experimental gill nets set 26-38 m deep. Six stations were sampled annually, once during May, June, July, and August from 1961 to 1990, with the exception of 1965. In 1991, three stations (2, 4, and 6) were sampled each month. The 1991 catches were adjusted to reflect the estimated average catch at all six stations, making them comparable to former years. For 1991, the catches at the three stations were adjusted to reflect the estimated catches at all six stations by using the relative proportions of the catch at these stations in former years. Experimental gill nets were white multifilament 8 ft (2.44 m) deep and were composed of two 25-yd (22.86-m) panels of 1.5- and 2-inch mesh and two sets of eight 50-yd (45.72-m) panels ranging from 2.5- to 6-inch stretched mesh in 0.5-inch intervals. In 1989 and 1990, all panels were 50 yards (45.72 m) long. In 1991, the same amount of effort was used with replicate multifilament multimesh (1.5- to 6-inch) nets 500 ft (152.4 m) long composed of 50-ft (15.24-m) panels. Catches are expressed as numbers per 100 m^2 of experimental net. The 95% confidence limits about the geometric mean catch, calculated for stations 2, 4, and 6, as determined by subsampling in 1989 and 1990 and replicate sampling in 1991 (N = 6), are indicated.

Catches of smelt and alewife in the gill nets were low compared to early years but were not significantly different than in 1989 and 1990 (Fig. 2). The confidence interval remained remarkably narrow, given the size of the catch. In 1991, alewife catches were significantly higher at station 4 than at any other station and significantly lower in May and higher in July than in the other three summer months (Table 1). Smelt catches were significantly lower at station 4 than at the other two stations and lower in May and June than in July and August. The largest smelt catches were taken in August (Table 1); smelt, like lake trout and whitefish, congregated in the deeper water of the Outlet Basin in mid- to late summer.

General trends in the catches of smelt and alewife in gill nets over the years are best described by the numbers of large individuals entangled in the coarse mesh (Fig. 3). The catch of large alewife in 1991 was as low as has been seen since the early 1980s. The number of large smelt has increased slightly in the past few years, but catches are still quite low compared with those of the late 1970s and early 1980s.

Yellow perch catches in the deep waters of the Outlet Basin continued to remain low since their striking decrease, which began in the early 1980s (Fig. 4). No apparent regular cycle of abundance exists now, as was present before this precipitous decrease.

In recent years, burbot catches in the deep waters of the Outlet Basin have increased markedly; this commenced in 1989 (Fig. 4). This may signal a major resurgence of burbot. However, the numbers are still quite low, and it appears to be mainly because of one strong year-class recruited in 1986.

The confidence limits about the trawl catches of smelt and alewife in 1991 were extremely broad, as in previous years, so there have been no significant changes in these catches in recent years (Fig. 5). However, trawl catches of smelt in midsummer in the Outlet Basin have shown an increasing trend over the years. The change in the number of smelt is attributed to an increase in the number of small young smelt because the trawls catch more of these fish than do the gill nets. Alewife catches appear to fluctuate more and show no similar trend. It is apparent that the confidence interval about the geometric mean catch, hence the sampling variability associated with trawl and gill net samples taken at the same location at approximately the same time, are very much different (Casselman 1992). The

TABLE 1. The 1991 geometric mean catch (CUE) and 95% confidence limits (lower--LCL, upper--UCL) separated by station and month for four species caught in standard white multifilament experimental gill nets ranging in mesh size from 1.5 to 6 inches fished once during each of May, June, July, and August in the Outlet Basin of Lake Ontario 30 to 38 m deep at three stations (2, 4, and 6). The confidence limits were calculated from the variance obtained by replicate sampling of a multimeshed gill net composed of 50-ft (15.24-m) panels. The variance was projected for the traditional white multifilament 3000-ft (914.4 m) experimental gill nets set at these stations by dividing the variance obtained for the replicate sample by the square root of the increased effort (square root of 6--2.45). Catch is expressed as number per 100 m^2 of net. Sample sizes are provided.

		Alewife			Lake trout			Lake whitefish			Rainbow smelt		
Variable	N	CUE	LCL	UCL	CUE	LCL	UCL	CUE	LCL	UCL	CUE	LCL	UCL
Station No.													
2[a]	4	6.1	4.4	8.4	4.9	3.9	6.2	0.6	0.5	0.7	3.0	2.0	4.3
4[a]	4	2.0	1.4	2.6	4.5	3.7	5.5	0.4	0.4	0.5	0.6	0.5	0.7
6[b]	4	3.3	2.4	4.4	5.6	4.5	6.9	1.4	1.1	1.7	2.3	1.7	3.1
Month													
May	3	1.5	1.2	1.9	2.4	2.0	2.9	0.2	0.2	0.3	0.5	0.4	0.7
June	3	4.5	3.4	6.0	6.3	2.0	19.5	0.4	0.4	0.5	0.7	0.6	0.9
July	3	8.6	6.0	12.3	8.3	4.8	14.2	1.4	1.2	1.6	1.7	1.5	1.9
Aug.	3	2.8	2.1	3.8	5.3	4.1	6.9	1.5	1.1	1.9	9.8	7.6	13.6
Overall mean	12	3.5	2.5	4.8	5.0	4.1	6.2	0.7	0.6	0.9	1.7	1.2	2.3

[a]Approximately 30 m deep.
[b]>30 m deep (approximately 35 m).

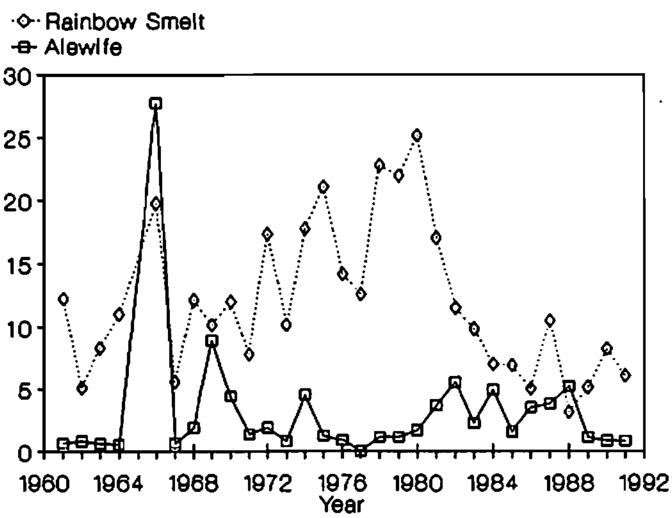

FIG. 3. Relative abundance of large alewife and rainbow smelt in the Outlet Basin of Lake Ontario, 1961-1990, as indicated by numbers entangled in selected meshes of experimental gill nets set 26-38 m deep. Six stations were sampled annually, once during May, June, July, and August from 1961 to 1990, with the exception of 1965. In 1991, three stations (2, 4, and 6) were sampled each month. The 1991 catches were adjusted to reflect the estimated average catch at all six stations, making them comparable to former years. For 1991, the catches at the three stations were adjusted to reflect the estimated catch at all six stations by using the relative proportions of the catches at these stations in former years. Experimental gill nets were white multifilament 8 ft (2.44 m) deep and were composed of two 25-yd (22.86-m) panels of 1.5- and 2-inch mesh and two sets of eight 50-yd (45.72-m) panels ranging from 2.5- to 6-inch stretched mesh in 0.5-inch intervals. In 1989 and 1990, all panels were 50 yards (45.72 m) long. In 1991, the same amount of effort was used with replicate multifilament multimesh (1.5- to 6-inch) nets 500 ft (152.4 m) long composed of 50-ft (15.24-m) panels. Catches are expressed as numbers per 100 m^2 of experimental net. Alewife catches were fish entangled in 3.0-, 3.5-, and 4.0-inch mesh. Smelt catches were fish entangled in 2.5-, 3.0-, and 3.5-inch mesh.

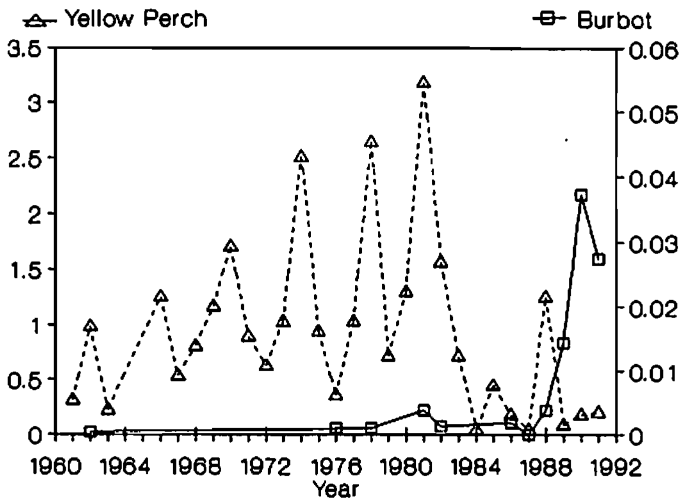

FIG. 4. Relative abundance of yellow perch and burbot in the Outlet Basin of Lake Ontario, 1961-1990, as indicated by numbers caught in experimental gill nets set 26-38 m deep. Six stations were sampled annually, once during May, June, July, and August from 1961 to 1990, with the exception of 1965. In 1991, three stations (2, 4, and 6) were sampled each month. The 1991 catches were adjusted to reflect the estimated average catch at all six stations, making them comparable to former years. For 1991, the catches at the three stations were adjusted to reflect the estimated catch at all six stations by using the relative proportions of the catches at these stations in former years. Experimental gill nets were white multifilament 8 ft (2.44 m) deep and were composed of two 25-yd (22.86-m) panels of 1.5- and 2-inch mesh and two sets of eight 50-yd (45.72-m) panels ranging from 2.5- to 6-inch stretched mesh in 0.5-inch intervals. In 1989 and 1990, all panels were 50 yards (45.72 m) long. In 1991, the same amount of effort was used with replicate multifilament multimesh (1.5- to 6-inch) nets 500 ft (152.4 m) long composed of 50-ft (15.24-m) panels. Catches are expressed as numbers per 100 m^2 of experimental net.

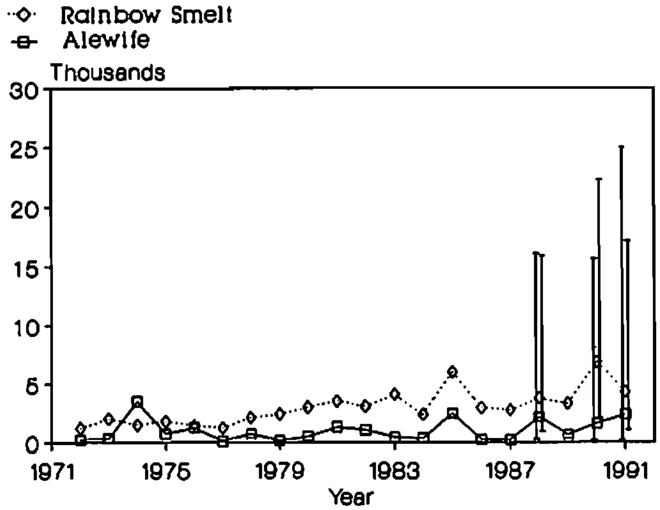

FIG. 5. Relative abundance of rainbow smelt and alewife in the Outlet Basin of Lake Ontario, 1972-1990, as indicated by number caught in a 1-mile (1609.3-m) tow of a three-quarter "Yankee Standard" No. 35 bottom trawl drug at depths of 26-30 m. Six stations were sampled annually, once during May, June, July, and August from 1961 to 1990, with the exception of 1965. In 1991, three stations (2, 4, and 6) were sampled each month. The 1991 catches were adjusted to reflect the estimated average catch at all six stations, making them comparable to former years. For 1991, the catches at the three stations were adjusted to reflect the estimated catch at all six stations by using the relative proportions of the catches at these stations in former years. The trawl was actually drug for 0.5 mile, and numbers were doubled to present as catches per one-mile tow. The trawl had a 0.5-inch cod end; however, from 1977 to 1990, with the exception of 1983, a 0.25-inch mesh liner was used. The 95% confidence limits about the geometric mean catch, calculated for stations 2, 4, and 6, as determined by replicate drags (1988--N = 4; 1990--N = 3; 1991--N = 6) are indicated.

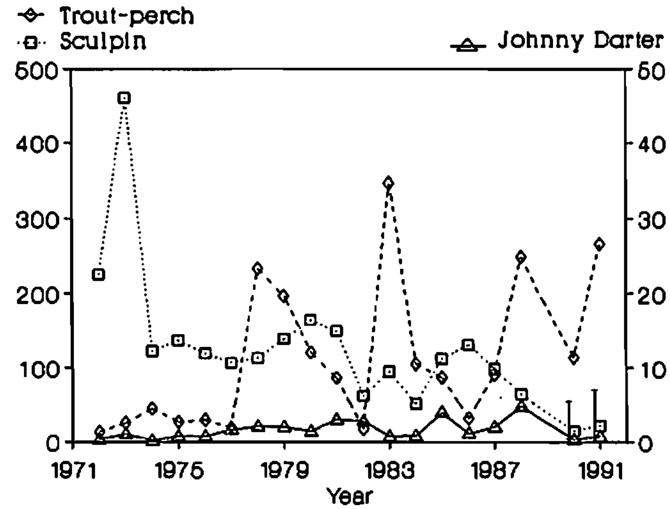

FIG. 6. Relative abundance of sculpin, trout-perch, and johnny darter in the Outlet Basin of Lake Ontario, 1972-1990, as indicated by number caught in a 1-mile (1609.3-m) tow of a three-quarter "Yankee Standard" No. 35 bottom trawl drug at depths of 26-30 m. Six stations were sampled annually, once during May, June, July, and August from 1961 to 1990, with the exception of 1965. In 1991, three stations (2, 4, and 6) were sampled each month. The 1991 catches were adjusted to reflect the estimated average catch at all six stations, making them comparable to former years. For 1991, the catches at the three stations were adjusted to reflect the estimated catch at all six stations by using the relative proportions of the catches at these stations in former years. The trawl was actually drug for 0.5 mile and numbers were doubled to present as catches per one-mile tow. The trawl had a 0.5-inch cod end; however, from 1977 to 1990, with the exception of 1983, a 0.25-inch mesh liner was used. The 95% confidence limits about the geometric mean catch, calculated for stations 2, 4, and 6, as determined by replicate drags (1988--N = 4; 1990--N = 3; 1991--N = 6) are indicated for sculpin.

confidence intervals, as determined by the 1991 catches of alewife and smelt for the trawls as compared with gill nets, were 7.6 and 2.9 times greater, respectively (Table 2). Because of the high degree of sampling variability associated with trawling, only a few significant seasonal and site differences were observed in 1991. Significantly fewer whitefish and slimy sculpin were observed at station 4 and fewer trout-perch in July.

Catches of trout-perch in the trawls have fluctuated rather widely since the 1970s but have shown an increasing trend (Fig. 6). Slimy sculpin catches in 1991 were extremely low but not significantly different than those observed in 1990. In contrast to the catches of trout-perch over this period, there has been a steady downward trend in the catch of slimy sculpin.

Catches of fish in the monofilament and multifilament gill nets were somewhat different; however, these differences were significant only for smelt (Table 3). Although the multifilament nets caught 40% more alewife and the monofilament 40% more lake trout, these differences, because of the intrinsic variability associated with gill net catches, were not significant, even with this relatively large number of comparisons (N >60). Given the differences in the shape of the mesh and number of meshes fished with these two types of nets, these relative differences would be expected. The whitefish catches were not significantly different either; however, the monofilament nets caught slightly more fish (14%)--a result that was not anticipated because of a previous comparison and because the multifilament nets have a unique hanging ratio specially selected for whitefish. Smelt readily became entangled by their teeth in strands of multifilament twine, so it was not surprising that the catch was significantly lower in the monofilament nets. At this point in our comparison, this appears to be the single most important difference between the two types of gill nets. It is apparent that a switch away from multifilament thread will affect the usefulness of these gill nets for indexing the relative abundance of smelt. This is unfortunate, because smelt catches in the gill nets provide an important index with narrow confidence limits that will increase with decreased catch and increased variance (Casselman 1992). For the four primary species, there was, however, a significant log-log relation between catches in these two types of nets (Table 3).

