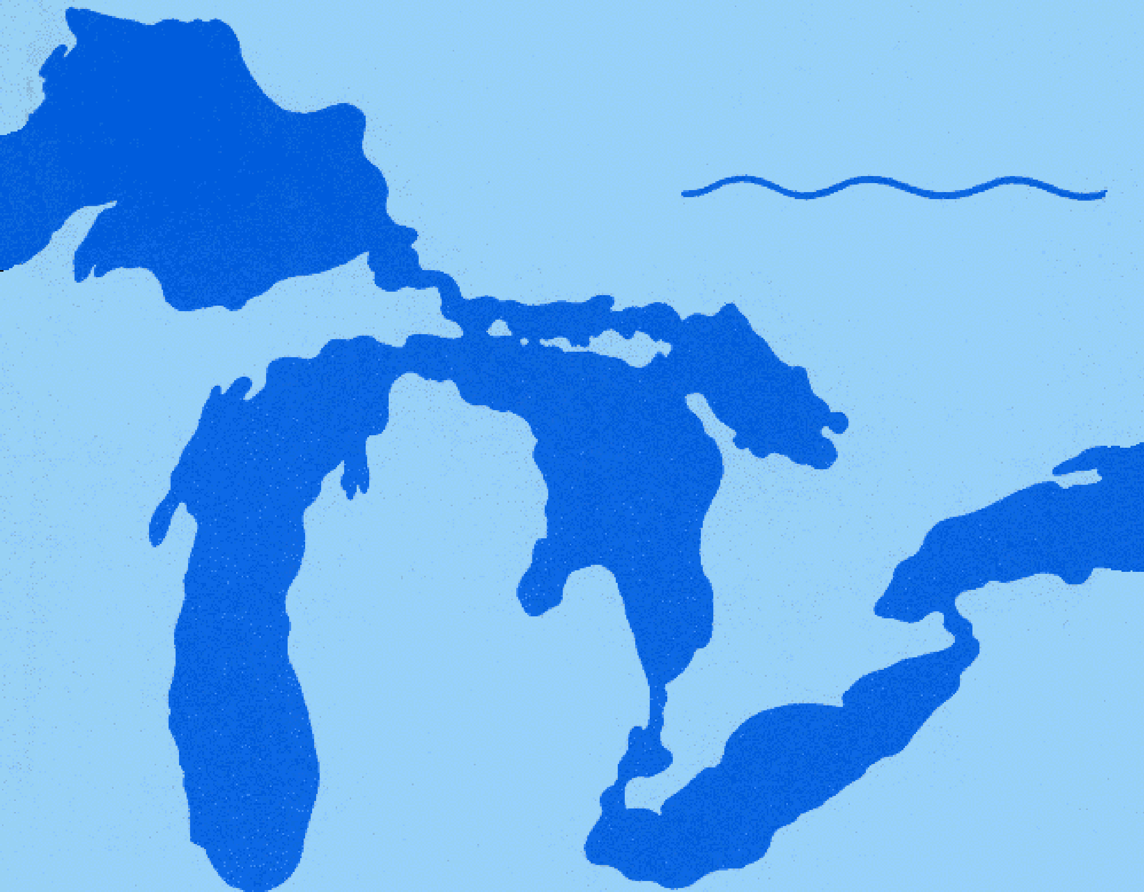
FISH-COMMUNITY OBJECTIVES FOR LAKE HURON



Great Lakes Fishery Commission

SPECIAL PUBLICATION 95-1

The Great Lakes Fishery Commission was established by the Convention on Great Lakes Fisheries between Canada and the United States, which was ratified on October 11, 1955. It was organized in April 1956 and assumed its duties as set forth in the Convention on July 1, 1956. The Commission has two major responsibilities: first, develop coordinated programs of research in the Great Lakes, and, on the basis of the findings, recommend measures which will permit the maximum sustained productivity of stocks of fish of common concern; second, formulate and implement a program to eradicate or minimize sea lamprey populations in the Great Lakes.

The Commission is also required to publish or authorize the publication of scientific or other information obtained in the performance of its duties. In fulfillment of this requirement the Commission publishes the Technical Report Series, intended for peer-reviewed scientific literature; Special Publications, designed primarily for dissemination of reports produced by working committees of the Commission; and other (non-serial) publications. Technical Reports are most suitable for either interdisciplinary review and synthesis papers of general interest to Great Lakes fisheries researchers, managers, and administrators, or more narrowly focused material with special relevance to a single but important aspect of the Commission's program. Special Publications, being working documents, may evolve with the findings of and charges to a particular committee. Both publications follow the style of the *Canadian Journal of Fisheries and Aquatic Sciences*. Sponsorship of Technical Reports or Special Publications does not necessarily imply that the findings or conclusions contained therein are endorsed by the Commission.

April 1995

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INTRODUCTION

Strategic fishery-management plans brought forward in recent years have common themes:

- maintenance of stable fish stocks,
- provision of sustainable benefits consistent with societal needs, and
- emphasis on a healthy environment and natural processes.

These ideas were held by all Great Lakes fishery agencies and resulted in A Joint Strategic Plan for Management of Great Lakes Fisheries (Joint Plan) published by the Great Lakes Fishery Commission (1980). The objectives that follow reaffirm the goal of the Joint Plan:

> *To secure fish communities, based on foundations of stable self-sustaining stocks, supplemented by judicious plantings of hatchery-reared fish, and provide from these communities an optimum contribution of fish, fishing opportunities and associated benefits to meet needs identified by society for:*
>
> *wholesome food,*
> *recreation,*
> *employment and income, and*
> *a healthy human environment.*

"Management by consensus" was identified in the Joint Plan as a necessary route for achieving this goal. Consistent with this approach, each lake committee for each Great Lake was directed to state mutually agreed-upon objectives for the fish-community structure for its lake. This statement of intent, the fish-community objectives for Lake Huron, represents a result of this process for the Lake Huron Committee (LHC).

This document sets out whole-lake fish-community objectives for Lake Huron and further commits management agencies to the protection and restoration of the lake's fish community. This statement of consensus is also intended to describe, in part, a "desirable" fish community bound by certain ecological concepts and guiding principles. Fish-community objectives provide an umbrella under which management agencies are expected to develop more-specific plans and strategies. In addition, this document proposes to move beyond the interests of the three signatory agencies and to act as a focal point and catalyst for other management agencies, political bodies, interest groups, and the general public. Public advisory committees on both the United States and Canadian sides of the lake have been instrumental in shaping these objectives for Lake Huron.

Fish-community objectives for Lake Huron rest on a set of ecological principles, tempered by social values, that give direction to management action and express management intent. The objectives reflect the understanding that natural systems are dynamic and provide some latitude in adjusting management approaches to different conditions that might arise. The objectives are not always quantitative. Where objectives are quantitative and expressed as fish yields, the yields are viewed-not as targets-but as an indication of community response. Monitoring can be relied upon to establish the degree to which the fish community has responded.

