THE STATE OF LAKE HURON IN 1992

Great Lakes Fishery Commission

SPECIAL PUBLICATION 95-2

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THE STATE OF LAKE HURON IN 1992

edited by

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EXECUTIVE SUMMARY

Management objectives and goals for the Lake Huron fish community were established in response to A Joint Strategic Plan for Management of Great Lakes Fisheries (Great Lakes Fishery Commission 1980). The objectives serve as the basis for this state of the lake report. The report describes the present status of fish stocks in Lake Huron and provides a base for measurement of progress toward achievement of the objectives. Based on the differences between the present status of fish stocks and the long-term objectives, management strategies can be developed to assist in achieving those objectives.

Objectives

The overall objective for Lake Huron is to:

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 an annual harvest of 8.9 million kg.

Specific objectives include:

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

Reestablish and/or maintain the walleye *(Stizostedion vitreum vitreum)* as the dominant cool-water predator in its traditional area with populations capable of sustaining a harvest of 0.7 million kg.

Maintain the yellow perch *(Perca flavescens)* as the dominant nearshore omnivore and sustain a harvestable annual surplus of 0.5 million kg.

Maintain the northern pike *(Esox lucius)* as a prominent predator throughout its natural range.

Maintain the muskellunge *(Esox masquinongy)* in numbers and sizes that will safeguard and enhance the species status and appeal.

Sustain a harvestable annual surplus of 0.1 million kg of esocids.

Maintain *the* channel catfish *(Ictalurus punctatus)* as a prominent predator throughout its natural habitat while sustaining a harvestable annual surplus of 0.2 million kg.

Maintain the present diversity of coregonines.

Manage *the* lake whitefish *(Coregonus clupeaformis)* and ciscoes *(Coregonus* spp.) at levels capable of sustaining annual harvests of 3.8 million kg.

Restore the lake herring *(Coregonus artedi)* to a significant level and protect, where possible, rare deepwater ciscoes *(Coregonus reighardi).*

Sustain the smallmouth bass *(Micropterus dolomieu)* and the largemouth bass (M. *salmoides)* and the remaining assemblage of sunfishes (Centrarchidae) at recreationally attractive levels in their natural range.

Increase abundance of *the* lake sturgeon *(Acipenser fulvescens) so* that the species is removed from its threatened status in United States waters.

Maintain or rehabilitate sturgeon populations in Canadian waters.

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

Reduce sea lamprey *(Petromyzon marinus)* populations to allow achievement of other fish-community objectives.

Achieve a 75% reduction of the parasitic sea lamprey by the year 2000 and a 90% reduction by the year 20 10.

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 *(Catostomus* spp.), burbot *(Lota Iota), gars (Lepisosteidus* spp.) and sculpins (Cottidae)-are important for three reasons. They have ecological significance; intrinsic value; and social, cultural, and economic worth.

Maintain and promote genetic diversity by conserving locally adapted strains.

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

- 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.

Progress

In some respects, the Lake Huron fish community in 1992 is returning to the state that was present early in this century. However, in many ways the fish community remains a distant image of what once existed.

- Total fish yields from Lake Huron from 1987 to 1992 amount to 60% of the fish-community objective of 8.9 million kg.

- Current yields of yellow perch, channel catfish, and coregonines now equal or exceed the fishery objectives for those species. The current yields may not be sustainable on a long-term basis.

- The yield objectives for salmonines, walleyes, and esocids are not being met. Current harvest levels for these fishes are not sustainable because the stocks are much reduced in size from historic levels.

- Lake trout are once again reproducing in Lake Huron-but only in limited areas and quantities.

- Lake sturgeon populations appear to be stable but well below historic levels of abundance.

- Introduced forage fish such as the rainbow smelt *(Osmerus mordax)* and the alewife *(Alosa pseudoharengus)* are now less abundant than 20 yr ago and the size structure of both species is much reduced. The bloater (Coregonus hoyi) is a native forage species that has increased to the point where it is now the most abundant prey species, but recruitment has recently declined substantially.

- The sea lamprey continues to impede achievement of fish-community objectives.