The variance in the catches in these two types of nets was linearly correlated for lake trout and smelt (Table 4), and the slight differences that they showed were not significant. As expected from the catch statistics, the most noticeable difference was with smelt; the coefficient of variation was two times greater in the monofilament nets (Table 4). Increased sampling effort will probably show this difference to be significant.

Studies of the relative abundance of various species caught in the gill nets over the years indicate some rather strong associations that no doubt reflect interaction and

TABLE 2. The 1991 geometric mean catch (CUE) and 95% confidence limits (lower--LCL, upper--UCL) separated by station and month for five species caught in the Outlet Basin of Lake Ontario in a 1/2-mile (804.7-m) tow of a three-quarter "Yankee Standard" No. 35 bottom trawl drug at depths of 30 to 38 m. Six replicate drags were made each month, May, June, July, and August, at three stations (2, 4, and 6) and during August at Station 3. Catch is expressed as number per tow. Sample sizes are provided.

		Alewife			Lake trout			Lake whitefish		
Variable	N	CUE	LCL	UCL	CUE	LCL	UCL	CUE	LCL	UCL
Station No.										
2[a]	4	530	161	1747	3.3	1.4	7.6	3.3	0.9	11.6
4[a]	4	276	30	2523	1.4	0.7	3.0	0.1	0.1	0.1
6[b]	4	90	5	1553	3.4	1.6	7.0	2.8	1.9	4.0
Month										
May	3	1887	637	5594	1.0	0.6	1.7	0.5	0.2	1.3
June	3	314	100	987	2.3	1.2	4.5	0.3	0.2	0.5
July	3	71	5	1086	4.9	2.4	9.7	0.5	0.3	1.1
Aug.	3	142	11	1770	2.4	0.9	6.6	1.7	0.4	6.8
Overall mean	12	271	26	2841	2.4	1.0	5.6	0.7	0.3	2.0

[a]Approximately 30 m deep.
[b]>30 m deep (approximately 35 m).

direct effects. Initial analyses reveal that since 1974, 94% of the variance in the catch of whitefish in the gill nets was explained by, and is positively correlated with, the catch of lake trout four years earlier. The log-log relation of CUE expressed as number per 100 m^2 of gill net was:

$$\text{Log CUE}_{\textit{whitefish}} = -0.66 + 0.97 \log \text{CUE}_{\textit{lake trout 4 years earlier}}$$

$$N = 13; r = 0.97; P = 0.00$$

It is difficult to see how the catch of lake trout would directly influence the catch of whitefish, but an indirect effect through smelt is plausible. The catch of smelt entangled in the gill nets was negatively correlated with the earlier catch of lake trout. Since 1974, 70% of the variation in the catch of smelt was explained by this previous catch of lake trout. The log-log relation was:

$$\text{Log CUE}_{\textit{smelt}} = 0.91 - 0.29 \log \text{CUE}_{\textit{lake trout 4 years earlier}}$$

$$N = 13; r = 0.84; P = 0.00$$

Hence, there is a direct and negative association between smelt catches and whitefish catches. Over the past 18 years, 70% of the variance in whitefish catches in the Outlet Basin is explained by smelt catches. The log-log relation is:

$$\text{Log CUE}_{\textit{whitefish}} = 1.77 - 2.77 \log \text{CUE}_{\textit{smelt}}$$

$$N = 18; r = 0.83; P = 0.00$$

This association is strong, and it is probably effected through direct predation of large smelt feeding on larval whitefish.

Future Directions

This was the last year that Research will continue to support the long-term data sets associated with the deep waters of the Outlet Basin. Research will focus on processes and specific problems such as: determining the factors that are limiting rehabilitation of lake trout stocks in Lake Ontario; determining the factors that affect year-class strength of the primary species such as whitefish and alewife; examining species interactions, seasonal movements, and migrations as they are affected by reproduction, growth, activity, and environmental requirements.

In 1992, Research's role of routinely index sampling the deep waters of the Outlet Basin will be formally transferred to Assessment. This will result in some changes to the traditional sampling design. However, sampling will continue at sites comparable to four of the six stations regularly sampled by Research. Stations 2 and 6 will be retained, but stations 1 and 3 will be amalgamated with the two deep index sites that essentially duplicate them (exactly the same site in the case of station 1) and are routinely sampled in the depth-stratified indexing program conducted by Assessment near shore at Grape Island and Flatt Point. Station 5 will be dropped because depth at this location is extremely variable, and this has caused variability in the past. To sample this station properly, depth stratification should be employed. Station 4 will be replaced by a comparably deep station closer to the Main Duck Sill. This will provide a more uniform distribution of effort over the deep waters of the Outlet Basin and will provide catch statistics that will better help examine fish movements in the Outlet Basin, especially between the main basin of Lake Ontario and the Outlet Basin. Sampling will be restricted to mid- and late summer. There will be no problem interpreting the seasonal significance of this change because summer seasonality has been thoroughly sampled in the Research index program and can be easily quantified. The new program will not measure summer seasonal diversity, but the sheer size of

TABLE 2. Continued.

Variable	N	Rainbow smelt			Troutperch			Slimy sculpin		
		CUE	LCL	UCL	CUE	LCL	UCL	CUE	LCL	UCL
Station No.										
2[a]	4	1492	439	5071	2.8	0.9	8.2	5.0	1.3	19.1
4[a]	4	473	100	2245	2.9	0.9	10.1	0.1	0.1	0.2
6[b]	4	1434	574	3584	1.1	0.5	2.4	1.4	0.6	3.2
Month										
May	3	901	314	2580	10.1	4.2	24.7	1.8	0.7	5.2
June	3	602	263	1376	2.7	1.3	5.6	0.9	0.3	2.8
July	3	573	109	3013	0.5	0.3	0.8	0.9	0.5	1.9
Aug.	3	1725	265	11208	1.3	0.4	5.0	2.2	0.5	10.3
Overall mean		880	199	3899	3.0	0.6	14.4	1.4	0.5	4.6

[a]Approximately 30 m deep.
[b]> 30 m deep (approximately 35 m).

TABLE 3. Log-log relations between geometric mean catches in multifilament and monofilament gill nets for paired replicate sets of multimesh 1.5- to 6-inch gill nets composed of 50-ft (15.24-m) panels set six times at three stations (2, 4, and 6) in the deep waters of the Outlet Basin of Lake Ontario once each during May, June, July, and August of 1991. Catch is expressed as number per 100 m^2 of multimesh net. Means and 95% confidence intervals (C.I.) are also indicated.

Species	Regression equation: Dependent variable catch multifilament	Regression equation: Independent variable catch monofilament	N	r	P	Multifilament mean	Multifilament 95% C.I.	Monofilament mean	Monofilament 95% C.I.
Alewife	LogY = 0.371	+ 0.498LogX	60	0.538	0.000	3.5	2.2	2.5	2.2
Lake trout	LogY = 0.062	+ 0.741LogX	67	0.585	0.000	5.0	1.7	7.0	1.6
Lake whitefish	LogY = 0.015	+ 0.732LogX	46	0.672	0.000	0.7	1.6	0.8	1.5
Rainbow smelt	LogY = 0.723	+ 0.885LogX	35	0.636	0.000	1.7	2.3	0.3	1.4

TABLE 4. Relations between geometric mean catches in multifilament and monofilament gill nets for paired replicate sets of multimesh 1.5- to 6-inch gill nets composed of 50-ft (15.24-m) panels set six times at three stations (2, 4, and 6) in the deep waters of the Outlet Basin of Lake Ontario once each during May, June, July, and August of 1991. Catch is expressed as number per 100 m^2 of multimesh net. Means and 95% confidence intervals (C.I.) of the coefficients of variation are also indicated.

Species	Regression equation: Dependent variable variance multifilament	Regression equation: Independent variable variance monofilament	N	r	P	Coefficient of variation: Multifilament mean	Multifilament 95% C.I.	Monofilament mean	Monofilament 95% C.I.
Alewife	Y = 6.235	+ 0.019X	12	0.050	0.976	43.2	20.8	54.7	29.1
Lake trout	Y = -1.573	+ 1.796X	12	0.976	0.000	16.5	12.6	13.8	8.7
Lake whitefish	Y = 3.513	– 0.132X	11	0.338	0.355	72.3	41.2	54.3	28.5
Rainbow smelt	Y = 2.765	+ 1.125X	10	0.788	0.003	49.7	21.3	100.9	48.4

the overall indexing program necessitates compromise; the indexing program is designed to sample in midsummer when conditions are more thermally homogeneous. It is Research's responsibility to place this sampling in an overall seasonal context based on reproduction, growth, activity, and environmental requirements. Indeed, a Research study will be initiated in 1992 that will address some aspects of this problem.

In 1992, Research will conduct a trawling study with some hydroacoustical sampling that will examine the seasonal changes in abundance and movement of small fish species in the Outlet Basin and the Bay of Quinte. This will provide a better understanding of the role of seasonal variability in sampling across the Outlet Basin of Lake Ontario and the Bay of Quinte and will provide directly comparable data with which to start a joint analysis of these two long-term data sets.

The Bay of Quinte is an important spawning and nursery habitat for many species, and the fish communities in the Bay of Quinte, the Outlet Basin, and the east end of Lake Ontario are integrally associated. Analysis of long-term data sets will be conducted to evaluate these linkages and examine the interaction, dynamics, and movement in fish populations and associated fish communities frequenting these waters.

A comparison of monofilament and multifilament gill nets will be continued both in the lake and in the bay to examine the significance of results observed in 1991. Specially designed sampling will be conducted to try to separate the effects of hanging ratio and twine type. This study will continue so that stronger conversions can be developed and previous catch statistics in these long-term data sets can be directly related to future catch statistics collected in the index series and other Research sampling programs.

A joint analysis of these long-term data sets has commenced to attempt to ascertain the degree of interaction. Attempts are being made to examine the validity of age assessment of species common to the two communities and to develop appropriate procedures so that accurate ages can be used to determine year-class strength and to increase precision of the analysis. Some progress has been made with whitefish. Not only have accurate age interpretation techniques been developed but also techniques are being developed using scales and otoliths that will make it possible to discriminate among various stocks of whitefish in eastern Lake Ontario and to assign individuals to their respective nurseries and stocks (Brown and Casselman 1992).

Acknowledgments

We wish to thank the technicians, biologists, and summer students who, over the years, have conducted the sampling and helped make this long-term data set possible. Most recently they were Dave Jeffrey, Dale Dewey, Steve Lawrence, Wayne Miller, Dawn Walsh, and Chuck Wood. Kelly Sarley and Ken Scott have done an excellent job of computerizing and validating all the data.

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Research Project: Fish Community Studies of the Bay of Quinte

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Lake Ontario Fisheries Unit, 1991 Annual Report, Section 19

Experimental gillnets constructed with monofilament and multifilament nylon twine in meshes from 38 to 127 mm in 13 mm intervals were set repeatedly at 3 sites in the Bay of Quinte. Alewife numbers in June continued a declining trend, while in August the abundance increased. White perch are still much reduced numerically, while yellow perch have increased. Walleye have remained at a consistent level since 1978. Comparison of catches by twine type have not been completed, but results show that monofilament mesh catches more yellow perch and walleye than multifilament. However, the reverse is true for brown bullhead. Differences in shape and spine configuration may account for the inconsistencies. Girth/mesh perimeter ratios were measured for several species for both twine types. The ratios are larger in monofilament twine possibly due to stretching. A 3/4 Western bottom trawl fished at several sites in the bay provides a measure of variability over years, since 1972, and within years. Walleye and yellow perch show significant increases, while alewife and white perch have decreased. These results match those from gillnet sets.

Gillnet Studies

Long-term Relative Abundance

Multimesh gillnets have been used extensively in the Bay of Quinte over the past 30 yr to monitor fish populations. Multifilament nylon mesh nets (38 to 127 mm stretched mesh in 13 mm increments) in lengths from 22.8 to 47.7 m were set at up to ten sites overnight (16 to 24 h) at locations stretching from Trenton in the upper bay to Lennox in the lower bay. The catch from each mesh size was counted and weighed and biological samples that included fork length, weight, sex, maturity, and some calcified tissue for later age determination were obtained from up to 30 individuals of each species from each mesh size. The sampling period extended from May through September in most years. After 1980, the sampling sites were reduced to three and have remained at this level since then.

Multifilament nylon mesh is becoming increasingly more difficult to obtain, so the decision was made to convert to monofilament mesh. In order to derive conversion factors to equate the two twine types, a series of monofilament-multifilament sets were made in 1991 at the three traditional sites. Meshes were identical in both series as were the length and depth of nets used. However, the hanging ratios of these nets were not the same. The monofilament twine was hung at 2.0:1.0 which resulted in a square configuration, while the multifilament twine was hung at 2.5:1.0 that resulted in a greater slackness of the net and a longer aspect in the vertical plane. This latter ratio was the traditional method of preparing nets in the eastern Lake Ontario commercial fishery and was, therefore, used in assessing fish stocks in this area.

Each twine type and mesh size was replicated three times and within each mesh a vertically orientated colored thread split the mesh into two equal halves that were treated as within-mesh replicates. Thus, N = 6 for each twine type in each location and at each sampling period: mid June and mid August.

The results of these studies, together with those of the past 4 yr, permitted estimates of confidence intervals around the geometric mean catches at each location and in each time period. Previous catch data could not be analyzed in this way. To date, only the upper bay samples at Big Bay have been collated so that a time sequence from 1972 to the present can be examined. Several of the most common species are discussed for both the June and August sampling at Big Bay.

Alewife abundance in June has remained essentially the same for the past 4 yr (Fig. 1). Note that the results from multifilament net are shown as MU91 while the monofilament results are given as MO91. The present abundance is similar to the lowest level recorded in 1978 and is much less than the levels generally seen in the mid 1970s, as well as the early and mid 1980s. In contrast, the August series shows a steady increase in alewife since 1987 (Fig. 2). Although still below levels in the early 1970s, the yearly differences are highly significant for the last few years.

White perch abundance in June showed a significant decline at Big Bay in 1991 (Fig. 3). Since the low point seen in 1978, white perch numbers have been fairly consistent over the years. Similarly, the August series showed a significant decline in 1991 over previous years (Fig. 4).

Yellow perch, on the other hand, have shown a marked increase in abundance in the last few years since 1988 (Fig. 5). Similarly, the August series showed a significant increase over 1988 values (Fig. 6). Current values are nearly the same as those seen in 1978 and the early 1980s.

Walleye abundance in June has remained fairly consistent in the last 4 yr and continues to show the general

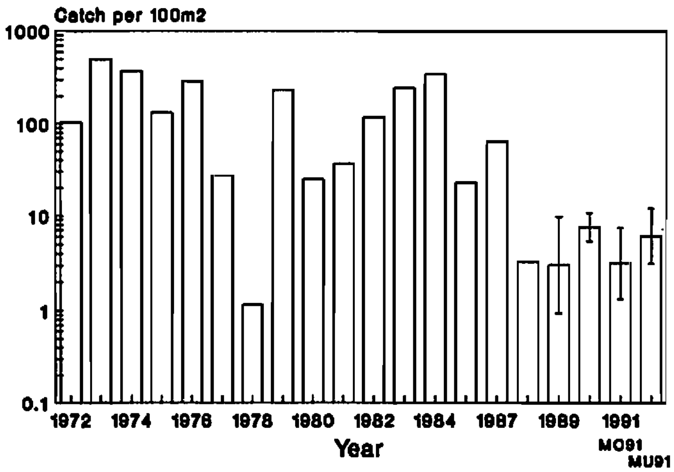

FIG. 1. Geometric mean catch of alewife per 100 m^2 of experimental gillnet at Big Bay during June for the years 1972-1991 (no fishing in 1985). 95% C.L. are shown for years 1989-1991. MO91 refers to catch in monofilament twine, and MU91 refers to catch in multifilament twine.