Fish-community objectives are, in part, statements of qualities sought from the fish community and, in the case of yield, of the kinds and quantities of fish that would be caught. As such, they are realistic points of focus and measurement for management activities. However, the fish community may not always respond in the way intended or expected.

Significant challenges and impediments exist and may prevent achievement of the fish-community objectives established for Lake Huron. Major areas of contention and opportunity are:

- habitat management,
- sea lamprey control,
- introduced exotics,
- public demands,
- monitoring and research requirements, and
- judicious stocking.

For example, after two decades of management, sea lampreys *(Petromyzon marinus)* remain a significant impediment to the rehabilitation and restructuring of the fish community. Both continued diligence and new initiatives directed towards their control are still required. Similarly, fish stocking was proven to be a powerful and successful management tool, but it is not a substitute for nurturing of natural populations and stewardship of fish habitat.

With these cautions in mind, this document strives to lay out an ambitious course of lake management for the next two decades that is based on sound ecological concepts and guided by realistic and practical management principles. These fish-community objectives are intended as guideposts providing measures of achievement.

Hopefully, the objectives will be an impetus to add further to a management foundation from which progressive policies and programs will originate for the benefit of the lake, its biota, and its users.

ECOLOGICAL CONCEPTS

Emphasis in fisheries management has been shifting to include species complexes and entire ecosystems-not just single species. Species sharing a common environment may be interacting as predator and prey or as competitors for food and living space. The relationships among species can be simple and readily evident or complex and not easily understood. Whether simple or complex, these relationships are dynamic and over time move the community through stages of ecological change influenced by exploitation, introductions, extinctions, and habitat alteration. Persistent and significant influences or stresses on an ecosystem have somewhat predictable outcomes. Within fish communities, the changes are often seen as altered species dominance. As fish communities mature, larger, long-lived species at or near the top of the food chain exert increasing control over smaller, short-lived species that feed mainly on plankton and macroinvertebrates. With this control comes a degree of community stability influenced by the longevity of the top predators and their modulating effect on prey species.

Stability

Stability, in the context of a fish community, does not imply a steady state, although within the bounds of natural variation some semblance of this may occur. Instead, stability refers more to the ability of the fish community to maintain its integrity:

- to persist in the face of possible invaders,

- to resist change in the face of a disturbance, and

- to recover quickly from any change following a disturbance.

Stability is a valued quality in a fish community because it lends predictability to the system in terms of its responses to manipulation and its ability to sustain fisheries.

Balance

Balance is another concept that is useful when describing the ecology of a fish community. Balance, in this case, refers to a state where the ratios of predators to prey allow a sustainable and efficient transfer of nutrients and energy up through the food chain. Fish communities are said to be shaped:

- from the bottom up by primary production (photosynthesis)

- from the top down by predation.

Balance implies a harmonious interplay of these two shaping forces and is important for achieving both stability and productivity in fisheries for highly valued species.

Sustainability

Sustainability embodies the concepts of long-term, desirable outcomes from natural systems to meet the aspirations of society for today and tomorrow. Arguably as much a political concept as an ecological one, sustainability emphasizes the need to view the whole system and to define and recognize an ecosystem's productive capabilities and importance. Society's future options should not be unduly constrained by the management actions of today. Inherent in the idea of sustainability is the recognition that "fixing it" is a more-difficult and costly pathway than is protection in the first place. Sustainable development-as it applies to aquatic ecosystems-requires that adverse impacts on the quality of air, water, and other natural elements are minimized to sustain an ecosystem's overall integrity. These concepts of stability, balance, and sustainability form a basis for describing, understanding, and anticipating responses of the lake's fish community.

Fig. 1. Commercial fishing boats in Lake Huron.

GUIDING PRINCIPLES

Fisheries science, management experience, and public input have given rise to a number of management principles that are the foundation for fisheries policies and programs. The LHC adopts the following principles as guides for formulating management policy:

- The lake must be managed as a whole ecosystem; this principle recognizes that all species and their habitats are interrelated.

- Preservation and restoration of habitat must be foremost in the whole-ecosystem approach.

The amount of fish harvested from healthy aquatic ecosystems is limited and is largely determined by the nutrients in the environment, habitat variables, and a fish-population's ability to respond to exploitation. Because humans may diminish this productive capability, healthy, naturally reproducing fish communities can only be ensured by managing human activities as a part of the ecosystem.

Naturally reproducing fish communities based on native (and naturalized) fish populations provide predictable and sustainable benefits with minimal long-term cost to society.

Exotic (non-native) species that have become established in Lake Huron must be viewed as parts of the fish community. The term rehabilitation, when applied to communities containing such species, obviously means the recovery of lost fishery production and fishery values and not a complete return to a pristine fish community. However beneficial some introductions may have been or could be in the future, the risks entailed when introducing a new species are great enough that no such introduction should be contemplated without clear justification and a comprehensive study of potential impacts.

Stocked fish are essential for continuing progress in restoring the biological integrity of the fish community, for developing spawning populations of species needing rehabilitation, and for providing fishing opportunities.

Rare and endangered native species add to the richness of a fish community and should be safeguarded in recognition of their ecological significance and intrinsic value.

Species diversity contributes to balance and stability within fish communities.

Genetic diversity, both within and among fish stocks, is important to overall species fitness and adaptability. Managers have a responsibility to maintain genetic diversity through protection of adapted stocks and care in the selection and stocking of particular strains of a fish species already introduced.

Socioeconomic values, such as the provision of opportunities to meet recreational and commercial fishing interests, are a priority in decision making.

- Fisheries are a priceless cultural heritage. Therefore, the social, cultural, and economic benefits and costs to society (both present and future) are important considerations in making sound resource-management decisions. The right to share in that heritage carries with it a stewardship role.

- Good management is based upon the best available scientific knowledge tempered and refined by society's mores.

DESCRIPTION OF LAKE HURON

With a total surface area of 59,570 km^2, Lake Huron is the second largest of the Great Lakes. The lake is rimmed on the north and on the east by the Precambrian Shield. Sedimentary formations surround the remainder of the lake and give rise to the Bruce Peninsula and the islands of the Manitoulin group, which together separate the lake into three relatively discrete basins:

- Georgian Bay (15,108 km^2),

- North Channel (3,950 km^2), and

- main basin (23,595 km^2 in the United States and 16,917 km^2 in Canada).

These fish-community objectives encompass all three basins and recognize but few distinctions between them. The objectives are broad enough to encompass differences in fish-species mix, yield parameters, and ecology among the basins.

Lake Huron is a deep oligotrophic lake, with a mean depth of 59 m and depths greater than approximately 30 m over two-thirds of its surface (Berst and Spangler 1973). The lake begins to thermally stratify in late June and has a well-defined thermocline at depths generally between 15 m and 30 m in July and August. In open waters, summer temperatures in the surface layer are usually in the range of from 15 ^{o} to 20°C (Bratsel et al. 1977). However, upwellings of cold, hypolimnia1 water are frequent on the more-exposed main-basin shores.