- Productivity in Lake Huron remains below historic levels because much of the Saginaw Bay basin continues to suffer habitat problems. Contaminants in Lake Huron fish are declining, but in certain areas those levels are sufficient to warrant a restrict-consumption advisory.

Salmonines

The harvest of all salmonines in 1992 was 1 million kg and amounts to 42% of the fishery objective. Lake trout made up only 13% of the total salmonine yield in 1992, chinook salmon *(Oncorhynchus tshawytscha)* made up 86%, and other species made up only 1%. The distribution of the salmonine harvest among lake trout and chinook salmon has been fairly constant for the last several years. Very little salmonine recruitment originated from natural reproduction. Except for pink salmon (0. *gorbuscha),* populations of salmonines continue to be maintained by stocking of hatchery-reared fish.

The status of lake trout populations varies tremendously among areas in the lake. Abundance of lake trout in Michigan waters is declining despite relatively constant stocking rates. In Ontario waters, lake trout abundance has remained stable and is related to stocking levels. Mortality rates on lake trout throughout most of Lake Huron are in excess of target levels. Survival of lake trout increases from north to south in the lake. Hatchery-reared lake trout are reproducing in South Bay on Manitoulin Island and in the Alpena, Michigan areas-but these populations are isolated and small. Sea lamprey-induced mortality on lake trout in Lake Huron continues to be excessive and accounts for anywhere from 20% to 75% of all lake trout deaths.

Stocking of salmonines other than lake trout has averaged 7.5 million fish annually since 1988. Chinooks made up 58% of all salmonines (besides lake trout) that have been stocked in 1988-92. The chinook harvest has remained fairly constant at 780,000 kg during the last 5 yr. The harvest of rainbow trout (0. *mykiss),* brown trout *(Salmo trutta),* pink salmon, Atlantic salmon (S. *salar),* and brook trout *(Salvelinus fontinalis)* has been more variable than the harvest of chinooks. Length-at-age data for chinooks have remained stable, but age at sexual maturity has increased, which suggests that some decline in growth has occurred. Most salmonines reproduce in Ontario tributaries of the Lake, but the levels of natural reproduction remain unknown. Some evidence exists of a decline in abundance of wild rainbow trout in Ontario waters.

Coregonids

The coregonid complex of Lake Huron presently consists of four species that have produced harvests averaging 92% of the fishery objective in 1988-92. The lake whitefish provides 80% of the coregonine harvest from Lake Huron. Lake whitefish populations are probably as abundant now as at any other time this century because of production of consistently strong year-classes. Bloater populations have recovered throughout the lake and are producing yields not attained since the 1960s. Lake herring populations continue to be depressed, but a few individuals remain in all basins and they may respond if exotic planktivores are suppressed. Round whitefish *(Prosopium cylindraceum)* numbers are stable. The shortnose cisco *(Coregonus reighardi)* is probably now extinct in the Lake-no specimens were found in recent surveys.

Cool-Water Fishes

Although the walleye is an important member of the Lake Huron cool-water fish community, its abundance remains well below fishery objectives. The walleye harvest was stable in 1988-92 but averaged only 20% of the fishery objective of 700,000 kg. An average of 1.6 million walleye fingerlings has been stocked in the Lake by all fishery agencies in 1988-92. Naturally reproducing populations of walleyes are found throughout the lake and most reproduction is in northern areas.

The 1992 commercial and sport harvest of yellow perch from the Lake exceeds the fishery objective, but the average harvest in 1988-92 represented 72% of the yield objective. The actual harvest of perch may be equal to or greater than the commercial harvest because the ice-fishery sport harvest is seldom surveyed. Yellow perch from Saginaw Bay grow slower than fish from other areas of the Lake-apparently due to a shortage of preferred invertebrates. Restoration of *the* burrowing mayfly *(Hexagenia* spp,) population appears to be essential to restoring normal perch growth in Saginaw Bay.

The northern pike is a prominent predator and popular sport fish and is found where suitable vegetation exists for reproduction and rearing of young and where water levels allow adults access to spawning areas. The harvest of northern pike from Lake Huron represents approximately 70% of the fish-community objective of 100,000 kg. Information on muskellunge is scarce and mainly anecdotal.

Lake sturgeon populations remain at low abundance and the species continues to be listed as threatened in Michigan waters. Management plans are being developed to assist in restoration of the sturgeon.