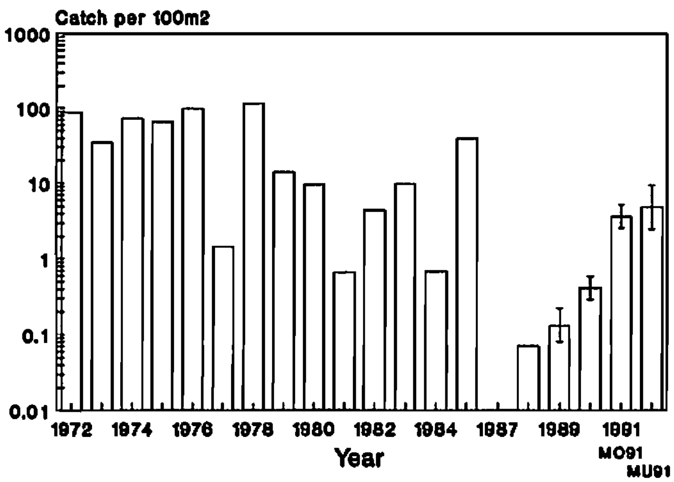

FIG. 2. Geometric mean catch of alewife per 100 m^2 of experimental gillnet at Big Bay during August for the years 1972-1991 (no fishing in 1985). 95% C.L. are shown for years 1989-1991. MO91 refers to catch in monofilament twine, and MU91 refers to catch in multifilament twine.

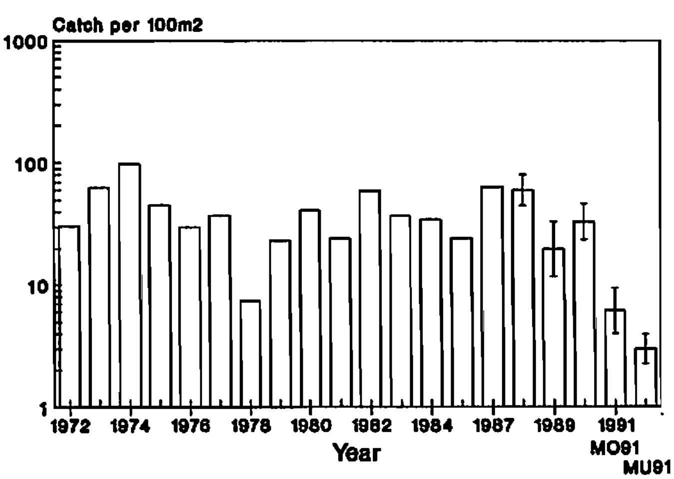

FIG. 3. Geometric mean catch of white perch per 100 m^2 of experimental gillnet at Big Bay during June for the years 1972-1991 (no fishing in 1985). 95% C.L. are shown for years 1989-1991. MO91 refers to catch in monofilament twine, and MU91 refers to catch in multifilament twine.

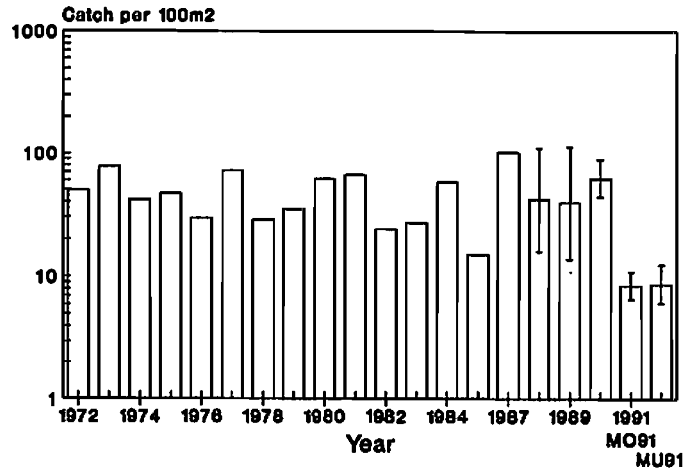

FIG. 4. Geometric mean catch of white perch per 100 m^2 of experimental gillnet at Big Bay during August for the years 1972-1991 (no fishing in 1985). 95% C.L. are shown for years 1989-1991. MO91 refers to catch in monofilament twine, and MU91 refers to catch in multifilament twine.

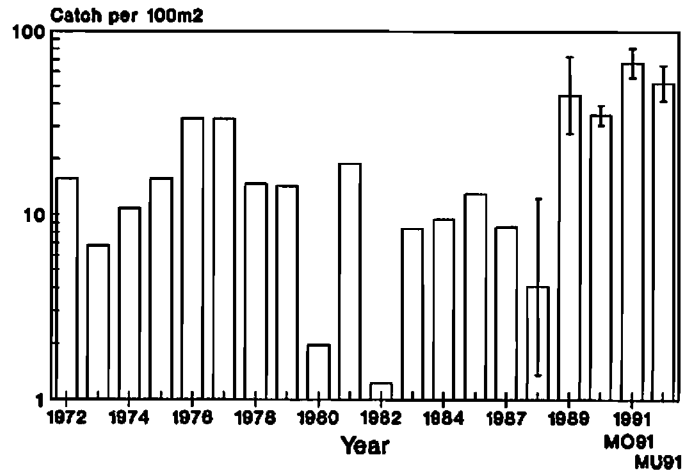

FIG. 5. Geometric mean catch of yellow perch per 100 m^2 of experimental gillnet at Big Bay during June for the years 1972-1991 (no fishing in 1985). 95% C.L. are shown for years 1989-1991. MO91 refers to catch in monofilament twine, and MU91 refers to catch in multifilament twine.

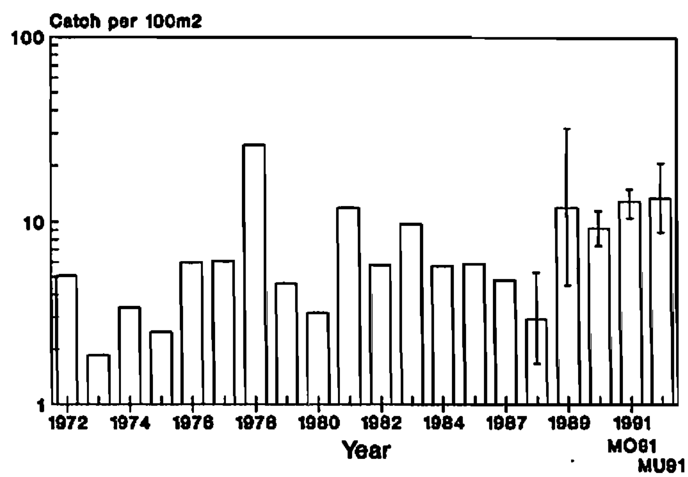

FIG. 6. Geometric mean catch of yellow perch per 100 m^2 of experimental gillnet at Big Bay during August for the years 1972-1991 (no fishing in 1985). 95% C.L. are shown for years 1989-1991. MO91 refers to catch in monofilament twine, and MU91 refers to catch in multifilament twine.

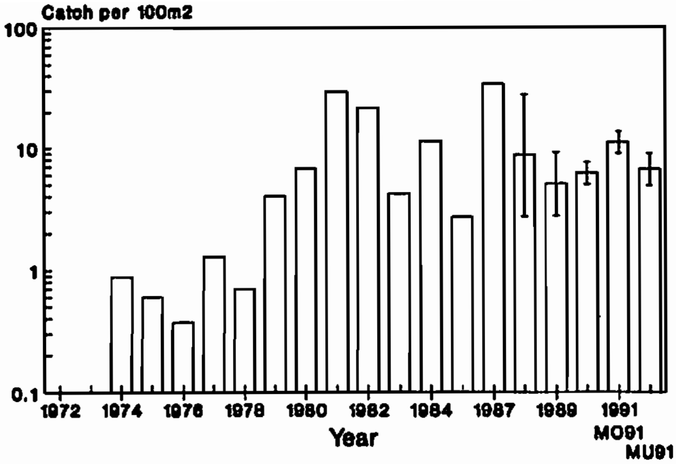

FIG. 7. Geometric mean catch of walleye per 100 m^2 of experimental gillnet at Big Bay during June for the years 1972-1991 (no fishing in 1985). 95% C.L. are shown for years 1989-1991. MO91 refers to catch in monofilament twine, and MU91 refers to catch in multifilament twine.

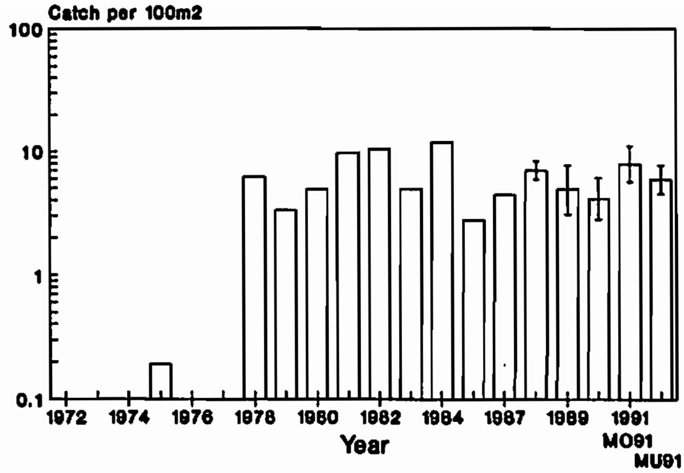

FIG. 8. Geometric mean catch of walleye per 100 m^2 of experimental gillnet at Big Bay during August for the years 1972-1991 (no fishing in 1985). 95% C.L. are shown for years 1989-1991. MO91 refers to catch in monofilament twine, and MU91 refers to catch in multifilament twine.

level of the population since the strong revival in the early 1980s (Fig. 7). The August series continues this same trend with no significant change recorded in the last 4 yr (Fig. 8). Even in years prior to the calculation of confidence limits, it appears that walleye numbers have been remarkably consistent since 1978.

Monofilament-multifilament Regressions

The expectation that relatively simple significant regressions for each species would permit the use of scaling factors to convert between mono- and multifilament gillnets was not generally realized. For example, at Big Bay in June 1991, brown bullhead, white perch, and walleye showed significantly different mean catches in the two twine types. Brown bullhead catches were greater in multifilament nets, possibly because the spines of this species could more easily slip through the smooth monofilament web but would become entangled in the multifilament web. For the other species, monofilament web caught more than multifilament.

Similar results were found for the other netting sites and dates where only a few species showed significant differences in catches according to twine type. When the results for both sampling times (June and August) were combined for a location, there was a significant regression relating twine type for a few species as given in Table 1.

Gillnet Catches Examined by ANOVA

Multifactor ANOVAs that examined the effects of twine type, mesh size, net placement, and replicates within nets were calculated for the major species captured in each of the three sampling locations and for each sampling period, June and August. This method permits an evaluation of the main treatment effects as well as the significance of the interactions of these main effects that influences the significance of the main factors in determining catch levels.

An example of the analysis is provided for yellow perch at Big Bay in June 1991. Here a preliminary analysis showed that two mesh sizes, 38 and 51 mm, caught large numbers of yellow perch, while other mesh sizes were not effective. The resulting ANOVA (Table 2) shows that all third level interactions were zero ($P = 0.8095$) as well as second level interactions for twine type and net location ($P = 0.6003$), and mesh size and net location ($P = 0.2111$). However, the interaction between twine type and mesh size was significant ($P = 0.0290$), indicating that the simple main effects for these two factors are influenced by the combined effects of both factors.

In this case, therefore, even though monofilament nets caught significantly more yellow perch than multifilament nets, the fact that 38 mm mesh also captured more yellow perch than 51 mm mesh, masked the simple effect of twine type alone. One way to overcome this interaction is to examine the effects of a single mesh size. When that was done for 38 mm mesh (Table 3), the interaction term was no longer significant as well as the main effect of net location. Twine type as a main effect was significant and examination of the mean catch for both types showed that monofilament net caught significantly more yellow perch than multifilament. Actually, in this case net location 1 caught significantly more than net location 2; however, the interaction between these two main effects did not mask the overriding influence of twine type. Finally, in completing this analysis the catch of yellow perch in 51 mm mesh showed no significant effect of either twine type or net location. In this case, therefore, only the 38 mm mesh size was significant in determining the effect of twine type.

One further analysis will illustrate the influence of several mesh sizes in determining the effect of twine type on the level of catch. In this case, walleye at Big Bay in June 1991 were caught in sufficient numbers by several mesh sizes to examine this effect. Here, all third level and second level interactions are not significant (Table 4). In addition, the main effects of mesh size and net location were not significant, while the effect of twine type was highly significant ($P = 0.0077$). Examination of the means for twine type showed that monofilament nets caught significantly more walleye than multifilament nets ($P < 0.01$).

TABLE 1. Regression equations that significantly related mono- and multifilament gillnet catches at three locations in the Bay of Quinte, 1991.

Species	Location	Regression	R^2
Alewife	Big Bay	Multi = 1.261 * Mono + 1.403	0.58
Gizzard shad	Big Bay	Multi = 0.419 * Mono + 2.852	0.80
Yellow perch	Big Bay	Multi = 0.697 * Mono + 5.581	0.90
Walleye	Hay Bay	Multi = 0.417 * Mono - 0.506	0.64
Gizzard shad	Hay Bay	Multi = 0.405 * Mono + 0.626	0.75
Walleye	Lennox	Multi = 0.798 * Mono - 1.694	0.93
Yellow perch	Lennox	Multi = 0.721 * Mono + 18.826	0.45
Alewife	Lennox	Multi = 3.447 * Mono - 17.284	0.97

TABLE 2. ANOVA results for catch of yellow perch at Big Bay in June, 1991.

Source	DF	Sum of squares	Mean square	F	P
Twine type	1	1001.0	1001.0	11.16	0.0059
Mesh size	1	3876.0	3876.0	43.21	0.0000
Net location	2	1057.6	528.8	5.89	0.0165
Twine * Mesh	1	551.0	551.0	6.14	0.0290
Twine * Net location	2	95.58	47.8	0.53	0.6003
Mesh * Net location	2	318.6	159.3	1.78	0.2111
Twine * Mesh * Net location	2	38.58	19.3	0.22	0.8095
Error	12	1076.5	89.7		
Total	23	8015.0			

TABLE 3. Effects shown by ANOVA of one mesh size (38 mm) on the catch of yellow perch at Big Bay in June, 1991.

Source	DF	Sum of squares	Mean squares	F	P
Twine type	1	1518.8	1518.8	11.17	0.0156
Net location	2	1252.7	676.3	4.61	0.0613
Twine * Net location	2	126.0	63.0	0.46	0.6498
Error	6	815.5	135.9		
Total	11	3712.9			
Mean for catch by twine type					
Multifilament	43.17				
Monofilament	65.67				
Mean for catch by net location					
Net 1	67.25				
Net 2	42.25				
Net 3	53.75				

TABLE 4. Walleye catches in mono- and multifilament gillnets analyzed by ANOVA at Big Bay in June, 1991.

Source	DF	Sum of squares	Mean squares	F	P
Twine type	1	14.02	14.02	8.17	0.0077
Mesh size	4	2.83	0.71	0.41	0.7981
Net location	2	6.40	3.2	1.86	0.1726
Twine * Mesh	4	4.57	1.1	0.67	0.6216
Twine * Net location	2	2.53	1.3	0.74	0.4866
Mesh * Net location	8	10.27	1.3	0.75	0.6498
Twine * Mesh * Net location	8	9.13	1.1	0.67	0.7175
Error	30	51.50	1.7		
Total	59	101.25			

Mean of catch by twine type	
Multifilament	1.767
Monofilament	2.733
Mean of catch by mesh size	
64 mm	2.083
76 mm	2.167
89 mm	2.583
102 mm	2.417
114 mm	2.000
Mean of catch by net location	
Net 1	2.650
Net 2	2.250
Net 3	1.850

ANOVA is a useful procedure in this instance where the effects of several factors, mesh size, location of nets, and replicates within nets, can be examined for the effects on the factor of interest, which in this case is twine type. The major species captured at the three sampling sites and the two sampling periods in 1991 have been examined. A complete report on these results, together with some additional experiments during 1992 intended to fill information gaps, will be available in early 1993.