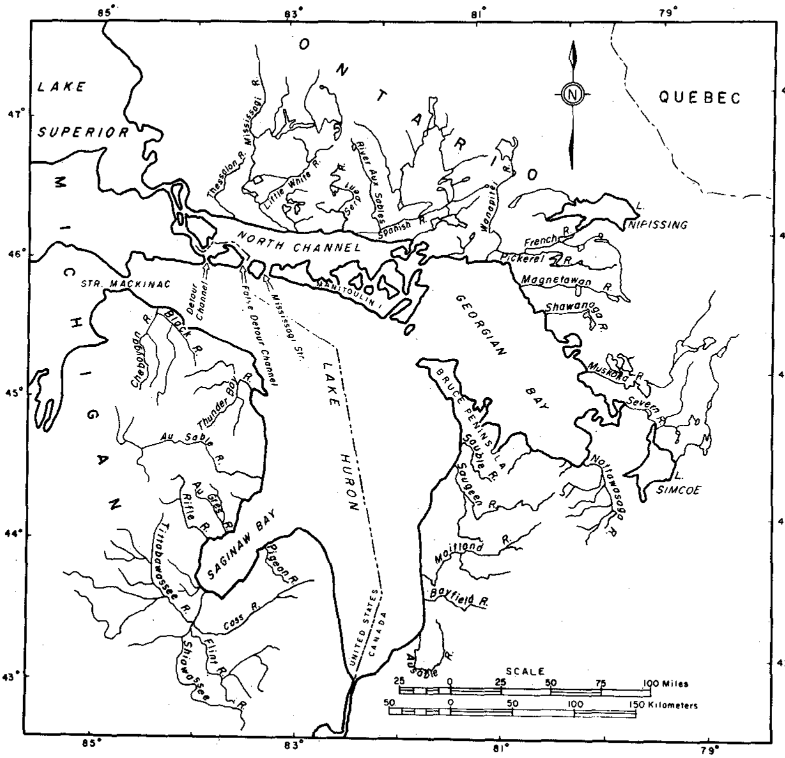


Fig. 2. The Lake Huron watershed showing major tributaries.

On the basis of water-quality information collected in 1980 (Bratsel et al. 1977), the Lake Huron ecosystem can be described as generally healthy. Only a relatively few habitat areas display unmistakable signs of human alteration and impairment, and these are the object of remedial action (Dolan et al. 1986). This impairment is in contrast, however, to the fish community that depreciated significantly in the first half of this century from the effects of intensive fishing and several detrimental species invasions.

THE FISH COMMUNITY, PAST AND PRESENT

Lake Huron has a fish community characteristic of a large, deep oligotrophic lake in the north-temperate zone. Historically, in the deeper, colder parts of the lake, the species complex consisted mainly of

- lake trout *(Salvelinus namaycush),*
- members of the whitefish subfamily (Coregoninae),
- burbot *(Lota lota),* and
- sculpins *(Cottus* spp. *and Myoxocephalus thompsoni).*

Deepwater ciscoes (Coregonus spp.) and lake herring (C. *artedi)-the* cisco component of the whitefish subfamily-and sculpins served as the principal prey species for lake trout and burbot. Lake herring was the dominant planktivore until the 1950s when the species collapsed throughout the lake. Lake whitefish (C. *clupeaformis),* a benthivore, was the first species to be heavily fished and it remains important. The fish community of the warmer, inshore waters was more variable and was dominated by the following species in differing proportions, depending on habitat:

- walleye *(Stizostedion vitreum vitreum)* and yellow perch *(Perca flavescens),*
- members of the sucker family (Catastomidae),
- smallmouth bass *(Micropterus dolomieu)* and largemouth bass *(M. salmoides),*
- northern pike *(Esox lucius),*
- lake sturgeon *(Acipenser flavescens),* and
- channel catfish *(Ictalurus punctatus).*

In all, 92 species of fish in 24 families are on record as having occurred at some time in Lake Huron proper, excluding tributaries (Appendix A). Of these 92 species, 77 of them are thought to be indigenous (Bailey and Smith 198 1). Four of the native deepwater ciscoes are now regarded as extinct and one other member of this group is very rare. Also extinct is the grayling *(Thymallus arcticus).* The status of many *cyprinids (minnows),* mostly *Notropis* spp., is uncertain. There are 16 non-indigenous (exotic) species that have either invaded the lake or been introduced. These include:

- sea lamprey,
- six salmonids,
- *carp (Cyprinus carpio),*
- alewife *(Alosa pseudoharengus),*
- gizzard shad *(Dorosoma cepedianum),* and
- rainbow smelt *(Osmerus mordax).*

The white perch *(Morone americana),* although a recent invader, has become established and is expanding its range. Five of the six salmonids were intentionally introduced:

- Atlantic salmon *(Salmo salar),*
- brown trout *(S. trutta),*
- rainbow trout *(Oncorhynchus mykiss),*
- chinook salmon *(0. tshawytscha),* and
- coho salmon (0. *kisutch)*

The pink salmon *(0. gorbuscha)* was inadvertently introduced. In southern Lake Huron, *grass carp (Ctenopharyngodon idella)* were recently captured, but this species may not exist as a breeding population.

Species introductions or invasions, beginning with carp and rainbow trout around the turn of the century, have all had some impact. Following the appearance of smelt in the 1920s, there was evidence of some displacement of whitefish and ciscoes (Berst and Spangler 1973). However, the greatest disruptive force was unquestionably the sea lamprey-first recorded in Lake Huron in 1937. Added to the already severe stress of fishing, lamprey parasitism was considered the deciding factor:

- in the extinction of lake trout from all but two small embayments, and

- in declines of the burbot, lake whitefish, and larger ciscoes.

These events set in action other changes. Relieved of predation, smelt and the later-arriving (1940s) alewife burgeoned to positions of dominance. The native bloater-a deepwater cisco *(Coregonus hoyi),* which thrived in deepwater habitat-collapsed during the 1960s from a combination of fishing and low recruitment (Brown et al. 1987). Alewives first appeared to benefit large-sized yellow perch by increasing their food supply, but they eventually proved a liability by interfering with perch reproduction (Smith 1968). In addition, the inshore presence of smelt and alewives had a detrimental effect on native forage species such as the emerald shiner (N. *atherinoides).* Clearly, the sea lamprey launched an era of unprecedented instability.

The fish community of Lake Huron is still in transition, but it is apparently more stable and productive than in the 1960s. Chemical control of sea lamprey, beginning in 1960 in Lake Huron, set the stage for recovery. Large-scale plantings, involving mainly lake trout, Pacific salmon *(Oncorhynchus* spp.), rainbow trout, and walleye, have reestablished some control by top predators. Lake whitefish have responded to reduced mortality from sea lampreys (Spangler and Collins 1980) fishing, and, perhaps, changing species interactions and resumed its historically prominent position in the cold-water community. Bloaters, likewise, have made a modest recovery and yellow perch numbers have started to rise once more. However, lake herring remain scarce in much of the lake-as do lake sturgeon. Walleyes occur as relatively discrete stocks that range from productive in lower Lake Huron to depressed in much of the Canadian Shield area.