Effects of Hanging Ratio on Gillnet Catches

Circumstances in 1991 did not permit a complete design for the mono-multifilament comparisons hung in ratios of 2.5:1.0 and 2.0:1.0. The results of the comparisons given above, therefore, are confounded by the lack of a completed experiment. This failing will be corrected in 1992 when the hanging ratios will be targeted.

For the 1991 data, however, the effect of girth and measurement of girth/mesh perimeter ratios for the two twine types was examined. Initially, fork length and girth measurements were examined for a number of species by twine type and by sex. As expected, the relationship between length and girth was highly significant (R^2 = 0.90 or greater). A cursory examination of the scatter plots identified a few outliers in the data set that were probably the result of mismeasurement or incorrect recording. These points were eliminated from further analysis.

Mean fork lengths for both yellow perch and walleye were examined by mesh size for each twine type. For both species the mean lengths in monofilament nets in all mesh sizes except one (64 mm for walleye) were greater than in multifilament nets (Fig. 9 and 10). When 95% C.L. were placed on the means, there was overlap in nearly every instance. Therefore, the trend was real, but the statistical significance was tenuous.

The girth/perimeter ratios were calculated for each mesh size for yellow perch and walleye. The modal points were determined for each mesh size and the mean values for these mesh sizes were determined. The resulting means for yellow perch were 1.14 for multifilament twine and 1.31 for monofilament twine, or 14.7% greater for monofilament twine. For walleye the G/P ratios were 1.13 for multifilament and 1.25 (10.5% greater) for monofilament twine. Although the reasons for this difference are not known, it is possible that monofilament twine is more elastic than multifilament and thus would tend to retain fish of somewhat larger girth in any particular mesh size. It is also possible that the 2.0:1.0 ratio in monofilament nets, which would result in a square, may appear to a fish to be a larger space than the diamond shape that resulted from the 2.5:1.0 hanging ratio in multifilament nets. Further experiments are required to explore these possibilities.

Bottom Trawl Studies

Long-term Relative Abundance

A 3/4 Western bottom trawl, 19 m long with 6 m wings and 1.3 cm stretched mesh in the cod-end, was used extensively at up to 8 sites in the Bay of Quinte since 1972. Generally, sampling was confined to the May-October period. The trawl was towed over a distance of 400 m at

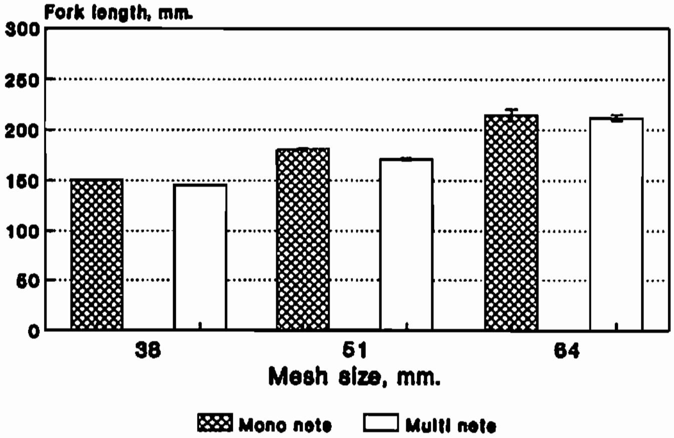

FIG. 9. Mean lengths of yellow perch captured in monofilament and multifilament gillnets fished simultaneously in June and August 1991. 95% C.L. are indicated.

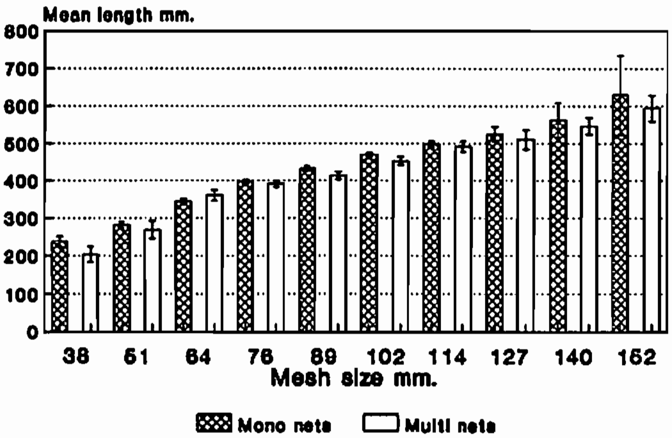

FIG. 10. Mean lengths of walleye captured in monofilament and multifilament gillnets fished simultaneously in June and August 1991. 95% C.L. are indicated.

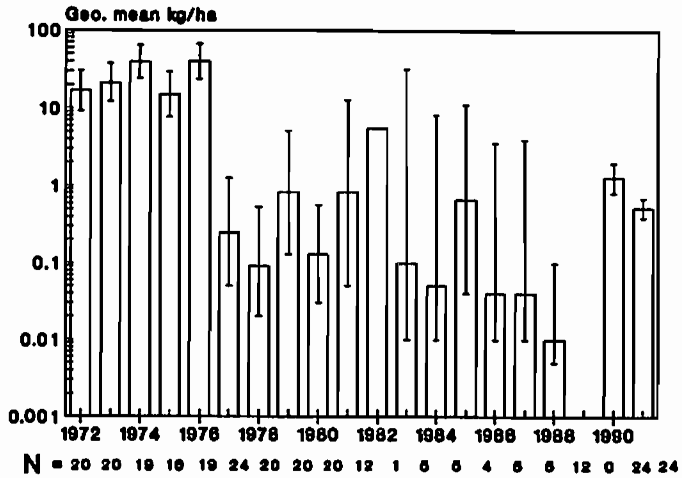

FIG. 11. Geometric mean seasonal trawl catch ($kg.ha^{-1}$) of alewife in the upper Bay of Quinte for years 1972-1991 with 95% C.L. indicated. Number of trawl tows indicated for each year (N).

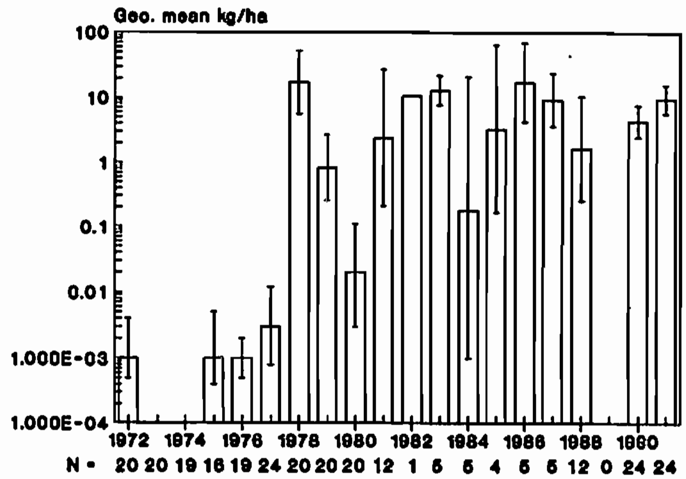

FIG. 12. Geometric mean seasonal trawl catch ($kg.ha^{-1}$) of walleye in the upper Bay of Quinte for years 1972-1991 with 95% C.L. indicated. Number of trawl tows indicated for each year (N).

a speed of 1.1 $m.s^{-1}$ and this formed the unit of effort. A transducer mounted on the trawl recorded the dimensions of the gear while it was in operation. Using the measured width of the opening and the length of travel, the area swept by one unit of effort was 0.273 ha. Catch numbers and biomass were expressed on a per ha basis.

Several species were examined from the upper bay, that portion between Trenton in the west and Deseronto on the east, where the mean water depth is 3.2 m. Abundance is presented as mean geometric biomass in $kg.ha^{-1}$. Dramatic shifts occurred since 1972 for alewife, white perch, and walleye.

Alewife, as a primary forage species for walleye, showed a significant decline in years when walleye were abundant, but also responded to abnormally cold winters in the late 1970s. The change in mean biomass together with the 95% C.L. after 1976 illustrates these effects (Fig. 11). Variation in catches also increased in the years after 1976, partly because of the decreased effort (1983-1987) and partly because of increasing shifts in alewife abundance from low adults numbers in June and July and large numbers of young alewife in August and September. Since 1990, the variance has reduced substantially even though the biomass is about an order of magnitude less than the 1972-1976 period.

Walleye biomass increased markedly in 1978 and has generally maintained a high biomass since then (Fig. 12). Values were fairly consistent with the exception of 1979 and 1980 when the C.L. were below most of the other years. Biomass has remained about 8-10 $kg.ha^{-1}$ in the last 2 yr.

White perch biomass has fallen substantially since 1977 (Fig. 13), and this drop corresponds to the increase noted among walleye. Increased variance was noted during some years after the population crash, again partly the result of decreased fishing effort as well as differences in temporal abundance. In 1990 and 1991, biomass was consistent and variability relatively small.

Yellow perch biomass has shown large cyclic swings from high values in the early 1980s, low values in the mid-1970s and 1980s, and a return to high values again in the 1990s (Fig. 14). Variance associated with yellow perch has generally been quite high as compared with other species. Only in 1990 and 1991 has this variability been relatively small.

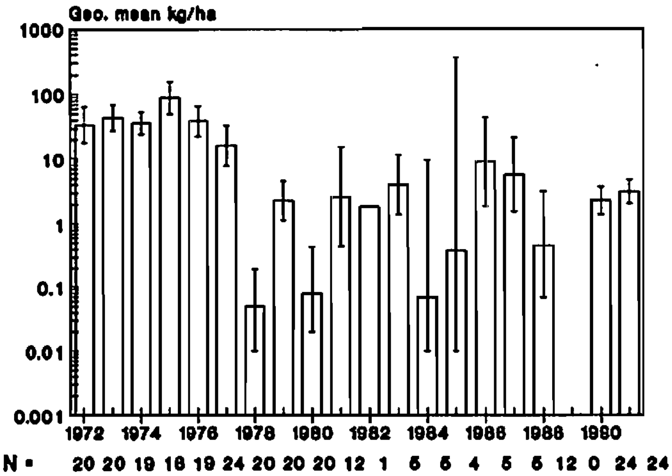

FIG. 13. Geometric mean seasonal trawl catch (kg.ha^{-1}) of white perch in the upper Bay of Quinte for years 1972-1991 with 95% C.L. indicated. Number of trawl tows indicated for each year (N).

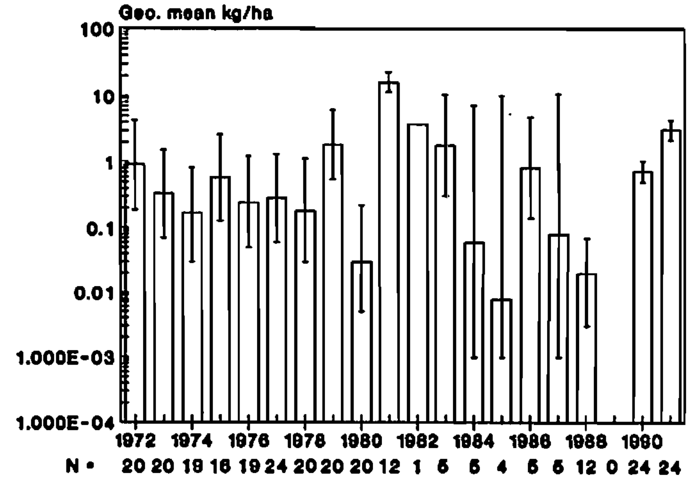

FIG. 14. Geometric mean seasonal trawl catch (kg.ha^{-1}) of yellow perch in the upper Bay of Quinte for years 1972-1991 with 95% C.L. indicated. Number of trawl tows indicated for each year (N).

Research Project: Variability Associated With Gill Net and Trawl Sampling the Fish Community of the Outlet Basin of Lake Ontario

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Lake Ontario Fisheries Unit, 1991 Annual Report, Section 20

From 1988 to 1991, sampling variability was measured either by subsampling gill net catches or replicate gill net and trawl sampling of the deep-water fish community of the Outlet Basin at six stations during the months of May to August. Catch statistics have been collected on this fish community for the past 31 years. However, sampling variability had not been measured or quantified. The average projected observational variability expressed as coefficient of variation was low for the four species taken most frequently in the gill nets: lake trout--11.2, alewife--17.2, rainbow smelt--25.3, and lake whitefish--37.7. The geometric mean catch and variance for the traditional large (3000-ft, 914.4-m) gill nets showed significant inverse log-log relations for all four species. The 95% confidence intervals for these four species were similar and relatively low: alewife--1.32, lake trout--1.23, lake whitefish--1.18, and smelt--1.34. Alewife catches were significantly lower at inshore stations and higher at offshore stations. More lake trout were taken in midsummer than during early and late summer. Gill net catches of lake whitefish and rainbow smelt increased markedly throughout the summer. Trawl catches were more variable. Rainbow smelt were taken most consistently (20.9%), followed by alewife (39.0%), whereas lake whitefish were taken least consistently (130.5%). The average coefficient of variation for the trawl catches of the four species that were taken most consistently in the gill nets was 68.3%--three times greater than the average for these species in the gill nets (21.4%). Approximately ten times more trawling effort would be required to obtain the same level of observational variability when sampling these species with trawls. These differences are, however, explained by the fact that smaller, younger fish are taken more frequently in trawls than in gill nets, and younger life stages have higher observational variability. As summer progressed, sampling variability of lake trout decreased, whereas that of trout-perch and slimy sculpin increased. No significant relations existed between variance and the catch of alewife or lake trout in the trawls. However, for these two variables, highly significant log-log relations existed that were inverse for rainbow smelt but direct for lake whitefish, trout-perch, and slimy sculpins. The 95% confidence intervals for the six species taken most frequently in the trawls were as follows: alewife--9.24, lake trout--2.73, lake whitefish--3.26, rainbow smelt--4.55, trout-perch--6.03, slimy sculpin--7.17. When compared with gill nets, these confidence intervals were very much greater: alewife--7.0x, lake trout--2.2x, lake whitefish--2.8x, and rainbow smelt--3.4x. Now that observational variability has been measured and generally quantified, more detailed analyses involving sampling variability can be conducted and applied to evaluate species interaction and the significance of relative changes that have occurred over the past 30 years in the fish community of the Outlet Basin.

Background and Objectives

From 1988 to 1991, Fisheries Research has conducted various types of replicate sampling during routine index sampling of the fish community of the deep waters of the Outlet Basin. This was conducted because sampling variability had not been evaluated on a long-term data set of very consistent gill netting that was conducted for 31 years and trawling that was carried out for 20 years. The original approach was to apply large single units of sampling effort with the assumption that variability, if not measured directly, would at least be low. Usually six stations were sampled each month from May to August with a single 24-h set of a multimesh experimental gill net that was 8 ft (2.44 m) deep and 3000 ft (914.4 m) long and with a single 1/2-mile (804.7-m) trawl tow. More details concerning gill netting and trawling are described in Casselman et al. (1991).

The purpose of this project was to measure the sampling variability associated with these gears and effort. It was assumed that if observational variability was measured, relations might be discovered between variability and catch, and these could be used to hindcast variance and estimate the confidence limits associated with previous sampling conducted in these long-term gill netting and trawling programs. If variance was measured and showed associations which indicated that the relations were universally applicable, then the results of this study might be applied more broadly when the same types of gear were used on similar fish communities in other studies and locations. Also, information would be obtained from this study to determine how observational variability varied with species, location, season (May to August), type of gear, and fish size. Empirical observations could be made that would provide direct information on how much sampling effort would be needed to attain a certain level of sampling variability when routinely sampling this deep-water fish community.

Although variability was variously measured and compared, the initial method in 1989 and 1990 was to subsample the catch within a particular mesh by 50-ft (15.24-m) intervals. Traditionally, the net was composed of two gangs, each gang containing a 50-yd (45.72-m) panel of each mesh, ranging from 1.5- to 6-inch stretched measurement. Six subsamples from each mesh size could be drawn from these nets and treated as replicates. Although subsampling a net of this configuration is not true replication, it still provided a way to estimate sampling variability without altering the original make-up of a net that had been used routinely for so many years. Also, this approach did not require an increase in sampling effort. Observational variability was also projected for the entire net by estimating the variability associated with the subsamples. The projected observational variability for the entire net was estimated by dividing the variability obtained from the subnet composed of 50-ft panels by the square root of 6. This extrapolation made it possible to estimate variability for the entire net without having to increase the sampling effort to impractical levels, which could not be afforded and would be unacceptably destructive of the population. This extrapolation can be performed because the reduction in variability is roughly proportional to the square root of the effort.

In 1991, the nets were reconfigured so that gill net sampling was more truly replicated. The same overall amount of effort was applied, but a multimeshed experimental gill net was used that was much smaller and consisted of 50-ft panels of 1.5- to 6-inch mesh size, for a total length of 500 ft (152.4 m)--a standard gill net unit. This standard gill net was then replicated six times within the set so that the same amount of effort was applied as in former years. The variance associated with these types of subsampling and replication could be somewhat different because the size of the mesh adjacent to a particular panel in the replication design was different, but always the same, with finer mesh on one side and coarser mesh on the other, whereas in the subsampling design, adjacent panels contained either the same size mesh on both sides or the same size on one side and a different size on the other--at one end finer mesh and at the other end coarser mesh.

Also in 1991, a comparison was conducted between monofilament and multifilament gill nets (Casselman and Scott 1992). Replicate sampling ($N = 6$) of both net types was required. Because of the overall size of the set containing six replicate multimeshed nets, each composed of ten 50-ft panels, it was necessary to conduct the replication over two consecutive days. To accomplish comparable replicate sampling, both net types were set each day--three monofilament and three multifilament. These nets were set continuously but with a 3-m space between each standard unit of net. Since the entire set was long and probably fished slightly different habitat, on the following day the location of the three consecutive monofilament and multifilament nets in the sequence was switched. Therefore, the replicates for any particular net type were drawn over two days but sampled the same location and habitat.

Since the amount of sampling effort at a particular station was doubled in 1991, it was necessary to sample fewer stations. This coincided with a plan in 1992 to transfer index sampling of the deep waters of the Outlet Basin from Research to Assessment. Therefore, only stations 2, 4, and 6 were routinely gill netted in the summer of 1991.

Observational variability for the trawls was measured by conducting replicate tows of the traditional standard distance of 1/2 mile. At each of the six stations during each of May, June, July, and August of 1988, four replicate 1/2-mile tows were made, whereas in 1990, three were made. In 1991, six tows were made at three of the six stations (2, 4, and 6).

Sampling variability was measured by adding 1 to the catch to eliminate 0 observations. Catch data were then log-transformed. The geometric mean was calculated and the standard deviation was divided by the mean to calculate the observational variability expressed as the coefficient of variation (CV).

Catch data were then log-transformed to calculate the variance and the coefficient of variation (CV) expressed as percent. Geometric mean gill net catches were calculated by subtracting 1 from the antilog of the mean of the log-transformed data. Geometric mean gill net catches were expressed as numbers of 100 m^2 of multimeshed experimental net set for 24 h.

A general summary is provided here of the sampling variability measured from the three years of data that have been collected on the experimental multifilament gill nets and trawls that have been routinely used by Research to sample the deep-water fish community of the Outlet Basin. Only salient observations and trends are provided; additional analyses are under way.

Progress

Sampling Variability of Gill Nets

The average projected observational variability was generally quite low for the four species taken most frequently in the experimental multifilament gill nets set in the deep waters of the Outlet Basin during the three years of this study (Table 1). The coefficient of variation was lowest for lake trout (11.2%) and highest for lake whitefish (hereafter referred to as whitefish) (30.7%). Regardless of location or month, lake trout were caught most consistently; the opposite was true for whitefish. For alewife, sampling variability was lower at stations 1, 2, and 3 than at the other three stations. It was lowest in June, with a tendency for variability to increase throughout the summer. Variability for lake trout was lowest at station 3 and highest at station 6 and remained low throughout the summer but

TABLE 1. Average observational variability of gill net catches in 1989, 1990, and 1991 calculated using geometric mean catch, expressed as coefficient of variation (CV) separated by station and month for four species caught in the standard white multifilament experimental gill net ranging in mesh size from 1.5 to 6 inches, fished once during each of May, June, July, and August in the Outlet Basin of Lake Ontario 26 to 38 m deep at six stations except in 1991, when three stations (2, 4, and 6) were fished. In 1989 and 1990, the variation was projected by subsampling the catch of the entire net (composed of 150-ft panels) by 50-foot (15.24-m) intervals. In 1991, replicate sampling was conducted using nets composed of 50-ft panels. The variation was projected for a traditional amount of effort involving the standard 3000-ft (914.4-m) net by dividing the variation of the subsamples or replicate samples by the square root of the increased effort (square root of 6--2.45). Sample sizes, means, and 95% confidence limits (lower--LCL, upper--UCL) are provided.

Variable	N	Alewife	Lake trout	Lake whitefish	Rainbow smelt	Mean	LCL	UCL
Station No.								
1[a]	8	13.9	8.9	19.9	19.0	14.9	10.2	19.6
2[a]	12	12.1	10.3	23.7	19.2	15.9	10.9	20.9
3[b]	8	12.8	4.4	40.7	18.1	19.1	6.1	32.1
4[a]	12	18.2	8.7	41.3	38.5	26.5	17.9	35.1
5[a]	8	23.1	13.2	33.4	31.4	24.7	16.3	33.1
6[c]	12	20.6	16.3	25.1	20.9	19.9	15.3	24.2
Month								
May	15	14.4	10.4	37.6	32.0	24.7	16.0	33.4
June	15	13.1	12.1	36.6	26.5	26.0	16.9	35.1
July	15	19.1	9.9	21.3	17.5	16.7	12.8	20.6
Aug.	15	21.7	10.6	21.6	12.1	16.7	12.6	20.8
Overall mean	60	17.2	11.2	30.7	25.3	21.4	16.0	26.9
LCL		14.1	8.3	12.3	19.8			
UCL		20.3	14.1	49.1	30.8			

[a]Approximately 30 m deep.
[b]< 30 m deep (approximately 25 m).
[c] > 30 m deep (approximately 35 m).

was usually lowest in July. For whitefish catches, sampling variability was slightly lower at stations 1 and 2 and also decreased somewhat as summer progressed. The same seasonal trend was seen for rainbow smelt (hereafter referred to as smelt) and, like alewife, was lower at stations 1, 2, and 3, especially 3, and higher at the other three stations, especially 4.

The average observational variability for these four species was 21.4% (Table 1). When considered together, all four species were taken more consistently at stations 1, 2, and 3 than at 4, 5, and 6, and in mid- to late summer (July and August) than during spring and early summer (May and June).

The projected variance and geometric mean catch for the entire gill net set (3000 ft) showed significant inverse log-log relations for all four species (Table 2). The correlation was least strong for alewife but was highly significant for lake trout, whitefish, and smelt. This indicated that if catches of these traditional large single gill net sets were known, then the variance and confidence limits associated with the catches could be estimated. These relations can be applied to the long-term data sets to assess the significance of previous changes in the catch. It would be extremely useful in future sampling programs if significant relations existed between variance and a single standard unit of gill net effort (multimesh net composed of 50-ft panels--500 ft long). Therefore, the relation between variance and the catch of one of these units of gill net effort was examined. Of the four species most often taken in gill nets in the deep waters of the Outlet Basin, only lake trout showed a relation that was highly significant for this amount of effort (Table 3). This is not surprising, given the extremely low sampling variability associated with the species. Since all species showed significant relations when six standard units were used, then significant relations would also exist for alewife, whitefish, and smelt if multiple units of the standard net were used. For these species, more than 1 and fewer than 6 units of effort would be required to obtain significant relations.

Since replicate sampling has been conducted for the past three years, it was possible to examine general differences in mean catch in the traditionally large (3000 ft) gill nets that were set. Average 95% confidence intervals for the catches of the four species taken most frequently in gill nets were very similar and relatively narrow and were as follows: alewife--1.32, lake trout--1.23, whitefish--1.18, smelt--1.34. The overall average for the past three years indicated that lake trout were most abundant (4.7/100 m^2 of multimesh net), followed by alewife (3.5), smelt (2.0), and whitefish (0.7) (Table 4).

There were some significant differences in the number of these four species that were taken at various stations

TABLE 2. Predictive regressions of the log-log relations between projected variance and geometric mean catch for four species caught in the white multifilament experimental gillnet ranging in mesh size from 1.5 to 6 inches, fished once during each of May, June, July, and August in the Outlet Basin of Lake Ontario 26 to 38 m deep at six stations in 1989, 1990, and 1991. The variance was estimated by subsampling in 1989 and 1990 and by replicate sampling in 1991. Six subsamples or samples were drawn from 50-ft (15.24-m) units of each mesh size. The variance was projected for the traditional amount of effort involving the standard 300-ft (914.4-m) net and was calculated by dividing the variance of the subsamples and replicates by the square root of the increased effort (square root of 6--2.45). Catch is expressed as numbers per standard 3,000-ft (914.4-m) multimesh (1.5- to 6-inch). Sample sizes, coefficients of variation, and probability levels are provided.

Species	Regression equation: Dependent variable variance / Independent variable geom. mean catch	N	r	P
Alewife	LogY = 3.734 – 0.004LogX	72	0.210	0.045
Lake trout	LogY = 0.780 – 0.283LogX	72	0.448	0.000
Lake whitefish	LogY = 2.345 – 1.161LogX	69	0.631	0.000
Rainbow smelt	LogY = 0.567 – 0.128LogX	68	0.453	0.000

TABLE 3. Log-log relations between variance and geometric mean catch for four replicate samples (1991) of the standard white multifilament experimental gillnets ranging in mesh size from 1.5 to 6 inches, fished once during each of May, June, July, and August in the Outlet Basin of Lake Ontario 26 to 38 m deep at six stations during 1989, 1990, and 1991. The variance was estimated by subsampling in 1989 and 1990 and by replicate sampling in 1991. Six subsamples or samples were drawn from 50-ft (15.24-m) units of each mesh size. Catch is expressed as numbers per multimesh (1.5- to 6-inch) net composed of 50-ft panels. Sample sizes, correlation coefficients, and probabability levels are provided.

Species	Regression equation: Dependent variable variance / Independent variable geom. mean catch	N	r	P
Alewife	LogY = 0.601 + 0.049LogX	72	0.059	0.786
Lake trout	LogY = 0.701 – 0.314LogX	72	0.305	0.002
Lake whitefish	LogY = 0.403 + 0.045LogX	69	0.135	0.293
Rainbow smelt	LogY = 0.411 + 0.048LogX	68	0.129	0.334

during May to August (Table 4). Alewife catches were higher at station 2 than at any other station, with the possible exception of station 1, and lowest at station 6, with the possible exception of station 5. Lake trout catches were highest at station 3 and were higher in July than in May and August, but the numbers caught during July showed some overlap with June. Whitefish catches were lowest at station 3 and highest at station 6. Fewer whitefish were taken in June and more in August than during other months. Fewer smelt were taken at stations 4 and 5 than at other stations, and the lowest catches of this species were in May and the highest in August. These deep-water catches in the Outlet Basin showed some obvious general trends. Alewife catches were lower at inshore stations and higher at offshore stations. More lake trout were taken in midsummer than during early and late summer. Gill net catches of whitefish and smelt increased markedly throughout the summer.

Replicate trawl catches at the six deep-water stations during 1988, 1990, and 1991 showed highly variable catches of the six species that were taken most frequently (Table 5). The average coefficient of variation was 74.2%. Smelt were taken most consistently (20.9%), followed by alewife (39.0%), whereas whitefish were taken least consistently (130.5%). Since gill netting and trawling were conducted at similar locations and at about the same time, it was possible to compare sampling variability of these two types of gear. The average coefficient of variation in the trawls for the four species that were taken most consistently in the gill nets--alewife, lake trout, whitefish, and smelt--was 68.3%; this is 3.2 times greater than the average coefficient of variation associated with the catches of these species in the gill nets (21.4%). To obtain the same level of observational variability when sampling these species with trawls, approximately 10 times more trawling effort would be required. Sampling variability of the trawls as compared with the gill nets was 2.3 times greater for alewife, 7.4 times for lake trout, 4.3 times for whitefish, and was quite similar for smelt, only 1.2 times greater. These differences would be expected because smaller, younger fish are taken more frequently in trawls than in gill nets, and younger life stages, when taken in the same gear, have higher sampling variability.

Differences in the observational variability of trawl catches among locations and months were not common (Table 5). However, there was some indication that observational variability was lower for alewife at stations 1 and 2, inshore, and higher in August than observed during the other three months. Sampling variability of lake trout decreased somewhat as summer progressed. Whitefish

TABLE 4. Combined 1989, 1990, and 1991 geometric mean catch (CUE) and 95% confidence limits (lower--LCL, upper--UCL) separated by station and month for four species caught in the standard white multifilament experimental gillnet ranging in mesh size from 1.5 to 6 inches, fished once during each of May, June, July, and August in the Outlet Basin of Lake Ontario 26 to 38 m deep at six stations. The confidence limits were calculated from projected variance obtained by subsampling the catch of the standard net by 50-foot (15.24-m) intervals (1989 and 1990) and by replicate sampling with multimesh nets composed of 50-ft panels. The projected variance was calculated by dividing the variance of the subsamples and samples by the square root of the increased effort (square root of 6--2.45). Catch of the entire net, composed of 2 x 150-foot (45.72-m) panels of each mesh in 1989 and 1990 and by six replicates of multimesh nets composed of 50-ft panels, is expressed as number per 100 m^2 of net. Sample sizes are provided.

		Alewife			Lake trout			Lake whitefish			Rainbow smelt		
Variable	N	CUE	LCL	UCL	CUE	LCL	UCL	CUE	LCL	UCL	CUE	LCL	UCL
Station No.													
1[a]	8	4.4	3.4	5.6	4.6	3.9	5.4	0.8	0.7	0.9	4.3	3.1	6.0
2[a]	12	6.4	5.0	8.2	4.0	3.4	4.8	0.8	0.7	1.0	3.7	2.7	5.0
3[b]	8	4.0	3.2	5.0	7.1	6.5	7.8	0.3	0.2	0.3	2.9	2.2	3.7
4[a]	12	2.9	2.2	3.8	6.1	5.1	7.3	0.5	0.5	0.7	0.6	0.5	0.8
5[a]	8	2.8	2.0	3.8	4.1	3.3	5.1	0.5	0.5	0.6	0.9	0.7	1.0
6[c]	12	2.2	1.7	2.8	3.5	2.7	4.5	1.1	0.9	1.3	2.2	1.7	2.8
Month													
May	15	3.4	2.7	4.2	3.4	2.9	4.0	0.4	0.3	0.4	0.6	0.5	0.8
June	15	4.4	3.5	5.6	4.8	3.8	6.0	0.3	0.3	0.3	0.8	0.7	1.0
July	15	3.8	2.8	5.2	6.7	5.4	8.3	1.0	0.9	1.2	2.8	2.2	3.6
Aug.	15	2.8	2.1	3.8	4.4	3.6	5.3	1.4	1.2	1.7	8.0	6.1	10.6
Overall mean	60	3.5	2.7	4.7	4.7	3.8	5.7	0.7	0.6	0.8	2.0	1.5	2.7

[a] Approximately 30 m deep.
[b] <30 m deep (approximately 25 m).
[c] > 30 m deep (approximately 35 m).

TABLE 5. Average observational variability of trawl catches in 1988, 1990, and 1991 calculated using geometric mean catch, expressed as coefficient of variation (CV) separated by station and month for six species caught in the Outlet Basin of Lake Ontario in a 1/2-mile (804.7-m) tow of a three-quarter "Yankee Standard" No. 35 bottom trawl drug at depths of 26-38 m (2, 4, and 6). Four replicate drags were made in 1988 and three in 1990 at six stations and six in 1991 at three stations once during each of May, June, July, and August. Sample sizes, means, and 95% confidence limits (LCL--lower; UCL--upper) are provided.