Harvests more typical of the production capabilities of Lake Huron were experienced only after the initial "fishing-up" process was complete. The period from 1912 to 1940 was one of relative harvest stability with total fish landings of 9 million kg annually (Table 1). This era was chosen as the base period for estimating historically stable yield prior to collapse of the native-fish community. During the base period, yield averaged 1.49 kg/ha/yr. Contributions to the historic yield by lake trout, coregonines (whitefish and ciscoes), and percids (yellow perch and walleye) were 27%, 43%, and 13%, respectively (Appendix B). During this period of high and stable yield, the catch from Lake Huron was believed to be at or near a maximum sustainable level. Significant depreciation of the fishery and reduced yields was particularly evident in the three decades following 1940.

Table 1. Average annual historic yield reported for Lake Huron, 19 12-40.

	Yield	
Top predators	lbs (millions)	kg (millions)
Lake trout	5.3	2.4
Walleye	1.5	0.7
Channel catfish	0.4	0.2
Esocids	0.2	0.1
Subtotal	7.4	3.4
Coregonines [1]	8.5	3.8
Yellow perch	1.1	0.5
Other[2]	2.6	1.2
Subtotal	12.2	5.5
TOTAL	19.6	8.9

1 Whitefish, lake herring, and deepwater ciscoes.
2 Bullheads (Ictalurus spp.), carp, smelt, sturgeon, suckers, and bass.

FISH-COMMUNITY OBJECTIVES

A fish community can be described by its species mix, those qualities (stability, balance, sustainability, and diversity) which enable it to persist, and by the measures of the fishing opportunities that it offers (yield and recreational hours). The historic perspective of the Lake Huron fish community is largely gained through harvest records. For this reason, and also because public attention is focused on the harvesting of fish, fish-community objectives will necessarily incorporate some reference to future harvest expectations including, in some cases, single-species considerations. However, the structure and functioning of the fish community ultimately determines its capacity to support fisheries, and meaningful fish-community objectives must also capture these elements of community character. In part, the objectives encompass broader ecological aspects.

When describing fish-community objectives, certain realities need to be considered.

- The number and composition of species in a fish community are strongly influenced by habitat features-for example, lake area, depths, and thermal characteristics-that are beyond human control.

- There are only a few options for altering fish-community structure in a Great Lake. Habitat manipulation is usually limited to remedial action in nearshore environments and tributary streams. Beyond the near shore, managers exert an influence through the regulation of fisheries, stocking, and sea lamprey control.

- Management actions are inexact. Their effects cascade to species well beyond those targeted, and those effects can have different time scales for different species. Short-term responses can be deceptive and long-range prediction can prove difficult.

- Real or potential invaders-for example, zebra mussel *(Dreissena polymorpha)* and ruffe *(Gymnocephalus cernuus)* may substantially alter the community.

Fish-community objectives for an entire lake cannot be taken to a high level of exactness-they are reasoned approximations of likelihoods. Management initiatives aimed at achieving objectives will continue to have a large experimental component, and the time frame needed in meeting some objectives will be measured in decades. Although continual evaluation of achievement will occur, the years 2000 and 20 10 are viewed as priority times for review of these objectives.

Overall Objective

Over the next two decades, restore an ecologically balanced fish community dominated by top predators and consisting largely of self-sustaining indigenous and naturalized species capable of sustaining annual harvests of 8.9 million kg.

Oligotrophic fish communities structured as described in the overall objective usually produce the species of fish most sought after by the public. The overall objective also implies that the fish community will exhibit maturity and stability through dominance of top predators. The 8.9 million kg noted in the objective is the recorded harvest from Lake Huron between 19 12 and 1940 and is considered the best measure of long-term harvest potential under the constraints imposed by the lake's morphometry and chemistry. More-refined measures of harvest potential are likely to emerge with time. For now, historic harvests provide the best insight into the lake's suitability for major families or subfamilies of fishes (salmonines, coregonines, percids, and others).

Salmonine (Salmon and Trout) Objective

Establish a diverse salmonine community that can sustain an annual harvest of 2.4 million kg with lake trout the dominant species and anadromous (stream-spawning.) species also having a prominent place.

Species diversity is of ecological and social value, contributes to community stability, and adds variety to fishing opportunities. However, diversification of the salmonine component of the fish community is a significant departure from the historic dominance by lake trout. The introduction of rainbow trout occurred nearly a century ago, but most other successful introductions, including Pacific salmon species, are comparatively recent in an ecological sense. Their short history makes it difficult to predict how the salmonine community will eventually sort itself out. With finite prey and habitat resources for salmonine production, each salmonine species (while adding to the species mix) will exist at some expense to the others.

There is an international consensus that the lake trout should be the dominant salmonine and rehabilitation programs for it are under way. Lake trout rehabilitation is supported by provincial and state plans as well as by a lakewide, international lake trout plan. Backcross-a brook trout *(Salvelinus fontinalis)* x lake trout hybrid-are a strain of lake trout used for rehabilitation in Ontario waters. However, the backcross will be only one of several lake trout strains used. Lake trout yields may approximate 1.4-1.8 million kg two decades into the next century. Presently, lake trout populations depend upon stocking programs. Evidence of successful natural reproduction is limited.

Anadromous species, which are naturalized and self-supporting to varying degrees, represent a significant part of the salmonine biomass and will probably continue to have a prominent role. This category includes rainbow trout, pink salmon, and chinook salmon. Time has enabled the rainbow trout to establish itself in virtually all streams where conditions suitable for natural reproduction exist. Rainbow trout are augmented by stocking in some locations-particularly in western Lake Huron where spawning tributaries are few. The species will be managed for self-sustainability where habitat is satisfactory. Pink salmon, which more recently have become established in Canadian waters, may have limited potential for range expansion. Chinook salmon are now widely distributed in Lake Huron because of planting and natural reproduction. Consistent with demand, chinook are expected to have an important future in the salmonine community.

Other anadromous salmonines include brown trout, Atlantic salmon, and coho salmon. Although brown trout occur naturally in some parts of the Lake Huron watershed, only a few progeny migrate from natal streams to the lake. Lake populations are supported by stocking. Atlantic salmon, stocked in limited numbers in United States waters, might be considered further for experimental releases. Coho salmon, currently present in low numbers, may persist because of limited natural reproduction or immigration from the other lakes, but will not be stocked because of

- potential conflicts with other riverine species,
- its relatively short period of availability for fishing, and
- poor returns from past stocking programs.

Anadromous salmonines may contribute 30% of the lakewide salmonine production. This figure is based on stocking programs, the number of spawning streams, and the potential of some of these streams for improvements in habitat and access.

For example, for lake trout yields ranging between 1.4 and 1.8 million kg, anadromous-salmonine yield may be approximately 0.4-0.5 million kg. For most United States waters, stocking will play a large role in maintaining anadromous-salmonine fisheries because of a lack of suitable tributaries for spawning.

Projected harvest levels for salmonines apply to post-rehabilitation periods. During rehabilitation, harvest will be managed to allow lake trout stocks to rebuild and achieve self-sustainability. Also, sea lamprey predation continues as a significant source of mortality affecting the survival and harvest of salmonines.

Percid (Walleye and Perch) Objectives

Reestablish and/or maintain walleye as the dominant cool-water predator over its traditional range with populations capable of sustaining a harvest of 0.7 million kg.

Maintain yellow perch as the dominant nearshore omnivore while sustaining a harvestable annual surplus of 0.5 million kg.

The walleye was the dominant nearshore predator in Lake Huron and it should resume this role. Viable walleye stocks exist and need only to be maintained. Other stocks, including those in Saginaw Bay and eastern Georgian Bay, have suffered from environmental degradation or from overfishing and require rehabilitation.

Yellow perch are widely distributed and an important constituent of the commercial- and sport-fish harvest. The greatest threat to its future is the recently arrived white perch-a member of the [true] bass family. The point at which white perch numbers stabilize in Lake Huron is uncertain but may be influenced by harvesting practices. Managing for yellow perch dominance may mean harvesting the species conservatively. The objectives for predator management are expected to complement yellow perch populations by exerting top-down effects on alewife and smelt because large populations of these species are believed to suppress yellow perch recruitment.

Esocid (Northern Pike and Muskellunge) Objectives

Maintain northern pike as a prominent predator throughout its natural range.

Maintain muskellunge (Esox masquinongy) *in numbers and at sizes that will safeguard and enhance its special status and appeal.*

Sustain a harvestable annual surplus of 0. I million kg of these esocids,

Northern pike will provide most of the esocid harvest because of its more-widespread distribution and greater abundance. As catch-and-release of muskellunge becomes more popular, harvesting may, in fact, decline as a primary criterion of management success. Preservation and enhancement of spawning and nursery habitat will be critical to the well being of both species.

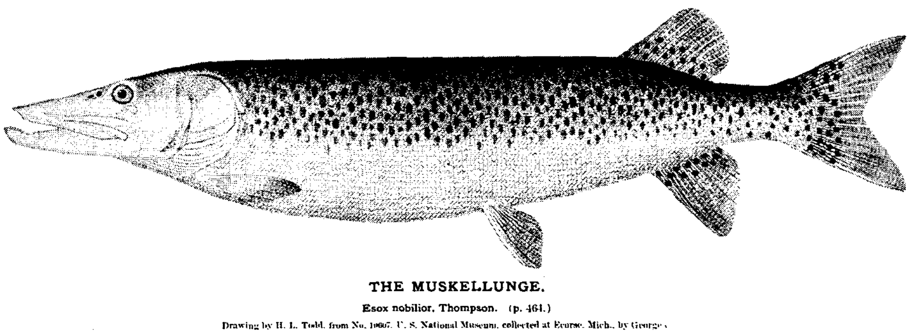


Fig. 3. The muskellunge (photo of illustration from Goode (1884)).

Channel Catfish Objective

Maintain channel catfish as a prominent predator throughout its natural range while sustaining a harvestable annual surplus of 0.2 million kg.

Channel cattish will be managed in recognition of their role as an important predator in some nearshore fish communities-for example, Saginaw Bay.

Coregonine (Lake Whitefish and Ciscoes) Objectives

Maintain the present diversity of coregonines.

Manage lake whitefish and ciscoes at levels capable of sustaining annual harvests of 3.8 million kg.

Restore lake herring to a significant level andprotect, where possible, rare deepwater ciscoes.

The lake whitefish has been one of the premium fishes of the Great Lakes and a cornerstone of commercial fisheries for more than a century. Recent landings have been among some of the highest on record for the main basin, the North Channel, and outer Saginaw Bay. Whitefish in Georgian Bay have yet to recover to the same extent, but increases are evident. The return of top predators has likely been beneficial to whitefish populations.

Deepwater ciscoes are the main inhabitants of the deep waters of the lake. Within this closely related species complex, the shortnose cisco (C. *reighardi)* is endangered, if not extinct. This species needs to be preserved to protect genetic diversity and to maintain, as much as possible, the structure of the original fish community. The bloater (the other remaining member of this group, and the only member in abundance) has considerable commercial value. The bloater is also valuable as a prey species primarily for lake trout and anadromous salmonines.

The lake herring, a valuable food fish and prey species, historically was a major link in the food chain. Its role has been usurped by the smelt and the alewife which, to a large degree, have displaced it. In greater numbers, it could add stability to the forage base. Recovery of the lake herring likely will depend on suppression of smelt and alewives by predators.

Centrarchid (Bass and Sunfish) Objective

Sustain smallmouth and largemouth bass and the remaining assemblage of sunfishes (Centrarchidae *spp.) at recreationally attractive levels over their natural range.*

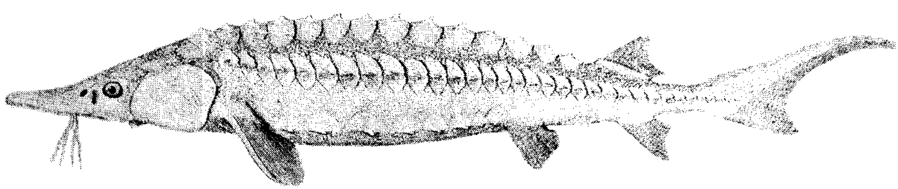
The smallmouth bass is an important species of the nearshore, warmwater fish community and it should continue as such. The largemouth bass is much more restricted in its range, but ranks with smallmouth bass in value (where it occurs). The black crappie *(Pomoxis nigromaculatus),* which occurs mainly in eastern Georgian Bay and Saginaw Bay, is valued as a recreational fish, but its management must be balanced with the potential for negative interactions with walleye. Reproduction of the two basses is strongly influenced by summer temperatures and lake levels, and abundance can rise or fall depending on the sequence of favorable years.

Sturgeon Objectives

Increase the abundance of lake sturgeon to the extent that the species is removedfrom its threatened status in United States waters.

Maintain or rehabilitate populations in Canadian waters,

The lake sturgeon has an exceedingly long generation time and is consequently highly sensitive to overfishing. In Lake Huron, its population was much reduced by 19 10. It was further aggravated by the damming of most of the larger rivers, which provided spawning and nursery habitat. Restoration strategies include harvest regulation, stocking, habitat restoration, and law enforcement. Michigan will maintain a zero-yield objective during rehabilitation while limited harvests will be allowed in Ontario waters.



THE LAKE STURGEON.

Acipenser rubicundus, Le S. (p. 661.)

Drawing by H. L. Todd, from No. 10252, U. S. National Museum, collected at Ecorse, Michigan, by J. W. Milner.

Fig. 4. The lake sturgeon (photo of illustration from Goode (1884)).