Variable	N	Alewife	Lake trout	Lake whitefish	Rainbow smelt	Trout-perch	Slimy sculpin	Mean	LCL	UCL
Station No.										
1[a]	8	18.9	61.9	62.6	7.8	78.1	37.0	32.3	11.0	53.6
2[a]	12	20.2	72.4	79.0	15.3	87.5	67.8	51.6	30.3	72.9
3[b]	8	30.8	130.4	74.7	36.1	60.5	99.5	48.5	24.4	72.6
4[a]	12	44.0	81.3	203.8	24.9	81.8	160.6	82.9	48.5	117.3
5[a]	8	57.3	88.9	103.4	19.9	81.1	59.4	67.4	39.0	95.4
6[c]	12	49.1	77.1	246.8	11.4	96.0	114.3	84.5	32.0	137.0
Month										
May	15	29.5	94.3	143.6	25.0	60.9	88.0	75.6	46.3	104.9
June	15	28.5	83.8	135.1	18.4	79.3	89.1	72.1	40.0	104.2
July	15	29.9	81.4	146.8	17.5	127.6	104.6	79.7	49.6	109.7
Aug.	15	49.0	73.1	105.5	22.4	194.2	105.6	69.8	46.5	93.1
Overall mean	60	39.0	82.6	130.5	20.9	109.6	99.6	74.2	47.3	101.1
LCL		29.2	45.2	41.6	15.4	61.4	56.8			
UCL		48.8	120.1	219.4	26.4	157.8	133.4			

[a] Approximately 30 m deep.
[b] < 30 m deep (approximately 25 m).
[c] > 30 m deep (approximately 35 m).

TABLE 6. Log-log relations between variance and geometric mean catch of six species caught in 1988, 1990, and 1991 in the Outlet Basin of Lake Ontario in a 1/2-mile (804.7-m) tow of a three-quarter "Yankee Standard" No. 35 bottom trawl drug at depths of 26-38 m once during each of May, June, July, and August. Replicate drags were made four times in 1988 and three times in 1990 at six stations and six times in 1991 at three stations (2, 4, and 6). Geometric mean catch is expressed as number per tow. Geometric mean catch is expressed as number per tow. Sample size, correlation coefficients, and probability levels are provided.

Species	Regression equation: Dependent variable variance = Independent variable geom. mean catch	N	r	P
Alewife	LogY = 0.648 + 0.091LogX	52	0.085	0.699
Lake trout	LogY = 0.453 + 0.076LogX	50	0.168	0.260
Lake whitefish	LogY = -0.863 + 0.784LogX	28	0.762	0.000
Rainbow smelt	LogY = 0.346 - 0.082LogX	56	0.482	0.000
Trout-perch	LogY = -0.322 + 0.201LogX	41	0.751	0.000
Slimy sculpin	LogY = -1.241 + 1.024LogX	42	0.734	0.000

were taken most consistently at stations 1, 2, and 3 inshore and during August. Smelt were taken more consistently at stations 1, 2, 5, and 6 than were any of the other species. Trout-perch were taken most consistently at station 3, and sampling variability increased markedly as summer progressed. Slimy sculpin showed a similar seasonal trend but were taken most consistently at station 1 and least consistently at station 4. The average sampling variability for the six species taken most frequently in the trawls showed no significant difference among the six stations or four months. However, there was some indication that the combined catch was somewhat less variable at station 1.

When variances in the trawl catches were compared with the geometric mean size of the catch, some significant correlations were found (Table 6). There were, however, no significant relations between variance and the catch of alewife or lake trout in the trawls. But for the other four species, highly significant log-log relations existed (Table 6), indicating that variance and catch were interrelated and that one could be used to estimate the other. This relation was inverse for smelt, a trend that was similar to those found for all the major species taken in gill nets. For whitefish, trout-perch, and slimy sculpins taken in trawls, direct relations existed, indicating that variance and catch increased together. The variance in trawl catches for smelt and the other three species indicates distributions in relation to abundance that appear to be intrinsically different; this probably is associated with schooling.

Predictive regressions of trawl catch on variance (Table 7) indicate that for whitefish, smelt, trout-perch, and slimy sculpin the catch required for a particular level of variance can be estimated.

Generally, the confidence limits about the geometric mean catch were very much higher for trawling than for gill netting. The 95% confidence intervals for the six species taken most frequently in the bottom trawl catches were as follows: alewife--9.24, lake trout--2.73, whitefish--3.26, smelt--4.55, trout-perch--6.03, and slimy sculpin--7.17. When compared with the gill net values, these intervals were very much greater: alewife--7.0 times, lake trout 2.2 times, whitefish--2.8 times, and smelt--3.4 times.

When mean catches at the various stations during the four months were compared, significant differences were rare (Table 8). Fewer whitefish were taken at stations 4 and 6 than at the other four stations. This lack of significant difference among catches in the Outlet Basin, as indicated by the trawls, resulted from extremely high sampling variability associated with this gear and not from a uniform distribution of individuals. For example, the overall mean catch of alewife in the trawls was 264; however, a lower confidence limit was almost one order of magnitude lower than the mean, and the upper confidence limit was almost an order of magnitude higher. Only very extreme differences in catch would be significantly different with this degree of sampling variability. Nevertheless, the mean values provided in Table 8 give rough approximations of the numbers of individuals taken in recent years when trawling the deep waters of the Outlet Basin.

TABLE 7. Predictive regressions of the log-log relations between variance and geometric mean catch for four species caught in 1988, 1990, and 1991 in the Outlet Basin of Lake Ontario in a 1/2-mile (804.7-m) tow of a three-quarter "Yankee Standard" No. 35 bottom trawl drug at depths of 26-38 m. Replication was conducted as indicated in Table 6. Catch is expressed as number per tow. Sample size, correlation coefficients, and probability levels are also provided in Table 6.

Species	Regression equation: Dependent variable geom. mean catch = Independent variable variance
Lake whitefish	LogY = 0.898 + 0.740LogX
Rainbow smelt	LogY = 3.343 - 2.837LogX
Trout-perch	LogY = 1.396 + 2.801LogX
Slimy sculpin	LogY = 1.051 + 0.526LogX

Future Directions

Now that observational variability has been measured and generally quantified, more detailed analyses involving sampling variability can be conducted and applied to better understand changes in relative abundance that have been observed over the past 30 years during which catch statistics have been collected on the fish community of the Outlet Basin. Confidence limits can now be applied to evaluate the significance of the relative changes that have been observed in the past. More detailed analysis of species interactions can follow. It will now be possible to

TABLE 8. Combined 1988, 1990, and 1991 geometric mean catch (CUE) and 95% confidence limits (lower--LCL, upper--UCL) separated by station and month for five species caught in the Outlet Basin of Lake Ontario in a 1/2-mile (804.7-m) tow of a three-quarter "Yankee Standard" No. 35 bottom trawl drug at depths of 26 to 38 m once during each of May, June, July, and August. Replicate drags were made four times in 1988 and three times in 1990 at six stations and six times in 1991 at three stations (2, 4, and 6). Geometric mean catch is expressed as number per tow.

		Alewife			Lake trout			Lake whitefish			Rainbow smelt			Slimy sculpin		
Variable	N	CUE	LCL	UCL	CUE	LCL	UCL	CUE	LCL	UCL	CUE	LCL	UCL	CUE	LCL	UCL
Station No.																
1[a]	8	888	235	3358	3.6	1.3	9.7	2.7	1.1	6.5	2552	1317	4943	16.8	5.5	51.1
2[a]	12	581	153	2214	3.0	1.0	8.5	2.3	0.8	7.0	1326	420	4179	8.1	1.7	38.0
3[b]	8	621	82	4723	1.3	0.4	3.8	7.6	1.4	39.5	680	61	7541	3.8	0.8	19.0
4[a]	12	164	17	1627	1.7	0.7	4.0	0.2	0.1	0.4	637	121	3346	0.8	0.3	2.0
5[a]	8	46	5	438	2.2	0.7	6.6	1.3	0.5	3.4	992	239	4120	10.7	2.4	48.2
6[c]	12	145	12	1750	2.1	0.8	5.3	0.2	0.1	0.3	1598	656	3896	11.2	0.6	207.1
Month																
May	15	941	119	7450	1.3	0.6	3.0	1.0	0.4	2.9	1004	170	5924	3.2	0.9	11.9
June	15	409	70	2381	1.9	0.7	4.9	1.0	0.4	2.5	763	214	2718	7.4	1.1	51.9
July	15	199	23	1720	2.2	0.8	6.0	1.3	0.4	4.5	1461	388	5500	5.9	0.7	47.1
Aug.	15	102	10	1032	3.2	1.1	9.8	2.3	0.6	8.7	1333	253	7027	6.8	0.7	61.7
Overall mean	60	264	29	2446	2.2	0.8	6.0	1.4	0.4	4.5	1118	246	5090	5.9	0.8	42.2

[a] Approximately 30 m deep.
[b] < 30 m deep (approximately 25 m).
[c] > 30 m deep (approximately 35 m).

evaluate the factors affecting sampling variability and to consider how it may be reduced. From these data, it will be possible to determine how much effort must be applied to attain a certain level of variability or, where appropriate, reduce the effort and eliminate unnecessary sampling.

The study has revealed that such species as alewife and smelt become entangled and caught in relatively coarse mesh in gill nets very consistently and that apparent incidental capture of this type can provide a very useful and precise index of relative abundance. On the other hand, bottom trawl catches of these two species were so variable that only drastic changes in relative abundance would be detected. These limitations must be examined if bottom trawling in the Outlet Basin is to be used routinely to index relative abundance.

A combined analysis of the variability associated with gill netting and trawling the fish community of the Bay of Quinte and the Outlet Basin will be conducted. This will provide a better understanding of how various factors, including environmental conditions, affect fish sampling variability associated with gill netting and trawling. No more replicate sampling is required to examine sampling variability associated with this long-term sampling series initiated and maintained by Research. However, in all Research projects in the future, sampling either will be intensive enough so that variance can be estimated using established correlations or will be replicated so that observational variability can be directly measured for the study.

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Research Project: Development of Criteria for Discriminating Among Lake Whitefish Stocks in Eastern Lake Ontario

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Lake Ontario Fisheries Unit, 1991 Annual Report, Section 21

Lake whitefish were collected from the spawning grounds in the Bay of Quinte and the Eastern Basin of Lake Ontario in 1988 and 1990 to examine stock discreteness. Whitefish from the two locations showed differences in both year-class distribution and length-at-age, based on interpretation of otolith acetate replicates. The lake samples showed strong year-classes in 1979, 1980 and 1985 while the bay samples showed strong year-classes in 1981, 1982 and 1985. "Lake" fish were larger then the"bay" fish at all ages, although this difference was significant only for age 3 fish in the 1988 sample and age 4 in the 1990 sample. Scales from both samples were interpreted using the CSAGES software package. Checks were typed based on configuration and spacing of the circuli associated with the check. Thirteen different types of checks were recognized on lake whitefish scales from these two samples. Two samples of yearling whitefish from the bay and the lake were selected from the Glenora Fisheries archives based on length frequency, one from the 1987 year-class and one from assorted year-classes. Scales of these fish were used to develop and evaluate criteria which could potentially separate these stocks. They are: (1) the type of check associated with the first annulus, (2) the distinctiveness of the first annulus ranked from 1 to 9, and (3) the spacing of the circuli before and after the check associated with the first annulus. There were considerable differences between lake and bay samples for all three criteria, however, similar results were obtained among year-classes. Checks associated with the first annulus on scales of lake fish usually consisted of irregular and fragmented circuli (55%), whereas on the scales of bay fish a crossover pattern was much more prevalent (58%). The annulus of the lake fish (mean rank = 5.6) was much less distinct than that of the bay fish (mean rank = 7.1). The lake sample showed no change in the spacing of circuli before and after the check associated with the first annulus (e.g. 1987 year-class, mean intercirculi spacing before =53.1 µm and after = 53.4 µm) while the bay sample showed significant differences before and after the check (before = 43.9 µm and after = 58.3 µm). The 95% confidence limits around the mean ratio of spacing after the check/spacing before the check were significantly different between bay and lake samples from both groups. A mean separation criteria of 1.23 was calculated (the mean value between the confidence limits). Application of these criteria to a subsample of the 1990 spawning samples classified 12% of the fish in both the lake and bay samples as having characteristics associated with development in the alternate nursery habitat,indicating considerable mixing between these two spawning groups.

Background and Objectives

For many years, it has been considered that there are two stocks of lake whitefish in the Eastern Basin of Lake Ontario: a "bay" stock, originating in the Bay of Quinte, and a "lake" stock, originating in the Eastern Basin (Casselman et al. 1991). This evidence was, however, generally circumstantial, because movement studies have not been definitive and no definite characteristics have been recognized or quantitative criteria developed that separate whitefish from these two sources (Casselman and Scott 1989). Many people, including commercial fishermen, claim that they can differentiate between the phenotypes of the stocks by colour. However, the differences are subtle, extremely subjective, and have not been properly tested. Midsummer catches of whitefish in the Outlet Basin of Lake Ontario are now as abundant as they have been in the past 30 years (Casselman and Scott 1992). Therefore, discrimination of these two punitive stocks, and any others that may exist, becomes extremely important in managing this species and allocating commercial quota. Also, zebra mussels are spreading into the Eastern Basin of Lake Ontario and the Bay of Quinte (Schaner 1992) and will probably establish at different densities, depending upon productivity and substrate. In the fall of 1991, they appeared on substrate used by spawning lake trout at Yorkshire Bar (Casselman, unpubl. data), so it is just a matter of time until they are observed on whitefish spawning habitat. Depending upon ultimate densities at various locations in eastern Lake Ontario, they may differentially affect lake whitefish and associated stocks.

As a result, a study was initiated in 1988 to determine whether calcified structures, that are routinely collected for age interpretation, can also be used for discriminating between whitefish stocks of the Eastern Basin of Lake Ontario. Originally, in the fall of 1988 and 1990, whitefish were collected from spawning locations in the Bay of Quinte at the mouth of the Trent River and in the Eastern Basin of Lake Ontario on the south shore of Prince Edward County. A random sample of approximately 100 fish was taken providing equal numbers of males and females from trap nets in the bay and from commercial gill nets in the lake. Scales and otoliths were removed from the fish and were subsequently interpreted for age by using routine procedures. In addition, planar shapes of the scales and otoliths were digitized for each sample in preparation for Fourier series analysis. Casselman et al. (1981) successfully applied this type of quantitative shape analysis to separate five sympatric whitefish stocks in Lake Huron, thus suggesting its potential for this study.

The objectives of this study were:

(1) obtain accurate year-class information for each stock based on the development of accurate age interpretation by using acetate replicas of otolith sections, validated by tracking year-classes through successive years of sampling,

(2) develop criteria for discriminating between these stocks based on analysis of the checks and zones on the calcified tissue and Fourier shape analysis of the planar shapes of scales and otoliths, and

(3) test these criteria and if necessary develop new criteria on samples of yearlings from known nurseries.

Materials and Methods

Additional Sampling

In addition to the samples collected in the fall of 1988 and 1990, two sets of yearling whitefish samples of known nursery origin were chosen from the Glenora archive. Length-frequency analysis conducted in conjunction with scale interpretations was used to validate age. The mean length of young-of-the-year (YOY) from the bay sample was 80.4 mm (95% confidence interval [C.I.] = 1.5) while the mean length of yearlings was 182.7 mm (C.I. = 7.1). Similarily, for the lake sample, the mean length of YOY was 90.1 mm (C.I. = 2.8) while the mean yearling length was 173 mm (C.I. = 7.9).

The first set of samples chosen was from the 1987 year-class, taken in 1988 by trawls in the Research index series. The bay sample was taken at Conway on June 23 (N = 27), and the lake sample was taken at Research station 3 in the Outlet Basin at Timber Island on July 8.

The second set of samples of yearlings was taken from the same locations and at the same time of year but from several years; therefore, it included an assortment of year-classes. All of these samples were taken at approximately the same time of year as the 1988 samples, and were also chosen by length frequency. The assorted sample of yearlings contained four year-classes--1986 (N = 10), 1990 (N = 23) from the bay and 1980 (N = 4), 1989 (N = 16) from the lake.