Prey Objective

Maintain a diversity of prey species at population levels matched to primary production and to predator demands.

Deepwater ciscoes, sculpins, lake herring, rainbow smelt, and alewives (in varying proportions) constitute the bulk of the prey biomass available to salmonines in colder regions of the lake. Alewife, smelt, gizzard shad, spottail shiners *(Notropis hudsonius),* emerald shiners, young whitefish, and yellow perch can also be important seasonally in the diet of nearshore predators. With the majority of prey species not being controlled by predation or fishing, their individual abundances may vary within wide limits. Species diversity will impart some overall stability to the prey-species base by minimizing effects of year-to-year variation within single species.

The fish community is healthiest and management costs generally least when interactions among species act to dampen oscillations in species abundance and in biomass shifts between trophic levels. Such a community is said to be self-regulating. Prey species are important regulators because of their top-down effect on phytoplankton and zooplankton.

The "balance" implied in the prey objective is normally achieved by manipulation of predator numbers through harvest control and stocking, but care is needed that neither harvest nor stocking is taken to an extreme. Emphasis should be on self-regulation. Fisheries for prey species are not easily adjusted to changing stock conditions and are best limited to segments of populations that have grown beyond sizes eaten by predators.

Sea Lamprey Objectives

Reduce sea lamprey abundance to allow the achievement of other fish-community objectives.

Obtain a 75% reduction in parasitic sea lampreys by the year 2000 and a 90% reduction by the year 2010.

Post-control sea lamprey abundance reached a five-year low between 1973 and 1977. Five- to eightfold increases in sea lamprey numbers in the mid-to-late 1980s preclude the achievement of rehabilitation objectives over major portions of the lake. Sea lamprey spawning runs are again becoming reestablished in tributaries that ceased to be sea lamprey producers during periods of low abundance.

Fish-community objectives are predicated on a high level of sea lamprey control. This includes control on the St. Marys River, which is considered to be the major single source of sea lampreys into Lake Huron. This major impediment to the achievement of fish-community objectives demands timely and aggressive management action.

Species Diversity Objective

Recognize and protect the array of other indigenous fish species because they contribute to the richness of the fish community. These fish-cyprinids, rare ciscoes, suckers, burbot, gar (Lepisosteidae *spp.), and sculpins-are important because of their ecological significance; intrinsic value; and social, cultural, and economic benefits.*

Lake Huron proper contains a fish community of at least 92 species, and'77 of these species are believed to be indigenous. These species contribute to the value and ecological integrity of the fish community. Further loss of native species should be avoided and those lost should be restored, where feasible. The diversity of indigenous fishes is recognized and valued.

Appendix A lists numerous species that are absent from the other objectives within this document but have ecological worth and as such need to be identified and appreciated. Some of these species are of uncertain status (for example, cyprinids) while others are designated as rare, threatened, or endangered (for example, one species of cisco). Such species may be of economic value, but mostly they are noted for their intrinsic worth and their integrative function within the fish community. As prey and predators, they act as energy vectors and provide balance and stability.

Specific objectives for other indigenous species are difficult to develop, but these fishes should be protected. Protection will occur through several means:

- Protect species of primary socioeconomic interest so that other species will enjoy some measure of protection.

- Designate some species as rare, threatened, or endangered to raise their profile and engender specific management actions.

- Protect and rehabilitate habitat to ensure the overall well being of a diverse fish community.

- Direct regulatory programs at specific species or families of fishes (for example, bait-fish harvest control and sucker dipnetting).

Some introduced fish species are not likely to make a beneficial contribution to the fish community (for example, white perch) and may in fact, displace native species. Other potential invaders (for example, ruffe) pose serious ecological risks.

Genetic Diversity Objectives

Maintain and promote genetic diversity by conserving locally adapted strains.

Ensure that strains of fish being stocked are matched to the environments they are to inhabit.

Genetic diversity contributes to the fitness of species and to their ability to accommodate change and is important to the quality and persistence of the fishery. In recognition of the need to help ensure generic diversity in fish populations, many recent studies and management programs have incorporated the identification of unique fish stocks. For example, in choosing lake trout strains for rehabilitation programs, particular attention has been paid to the characteristics of the parent stocks and to matching their traits to stocking locations. Similarly, fish culturists have instituted practices aimed at preserving the genetic integrity of hatchery brood stocks. Other management measures directed at walleye, rainbow trout, and remnant lake trout populations (Iroquois and Big Sound lake trout stocks, both located in Georgian Bay) have been undertaken to protect and rehabilitate unique strains.

Habitat Objectives

Protect and enhance fish habitat and rehabilitate degraded habitats.

Achieve no net loss of the productive capacity of habitat supporting Lake Huron fish communities and restore damaged habitats.

Support the reduction or elimination of contaminants.

In a changing and expanding society, protection of habitat does not mean an unchanging habitat; but, change should be neutral or beneficial in its effect on the fish community. No net loss is a requirement, and a net gain, resulting from any physical or chemical alteration of the lake environment is preferable. Habitat management is an integral component of these fish-community objectives, and their ultimate achievement will hinge on the protection and rehabilitation of habitats. The no-net-loss objective is firmly anchored in this belief.

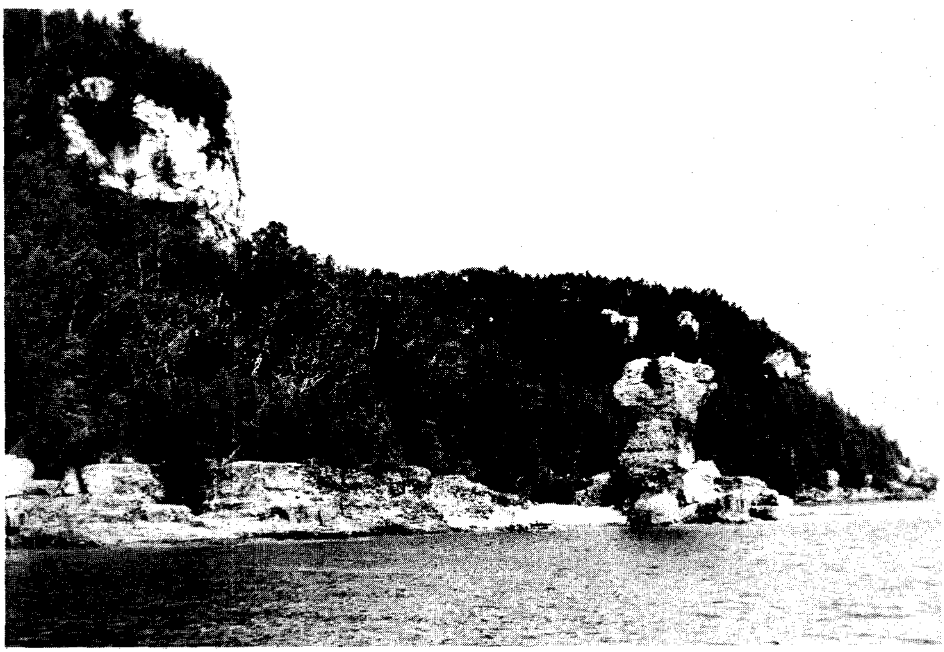


Fig. 5. A view of Lake Huron in Georgian Bay.