Additional samples of spawning adult fish were collected from trap nets and commercial gill nets in November 1991 from five locations: two in the bay (Hay Bay and the mouth of the Trent River), two in the lake (at Brighton and on the south shore of Prince Edward County), and one near the mouth of the Bay of Quinte in the Outlet Basin at Amherst Island. As in previous samples, approximately 100 fish were sampled randomly from each location, with equal numbers of males and females. Basic biological data, otoliths (sagittae), and scales from a key location in the mid-lateral region of the body were collected from all fish.

Analysis of Samples

Adult samples, 1988 and 1990

Two interpreters conducted multiple assessments of age on acetate replicas of otolith sections (Casselman 1987). The modal age interpretation was used to determine year-class and to prepare histograms to examine relative year-class strength.

Scales from all fish of both years were interpreted with the CSAGES software (Calcified Structure Age and Growth Extraction System--Casselman and Scott, unpubl.) to extract and quantify age interpretations and scale growth. All scale checks were digitized, ranked according to the estimated proportion of the circumference of the scale containing the check (recorded in ninths), and classified by type (i.e. annulus, pseudoannulus, and simple check). Initial examination of these data focused on checks proximal to the check associated with the first annulus, including distance to the first annulus and number of checks before the check associated with the first annulus. Also, the planar shapes of scales and otoliths were digitized so that Fourier series analysis could be conducted. A random subsample of approximately 30 scale samples of spawning whitefish from the bay and the lake was chosen from the 1990 sample for more detailed analysis.

Yearling Samples

The yearling samples were used to develop criteria for differentiating fish considered to be of bay and lake stock. Criteria involved scale check and growth characteristics during the first two growing seasons. The scales were easy to interpret because the fish were known age, young, and came from juvenile habitats that by virtue of their location were associated with their respective nurseries. The scales from all samples were interpreted with CSAGES. As well, a classification system was developed to categorize the configurations of the circuli associated with the various types of checks found on whitefish scales. A preliminary examination of scale samples from the two sources revealed that there might be differences based on spacing of the circuli adjacent to the first annulus, so the spacing of the circuli on either side of the check containing the first annulus was measured. This was done in the lateral region of the scale by measuring the distance from the first circulus on either side of the check that completely circumscribed the lateral region and delineated the check to the fifth circulus both distal and proximal to these delineating circuli.

In addition, the planar shape of the first annulus on scales from all samples was digitized, and is being analyzed using Fourier series, and compared by using discriminant function analysis.

Results

Year-Class Data

In the 1988 sample, relative strengths of various year-classes of spawning populations in the bay and the lake were quite different. In the lake sample, 1979 and 1980 were strong, representing 44% of the total sample, whereas the 1981 and 1982 year-classes were strong in the bay sample, representing 30% (Fig. 1a and 1b). The 1984 and 1985 year-classes were strong in both populations, representing 27% of the lake sample and 50% of the bay sample. In addition, two very old fish were taken in the lake sample--one from the 1962 year-class and one from the 1968 year-class.

Strong year-classes of 1979, 1980, and 1981 were present in both the 1988 and 1990 samples, confirming that age interpretation was probably valid because strong year-classes had been detected in successive samples (Fig. 1a). The 1985 year-class was strong in both samples; however, the frequency of occurrence of the smaller fish was probably affected by gear selectivity. By contrast, the relatively strong 1982 year-class in the 1988 sample from the bay (Fig. 1b) was not apparent in the 1990 sample, but there was some indication that there were slightly more fish in the 1981 year-class in the 1990 sample from the bay, although numbers were too few to evaluate the significance of the difference. In the 1990 samples, both locations showed strong year-classes in 1985 and 1986. The latter constituted 48% of the lake sample and 45% of the bay sample.

Age distribution was different in the two samples of spawning whitefish. Whitefish from the lake sample were older than those from the bay. In the 1988 samples, mean age of the lake fish was 7.0, with 68% of the fish being older than 5 years, while the bay sample had a mean age of 4.9, with only 36% of the fish older than 5 years. Similarly, in the 1990 sample, the mean age of the lake fish was 5.7, with 36% of the fish being older than 5 years, while the mean age in the bay sample was 4.6, with only 14% being greater than age 5.

Length-at-Age

Size at otolith age was examined for the two sets of samples taken in 1988 and 1990. Trends were quite consistent: in both years, mean size at all ages for fish from the lake samples was greater than that of fish from the bay samples. However, these differences were significant only for fish of age 3 in the 1988 sample and age 4 in the 1990 sample (Fig. 2a and 2b). Considering the normal variability seen in fish growth, there is some evidence that linear body growth is greater for fish from the lake than from the bay. This difference appears to become established in young fish and then to be maintained throughout life.

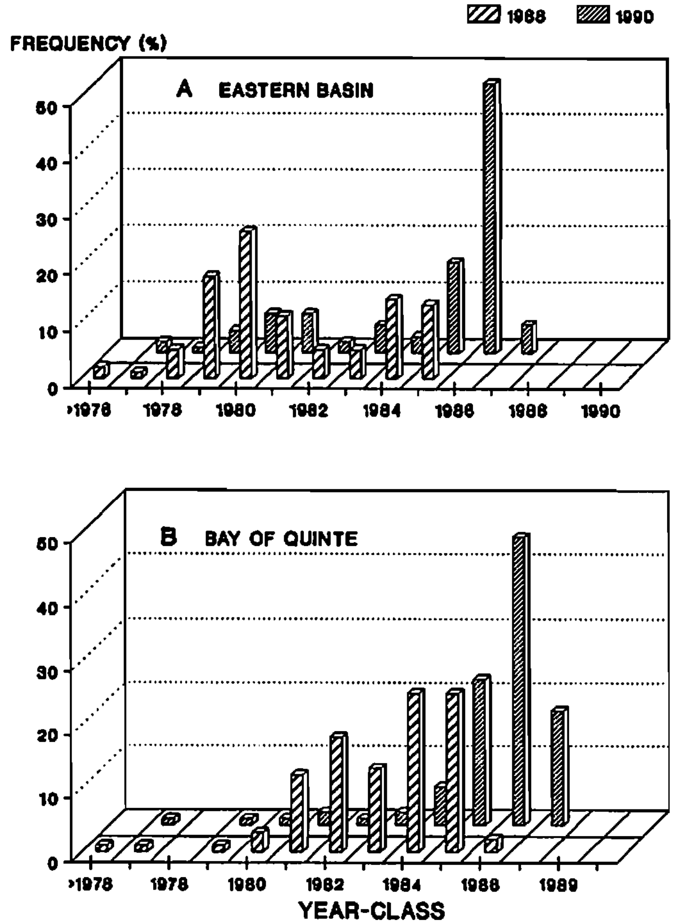


FIG. 1. Year-class distribution of the 1988 and 1990 lake whitefish samples collected at spawning time from A) Eastern Basin, south shore of Prince Edward County and B) Bay of Quinte, mouth of the Trent River. Age was based on interpretatiions of acetate replicas of otolith sections. Sample sizes = 100.

Scale Check Analysis

Adult samples, 1988 and 1990

Preliminary analysis of the CSAGES interpretations revealed no significant differences in mean distances to the check associated with the first annulus on the scales of fish from lake and bay samples. Variability was high. Similarly, there was no significant difference in the distances to checks proximal to the first annulus. However, scales from the lake sample had considerably more checks proximal to the first annulus than scales from the bay sample (91% vs. 59% in the 1988 sample, 87% vs. 72% in the 1990 sample). In addition, scales of fish from the lake sample were more difficult to interpret, and the checks associated with annuli were less distinct than those of scales from the bay sample.

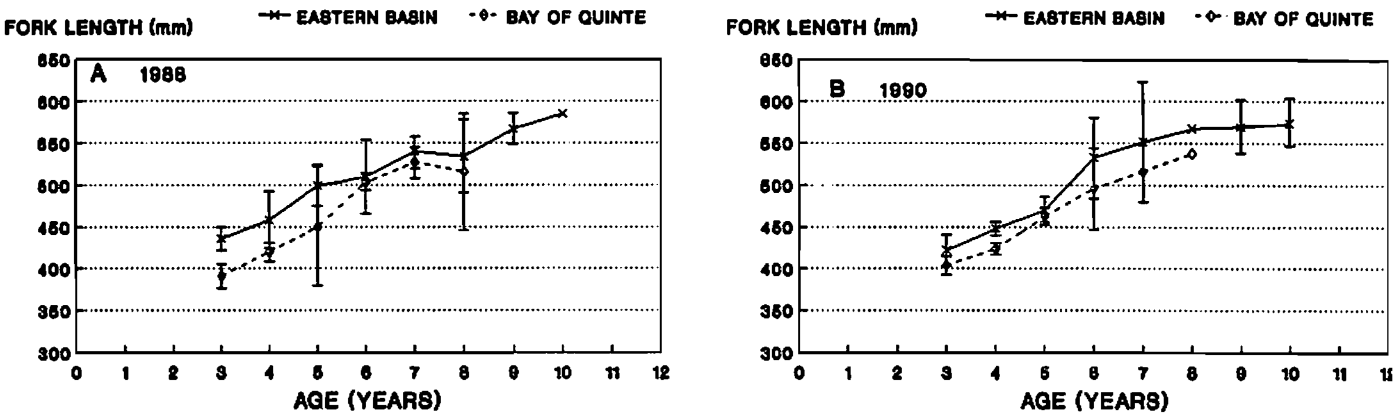


FIG. 2. Length-at-otolith-age for samples taken at spawning time from the bay and lake for A) 1988 and B) 1990. 95% confidence limits are indicated.

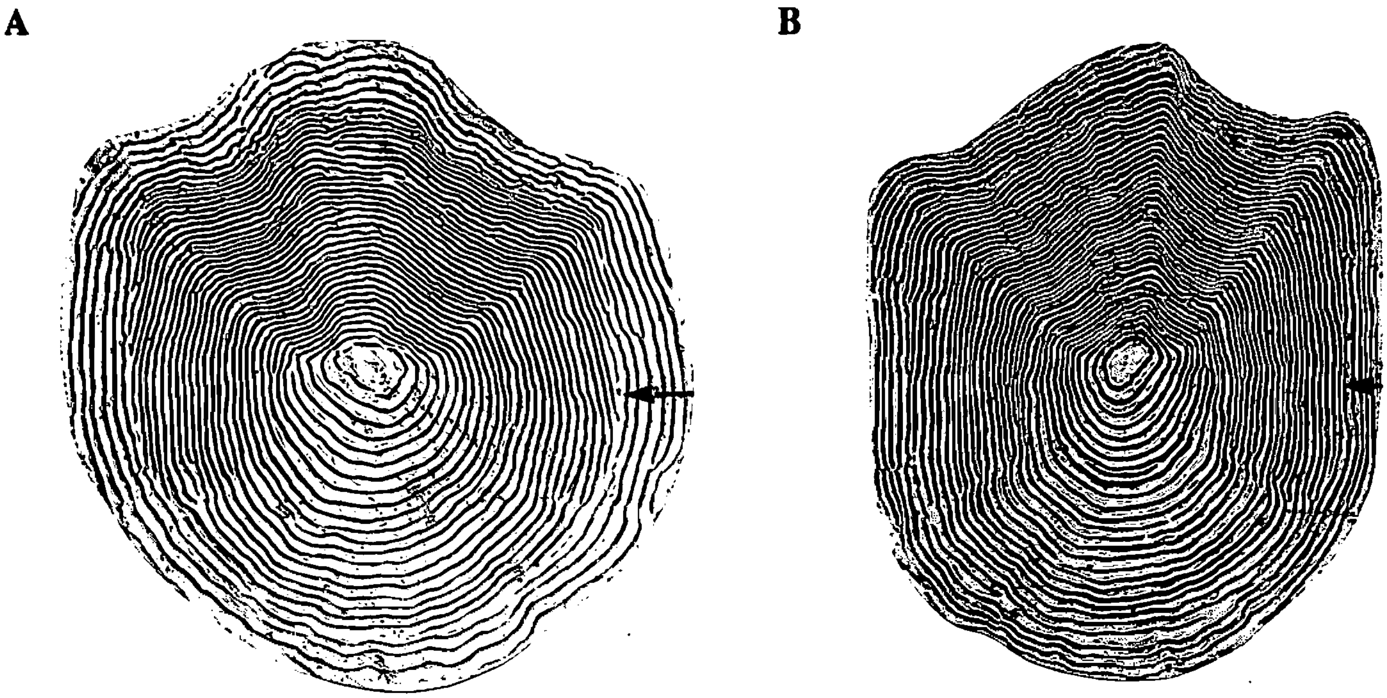


FIG. 3. Photographs of typical scales from yearling whitefish taken by trawls from A) Bay of Quinte (Research station--Conway, 88.06.23, FL = 173 mm) and B) Outlet Basin of Lake Ontario (Research station 3--Timber Island, 88.07.08, FL = 191) showing typical check and growth characteristics. Arrows indicate the location of the first annulus and associated check. Magnification = 22.5x.

Yearling Samples

There was considerable variability in the location of checks on scales from the adult samples, so scales of yearlings of known origin were examined to determine whether scale growth and check characteristics in early life differed in the samples from these two areas.

A detailed CSAGES examination of the scales of yearlings of the 1987 year-class showed that there were distinct differences in the configurations of the circuli associated with growth in the first year and about the check that contained the first annulus. The scales of fish of lake origin contained a check at the first annulus that was very indistinct as opposed to a very distinct check on the scales of fish from the bay (Fig. 3). Also, the configurations of the circuli associated with the first annulus were quite different; the check on the scales from the lake was fragmented, and that on the bay scales was a crossover type of pattern. This led to the development of a system for classifying types of checks found on lake whitefish scales. A total of 13 types of checks have been found on whitefish scales (Fig. 4). These were used to classify the first annulus on scales from both the 1987 and assorted year-classes.

FIG. 4. Classification of the types of checks found in the lateral region of scales of yearling whitefish from eastern Lake Ontario (approx. magnification = 50 x).

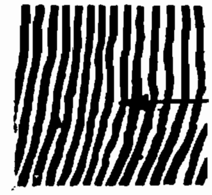
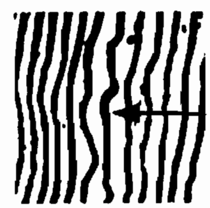
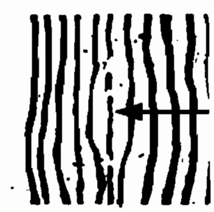
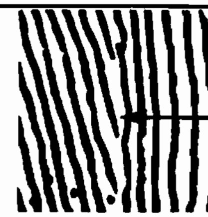
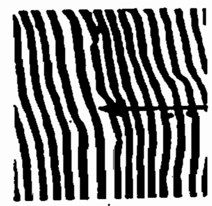
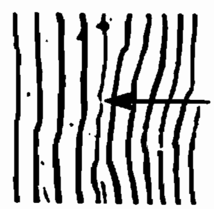
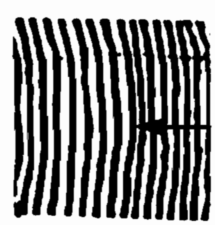
CHECK TYPE	DEFINITION	DESCRIPTION	ILLUSTRATION
1	NARROW TO WIDE	NO FRAGMENTATION OR IRREGULARITY BETWEEN NARROW AND WIDE SPACED CIRCULI.	
2	NARROW TO WIDE WITH CROSSOVER	"CROSSOVER" - SEVERAL INCOMPLETE CIRCULI WHICH BECOME PROGRESSIVLY LONGER AS YOU APPROACH THE POSTERIOR PORTION OF THE SCALE. THESE ARE FOLLOWED BY REGULAR, COMPLETE CIRCULI.	
3	NARROW TO WIDE AND IRREGULAR	"IRREGULAR" - COMPLETE CIRCULI FOLLOWED BY 1 TO 2 WAVY OR INCOMPLETE CIRCULI FOLLOWED BY COMPLETE CIRCULI.	
4	NARROW TO WIDE AND FRAGMENTED	"FRAGMENTED" - COMPLETE CIRCULI FOLLOWED BY 1 TO 2 FRAGMENTED OR "BRANCHED" CIRCULI WHICH DO NOT FORM A COMPLETE CIRCULI.	
5	NARROW TO WIDE WITH CROSSOVER AND NARROW HYALINE	SIMILAR TYPE OF CHECK AS DESCRIBED IN #2, EXCEPT THAT A PROMINENT BAND IS FORMED AROUND THE DISTAL EDGE OF THE CHECK. ONE CIRCULI APPEARS MISSING.	
6	WIDE TO NARROW WITH CROSSOVER	SIMILAR TO CHECK TYPE 2, EXCEPT THAT THE SPACING OF THE CIRCULI GOES FROM WIDE SPACED BEFORE THE CHECK TO NARROW SPACED AFTER THE CHECK.	