Although water quality in Lake Huron is generally high, four specific areas of concern have been identified by the International Joint Commission's Water Quality Board, and remedial action is under way or planned:

- Saginaw River/Bay in the United States, and

- Penetang Bay to Sturgeon Bay, the Spanish River, and Collingwood Harbour in Canada.

Fisheries considerations are being fully integrated into Remedial Action Plans for these Areas of Concern. Future habitat enhancement might take other forms including, but not restricted to:

- wetland improvement,

- site restoration involving the removal of physical structures,

- spawning-ground reconstruction, and

- improved access by fish to riverine habitat.

Contaminants bioaccumulate in the environment and are a source of ecological malaise variously seen as physical deformities, reproductive failures, tumors, and physiological effects among exposed invertebrates and fish. Levels of contaminants in fish in Lake Huron are generally, but not totally, within current guidelines for human consumption-exceptions are the largest specimens of a few top predators in localized areas. Controls on the production and use of persistent toxic chemicals have been shown to be effective in reducing levels of contaminants in the Great Lakes. Progress has been made as evidenced by declining PCB levels in salmon and trout. Management agencies are strongly encouraged to undertake policy and legal action to ensure that persistent toxic contaminants are reduced or eliminated at their source.

MEASURES OF ACHIEVEMENT

Changes in fish harvest levels and population abundance will be used to measure success. In the absence of a fishery for a particular species, abundance and change rates can be assessed through independent surveys:

- A combination of creel surveys, commercial catch sampling, and index netting will be maintained to assess fish communities.

- Community health can be evaluated in terms of the range, status, and age structure of populations of top predators and large benthivores (bottom-dwelling fish).

- An assessment of community balance and stability will require measures of growth and variability in the abundance of predator and prey species.

- Species dominance will be evident from harvest statistics or survey data.

- Species persistence will be indicated by presence or absence

- Changes in the status of rare species may be known only through special field surveys.

- Genetic diversity will most likely be assessed in qualitative terms, for example, whether or not a particular stock or strain is being maintained in numbers likely to safeguard its genetic makeup.

Where restoration of a fish species is desired, progress must be determined from population parameters and not from harvest. Parameters include measures of natural reproduction, relative abundance, total mortality, age structure, and growth. The following information will be gathered and used to assess sea lampreys and their potential impact on other species:

- sea lamprey wounding rates on host species,

- observed sea lamprey attachments on harvested fish, and

- captures of returning adults in sea lamprey-spawning streams.

Ultimately, the adequacy of sea lamprey control will be judged on the basis of success in achieving other community objectives.

Conventional abiotic and biotic descriptions of habitat will be used for inventory purposes and for habitat classification. Assigning values to and assessing the consequence of habitat modification are difficult but important in achieving community objectives and will require further studies of habitat use and requirements. Standards exist for acceptable contaminant levels in fish, although these relate to human and not fish-health needs. Uniform sampling procedures and standards and policies aimed at further reduction of contaminants are required.

Although continual evaluation of achievement will occur, the years 2000 and 20 10 are viewed as priority times for review of these objectives.

ISSUES OF CONCERN

Habitat alteration and loss, if viewed as an inevitable consequence of development, will undermine efforts to sustain and restore fishery resources. New policies and procedures for dealing with potentially destructive activities represent a turnabout requiring diligent application and a much-improved knowledge base. Wetlands, riverine habitats, and nearshore spawning and nursery areas, in particular, will require protective measures and restoration. Improvement of fish passage to potentially productive spawning and nursery habitat is also necessary.

The sea lamprey remains the most serious impediment to achieving Lake Huron fish-community objectives. Its numbers have been increasing despite control efforts. They have reached levels similar to those seen prior to the implementation of sea lamprey control-levels that bring rehabilitation objectives into question. Effective sea lamprey control is the foundation for fishery rehabilitation in the Great Lakes. In Lake Huron, this entails stepped-up control efforts including new initiatives directed at the St. Marys River.

Burbot stocks are currently at high abundance levels lakewide-probably in response to low population levels of lake trout and lack of exploitation. Burbot stocks should continue to be monitored to determine their effect on other species.

Effective controls on ship ballast water, which is a vector for invasive organisms, are imperative, Introduced species lend an air of unpredictability to the fish community:

- The zebra mussel, now in Lake Huron, is an example of an exotic causing concern.

- The white perch, also an exotic, undoubtedly will bring about some displacement of native species.

- Ruffe threaten to invade from Lake Superior with expected consequences to coregonine and percid fishes.

- The European cladoceran (Bythotrephes cederstroemi) is now successfully established, but its ecological effects are unknown. It competes with newly hatched fishes.

New knowledge is the pathway to more-effective ecosystem management:

- Monitoring must extend beyond the species of primary interest and include major prey species.

- Research must include bioenergetic studies to identify and quantify interactions between species and to assess their importance to overall community dynamics.

- Managers should influence research priorities to help ensure that research applies to the pressing concerns associated with maintaining and rebuilding Lake Huron fish communities.

Rehabilitation efforts depend in part on the stocking of fish. Despite much success, facilities and brood stocks required in support of achieving fish-community objectives can be improved to increase and secure the supply of hatchery-reared fish. Learning to better use fish culture as a tool in rehabilitation is needed. At the same time, the stocking of fish must not be regarded as a substitute for nurturing natural populations and care of habitat.

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APPENDIX A
FISHES OF LAKE HURON PROPER

P = Planned Introduction A = Accidental Introduction E = Extinct

Petromyzontidae	
silver lamprey	*Ichthyomyzon unicuspis*
sea lamprey (A)	*Petromyzon marinus*
Polyodontidae	
paddlefish (E)	*Polydon spathula*
Acipenseridae	
lake sturgeon	*Acipenser fulvescens*
Lepisosteidae	
longnose gar	*Lepisosteus osseus*
Amiidae	
bowfin	*Amia calva*
Anguillidae	
American eel (A)	*Anguilla rostrata*
Hiodontidae	
mooneye	*Hiodon tergisus*
Clupeidae	
alewife (A)	*Alosa pseudoharengus*
gizzard shad	*Dorosoma cepedianum*

‘Modified from Bailey and Smith (1981).

Salmonidae (Salmoninae)	
pink salmon (A)	*Oncorhynchus gorbuscha*
coho salmon (P)	*0. kisutch*
chinook salmon (P)	*0. tshawytscha*
kokanee salmon (P)	*0. nerka*
rainbow trout (P)	*0. mykiss*
Atlantic salmon (P)	*Salmo salar*
brown trout (P)	*S. trutta*
brook trout	*Salvelinus fontinalis*
lake trout	*S. namaycush*
Salmonidae (Coregoninae)	
lake whitefish	*Coregonus clupeaformis*
lake herring (cisco)	*C. artedi*
bloater	*C. hoyi*
deepwater cisco (E)	*C. johannae*
kiyi (E)	*C. kiyi*
blackfin cisco (E)	*C. nigripinnis*
shortnose cisco	*C. reighardi*
shortjaw cisco (E)	*C. zenithicus*
round whitefish	*Prosopium cylindraceum*
Osmeridae	
rainbow smelt (A)	*Osmerus mordax*
Umbridae	
central mudminnow	*Umbra limi*
Esocidae	
northern pike	*Esox lucius*
muskellunge	*E. masquinongy*
Cyprinidae	
northern redbelly dace	*Phoxinus eos*
lake chub	*Couesius plumbeus*
grass carp (A)	*Ctenopharyngodon idella*
carp (A)	*Cyprinus carpio*
goldfish (A)	*Carassius auratus*
golden shiner	*Notemigonus crysoleucas*

emerald shiner	*Notropis atherinoides*
common shiner	*N. cornutus*
blacknose shiner	*N. heterolepis*
spottail shiner	*N. hudsonius*
rosyface shiner	*N. rubellus*
spotfin shiner	*N. spilopterus*
sand shiner	*N. stramineus*
mimic shiner	*N. volucellus*
bluntnose minnow	*Pimephales notatus*
fathead minnow	*P. promelas*
longnose dace	*Rhinichthys cataractae*
Catostomidae	
quillback	*Carpiodes cyprinus*
longnose sucker	*Catostomus Catostomus*
white sucker	*C. commersoni*
northern hogsucker	*Hypentelium nigricans*
lake chubsucker	*Erimyzon sucetta*
black buffalo	*Ictiobus niger*
silver redhorse	*Moxostoma anisurum*
greater redhorse	*M. valenciennesi*
shorthead redhorse	*M. macrolepidotum*
Ictaluridae	
yellow bullhead	*Ictalurus natalis*
black bullhead	*I. melas*
brown bullhead	*I. nebulosus*
channel catfish	*I. punctatus*
stonecat	*Noturus flavus*
tadpole madtom	*N. gyrinus*
Percopsidae	
troutperch	*Percopsis omiscomaycus*
Gadidae	
burbot	*Lota lota*
Cyprinodontidae	
banded killifish	*Fundulus diaphanus*

Gasterosteidae	
brook stickleback	*Culaea inconstans*
threespine stickleback (A)	*Gasterosteus aculeatus*
ninespine stickleback	*Pungitius pungitius*
Percichthyidae	
white bass	Morone *chrysops*
Centrarchidae	
rock bass	*Ambloplites rupestris*
pumpkinseed	*Lepomis gibbosus*
bluegill	*L. macrochirus*
longear sunfish	*L. megalotis*
smallmouth bass	*Micropterus dolomieui*
largemouth bass	*M. salmoides*
white crappie	*Pomoxis annularis*
black crappie	*P. nigromaculatus*
Percidae	
yellow perch	*Perca flavescens*
sauger	*Stizostedion canadense*
walleye	*S. vitreum*
Iowa darter	*Etheostoma exile*
Johnny darter	*E. nigrum*
logperch	*Percina caprodes*
channel darter	*P. copelandi*
river darter	*P. shumardi*
Sciaenidae	
freshwater drum	*Aplodinotus grunniens*
Cottidae	
mottled sculpin	*Cottus bairdi*
slimy sculpin	*C. cognatus*
Spoonhead sculpin	*C. ricei*
deepwater sculpin	*Myoxocephalus thompsoni*

APPENDIX B
AVERAGE ANNUAL HISTORIC YIELD (IN MILLIONS) REPORTED FOR LAKE HURON, 1912-40, CANADIAN AND UNITED STATES WATERS

	Canadian waters		United States waters		Total	
	lbs	kg	lbs	kg	lbs	kg
Lake trout	3.6	(1.60)	1.7	(0.80)	5.3	(2.4)
Walleye	0.4	(0.20)	1.1	(0.50)	1.5	(0.7)
Channel catfish	0.3	(0.10)	0.1	(0.05)	0.4	(0.2)
Esocids	0.1	(0.05)	0.1	(0.05)	0.2	(0.1)
Coregonines	2.4	(1.10)	6.1	(2.70)	8.5	(3.8)
Yellow perch	0.1	(0.05)	1.0	(0.50)	1.1	(0.5)
Other (bullheads, carp, smelt, sturgeon, suckers, and bass)	0.4	(0.20)	2.2	(1.00)	2.6	(1.2)
TOTAL,	7.3	(3.30)	12.3	(5.50)	19.6	(8.9)

GLOSSARY

Abiotic
Not a living organism or produced by one.

Anadromous
Fish leaving the lake or sea and entering a river to spawn.

Balance
An ecological state in which predators and prey occur in proper proportions relative to each other's needs.

Benthivore
Feeding primarily on bottom-dwelling organisms.

Bioaccumulate
A process by which substances retained by organisms become increasingly concentrated with movement through the food chain.

Bioenergetic
Pertaining to the flow of energy through a biological system.

Biomass
The combined weight of a group of living organisms.

Biotic
Related to living organisms.

Bottom-up effect
The impact of nutrients on plankton and on the quantity and composition of fish higher in the food chain.

Community integrity
Having a wholeness and interconnectedness that bestows a high degree of self-regulation.

Ecosystem
A system formed by the interaction of a community of organisms with the environment.

Exotic (species)
A species not native to the environment in question.

Fishing-up
Removing more fish than is surplus to stock maintenance requirements.

Forage base
Prey species forming the food supply for predators.

Genetic diversity
A measure of the variation among genes that control hereditary characteristics in individuals, populations, and species.

Hypolimnion
The cold, lower layer of a thermally stratified lake.

Indigenous
Native to the area.

Introduction
The release of a species into an environment where it previously did not occur.

Invasion
Entry of a new species into an environment via some natural or man-made route.

Maturity (with respect to a fish community)
The degree to which top predators dominate.

Naturalized
Having achieved permanent residency through natural reproduction.

Oligotrophic lake
A lake low in nutrients and usually deep.

Omnivore
Both plankton and fish comprise the diet.

Planktivore
An organism that feeds on plankton.

Phytoplankton
The plant organisms in plankton.

Primary production
The production of new tissue by photosynthesis.

Rehabilitation
To return a system (for example, a lake) to a healthy and productive state as defined by a set of criteria.

Riverine
Living in a river environment.

Species complex
A group of closely related species.

Stability
Resistance to change from disturbance.

Strategic planning
The process of defining broad approaches for the attainment of objectives,

Thermocline
A transition zone between the warm, upper layer and the cold, lower layer of a thermally stratified lake.

Top-down effect
Control exerted by predators on the quantity and composition of organisms lower in the food chain.

Trophic level
A level within a food pyramid within which organisms have a common nutrient source.

Yield
The harvest of fish from a lake expressed on a per unit area basis.