FIG. 4. Continued.

CHECK TYPE	DEFINITION	DESCRIPTION	ILLUSTRATION
7	CROSSOVER NO CHANGE	A CROSSOVER TYPE CHECK, WITH THE CIRCULI ON EITHER SIDE OF THE CHECK BEING EQUALLY SPACED.	
8	CROSSOVER NO CHANGE WITH NARROW HYALINE	SIMILAR TO CHECK TYPE 5, EXCEPT THAT THE SPACING OF THE CIRCULI ON BOTH SIDES OF THE CHECK IS THE SAME.	
9	NARROW TO WIDE AND IRREGULAR TO NARROW	NARROW SPACED CIRCULI FOLLOWED BY 1 TO 2 WIDE SPACED IRREGULAR CIRCULI FOLLOWED BY NARROW SPACED CIRCULI.	
10	FRAGMENTED WITH NO CHANGE	FRAGMENTED CHECK AS DESCRIBED BY TYPE 4, WITH NO CHANGE IN SPACING OF THE CIRCULI FROM ONE SIDE OF THE CHECK TO THE OTHER.	
11	IRREGULAR WITH NO CHANGE	IRREGULAR CHECK AS DESCRIBED BY TYPE 3, WITH NO CHANGE IN IN CIRCULI SPACING AROUND THE CHECK.	
12	WIDE TO NARROW TO WIDE SPACING	WIDE SPACED COMPLETE CIRCULI FOLLOWED BY 1 TO 2 NARROW IRREGULAR CIRCULI, FOLLOWED BY WIDE SPACED AND COMPLETE CIRCULI.	
13	WIDE TO NARROW SPACING	A TRANSITION BETWEEN WIDE SPACED COMPLETE CIRCULI AND NARROW SPACED COMPLETE CIRCULI.	

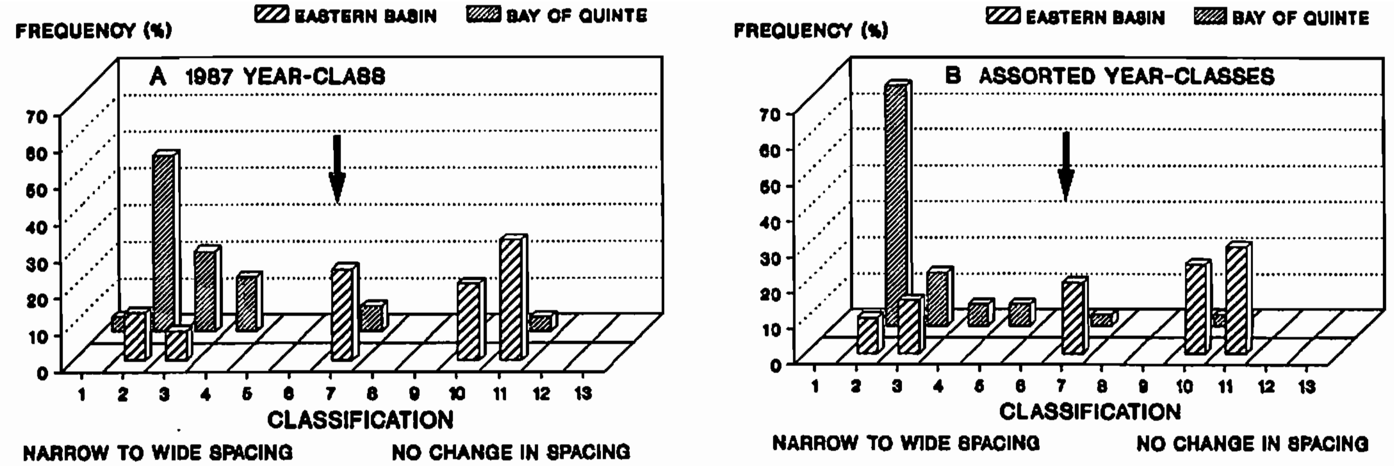


FIG. 5. Distribution of the types of checks associated with the first annulus on scales of yearling whitefish from A) 1987 year-class and B) assorted year-classes. Arrows indicate the point of separation for samples from the two locations (separation criterion = 6). Samples sizes = 20.

A systematic examination that typed the scale checks from the 1987 year-class showed that 88% of the fish originating in the bay had checks at the first annulus classified as 4 or less, with 48% being classified as type 2 (narrow to wide spacing with crossover) (Fig. 5a).

The first annulus on the lake sample scales was classified as 7 or greater in 80% of the samples, with 33% being classified as type 11 (irregular, no change in spacing). Similarly, for assorted year-classes, 94% of the scales from bay fish had checks associated with the first annulus that were classified as 4 or less, with 67% being classified as type 2, whereas in the lake sample, 75% of the checks associated with the first annulus were type 7 or greater, with 30% being classified as type 11 (Fig. 5b). Interestingly, 25% of the lake sample that was typed as <7 came from fish in one specific trawl, which may have been schooling together. Therefore, checks classified as less than type 6 appear to represent characteristics indicative of the bay, while types greater than 6 were indicative of the lake.

In addition to classification of checks based on the types and configurations of the circuli, each check associated with the first annulus in the yearling samples was given a numerical rank from 1 to 9 that indicated its conspicuousness, with 1 being extremely indistinct, with the check occupying over only 1/9 of the circumference of the scale, to 9, being extremely distinct, with the check occurring in 9/9s of the circumference of the scale. In both sets of yearlings, the checks associated with the first annulus were more conspicuous in samples from the bay than from the lake (Fig. 6). The mean rank of the check associated with the first annulus in the 1987 year-class was 5.6 for the lake sample and 7.0 for the bay sample (Fig. 6a). Similarly, in the sample of assorted year-classes, the mean rankings were 5.6 in the lake and 7.2 in the bay (Fig. 6b).

A third set of quantitative characteristics associated with the first annulus, which could separate these stocks, is the spacing of circuli on either side of the check. In the 1987 year-class, the scales of lake fish had a mean intercirculus spacing before the check of 53.1 µm, and 53.4 µm after the check, while in the bay fish, the spacing before the check was 43.9 µm, and 58.3 µm after the check. Similarly, in the sample of assorted year-classes, scales from the lake fish had a mean circulus spacing of 40.0 µm before the check, and 44.8 µm after the check, whereas scales from the bay fish had mean circulus spacing of 34.5 µm before the check, and 49.9 µm after the check. It was obvious that the spacing of the circuli about the check was different for fish from these two locations. To quantify the difference, the spacing of the circuli outside the check was divided by the mean spacing inside. The 95% confidence limits about the mean ratio were significantly different between the bay and lake samples for both samples of yearlings (Fig. 7). The bay sample had a higher ratio, created mainly by wider spaced circuli after the first annulus. To develop a separation criterion, the mean difference between the confidence limits for each sample was determined (i.e. bay 1987 year-class limits = 1.509 and 1.375, lake 1987 year-class limits = 1.057 and 0.957; therefore, the mean difference is (1.375 + 1.057)/2),1.18. The assorted year-class sample had a separation criteria of 1.274; therefore,the mean seperation criteria for the two groups was 1.23. In both lake and bay samples, 4 of the 40 fish in each sample deviated from this value indicating a misclassification rate of 10%.

Application to Subsample of 1990 Adults

A subsample of spawning adults from 1990 was examined to test criteria developed from yearlings on adults spawning in the bay and lake. This subsample consisted of 32 bay fish and 30 lake fish selected at random from the 1990 fall samples. Each was examined for the three types of scale characteristics and criteria previously developed.

Based on these characteristics and their separation criteria, 77% of the lake sample showed typical characteristics; however, 7 fish, or 23% were atypical and more similar to those of the bay. Similarly, in the bay sample, most of the fish were typical (78%), but 22% showed values for these three criteria that were more typical of the lake. Although approximately 22% of each sample was atypical, there was a significant difference at the 95% level in the ratio of the mean spacing of the circuli adjacent to the check associated with the first annulus (Fig. 8). The separation criterion was 1.25 for these samples, a value very similar to that calculated for the yearlings (1.23). However, 7 fish in each sample fell well outside this point of separation.

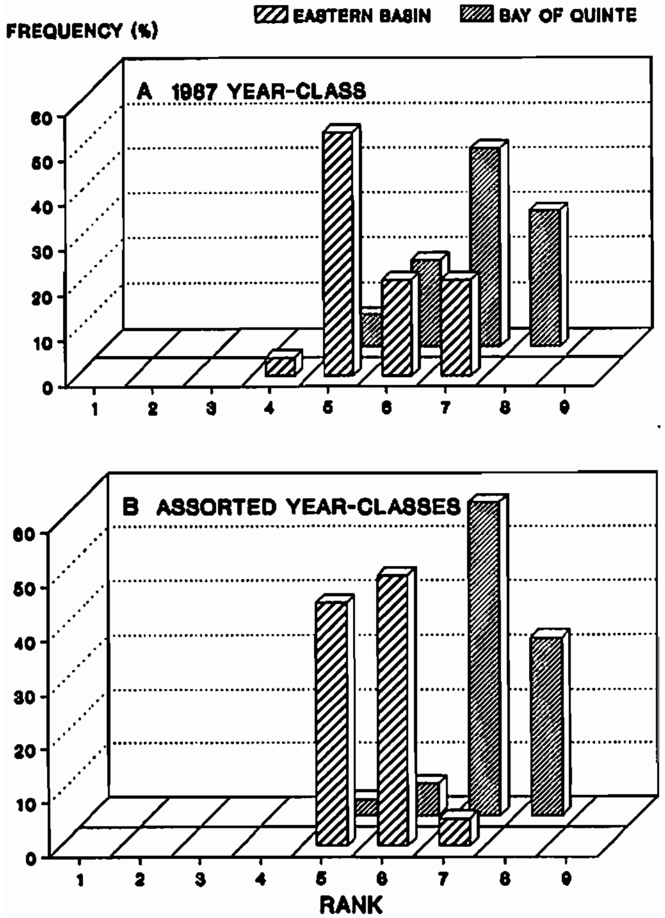


FIG. 6. Distribution of the rank of the conspicuousness of the check associated with the first annulus on scales of yearling whitefish of bay and lake origin for A) 1987 year-class and B) assorted year-classes. Samples sizes = 20.

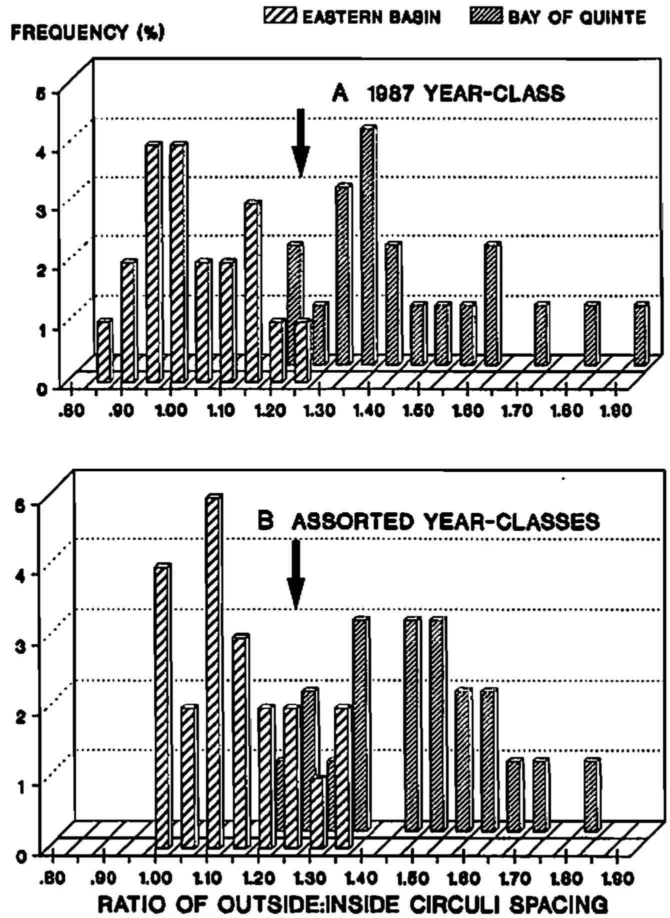


FIG. 7. Distribution of the ratio of mean spacing of circuli outside to inside the check associated with the first annulus on scales of yearling whitefish of bay and lake origin for A) 1987 year-class and B) assorted year-classes. Arrows indicate the point of separation for samples from the two locations (separation criterion = 1.23). Samples sizes = 20.

Conclusions and Future Direction

The three types of characteristics associated with the first annulus and described above: (1) classification of the type of check, (2) rank of the degree of conspicuousness,and (3) relative spacing of the circuli adjacent to the check--all appear to have potential for discriminating between bay and lake whitefish. These characteristics all pertain to scale growth in the nursery habitat. Application of these characteristics to analysis of the adult sample showed that approximately 22% of the fish on the respective spawning grounds had characteristics indicative of development in the alternative nursery habitat. Assuming a misclassification rate of 10% in each group, there appears to be approximately 12% mixing in these two spawning populations. To evaluate the significance of these exceptions, these criteria are being examined on a more extensive sample of yearlings of known origin more diversely scattered throughout eastern Lake Ontario. This sample will be used to develop a system that incorporates error testing in the discrimination process. The sample will provide a broader indication of the accuracy of these characteristics and will determine how they might vary in juvenile whitefish from other areas and possible stocks. In addition, planar shape at the first annulus is currently being analyzed using discriminate function analysis and shows some potential for separating these stocks. Scale check and growth characteristics, as well as shape associated with the end of the first growing season, are relatively easy to collect and may provide accurate discrimination of these groups of fish based on spawning and nursery origin. We are also extending the analysis to other samples of adults collected at spawning time, including those taken in 1991. Age and growth interpretation and analysis of year-class strength will be completed for the 1991 samples. Otolith shape and characteristics associated with the translucent and opaque zones will be examined in the juvenile samples and applied to the adult samples. Attempts will be made to determine the degree of mixing that occurs at spawning time and to evaluate the effects of this on developing and testing criteria for discriminating among the various stocks. Then the technique will be applied to adult samples collected at other times of the year, especially those taken in midsummer in the Outlet Basin. This can also be used to provide a measure of the degree of mixing that occurs in the summer habitats.

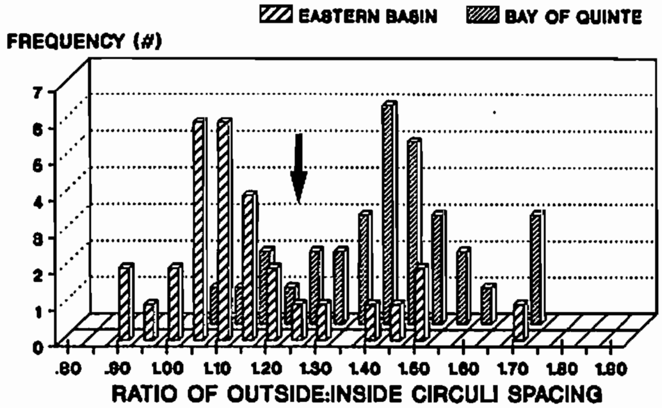


FIG. 8. Distribution of the ratio of spacing of circuli outside to inside the check associated with the first annulus for subsamples of the sample of adults collected at spawning time in 1990 from A) Eastern Basin (N = 30) and B) Bay of Quinte (N = 32). Arrow indicates the point of separation for samples from the two locations (separation criterion = 1.25).

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