Warm-Water Fishes

The current average harvest of channel catfish is 30% greater than the fishery objective of 200,000 kg. Almost 90% of the channel catfish harvest comes from Saginaw Bay.

Populations of centrarchids are sufficient to produce recreationally attractive fisheries in the Lake. The smallmouth bass is probably the single most important fish species to the sport fishery in Ontario waters and is one of the top ten fish species caught by *Michigan* anglers. Rock bass *(Ambloplites rupestris)* made up 75% of the harvest of all centrarchids from Michigan waters in 1986-88.

Prey Species

Species that serve as food for the Lake's predators include the rainbow smelt, alewife, bloater, slimy sculpin (Cottus *cognatus),* deepwater sculpin *(Myoxocephalus thompsoni),* ninespine stickleback *(Pungitius pungitius),* threespine stickleback *(Gasterosteus aculeatus),* and trout-perch *(Percopsis omiscomaycus).* The biomass of bloaters eclipsed that of rainbow smelt and alewives during the 1980s, yet few predators appear to utilize bloaters as food. Rainbow smelt populations have been stable compared with those of the bloater and alewife. Rainbow smelt are used extensively as food by the Lake's predators. The adult population of rainbow smelt has generally been smaller since bloaters became the dominant planktivore in Lake Huron. The alewife is the least abundant of the three major prey species in Lake Huron, but it is an important component in the diet of predator species.

Sea Lamprey

The sea lamprey continues to impede achievement of other fish-community objectives. Attainment of a 75% reduction in sea lamprey abundance by the year 2000 will require an integrated program to reduce recruitment of the sea lamprey from the St. Marys River system. The number of parasitic-phase sea lampreys in Lake Huron is greater than the number of sea lampreys in all the other Great Lakes combined. The St. Marys River is probably the major source of them.

Species Diversity

The burbot is an important member of the the Lake's fish community, and its populations have been slowly recovering throughout the lake. This species consumes a wide variety of prey and, as such, is a potential competitor with lake trout and other salmonines. Burbot from Six Fathom Bank were found to consume recently stocked lake trout.

Genetic Diversity

Preservation of the Iroquois Bay and Parry Sound native lake trout stocks must be given high priority because they are locally adapted and contain some of the original Lake Huron lake trout gene pool. Genetic integrity and fitness of hatchery stocks should be a major consideration of future stocking. In addition, these stocking programs should be examined to determine its potential effects on the genetic integrity of indigenous Lake Huron fishes.

Habitat

Significant steps have been taken to protect and enhance fish habitat in Lake Huron:

- The relicensing of hydroelectric facilities in Michigan has provided a mechanism to rehabilitate degraded habitat, provide fish passage, and increase natural recruitment to the Lake.

- The Ontario Ministry of Natural Resources has embarked on an initiative to protect nearshore habitat in the Lake by identifying ecologically sensitive areas and developing a management strategy for them.

- Remedial action plans are being developed for five areas in the Lake basin where fish and wildlife uses have been impaired.

- The Saginaw Bay Watershed Initiative has been created as a significant step toward improving fish habitat and Lake Huron productivity. The initiative is a process for determining and funding environmental protection and natural-resources-management priorities by watershed.

- Several studies have been started to evaluate the effects of winter navigation on fish habitat and fish resources in the St. Marys River system.

The highest levels of contaminants in fish flesh usually occur in specific locations-not throughout the lake. Contaminant levels in Lake Huron fish are declining, but certain contaminants are still at sufficient concentrations in fish flesh to warrant consumption advisories.

HISTORY

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Introduction

Management objectives and goals for the Lake Huron fish community (DesJardine et al. 1995) were established in response to A Joint Strategic Plan for Management of Great Lakes Fisheries (Joint Plan) (Great Lakes Fishery Commission 1980). The Joint Plan charged the Lake Huron Committee (LHC) - sponsored by the Great Lakes Fishery Commission (GLFC)-to define objectives for what the fish community of Lake Huron should be in the future and to develop means for measuring progress toward the objectives. The LHC is composed of one fishery manager each from the state of Michigan, Province of Ontario, and the Chippewa-Ottawa Treaty Fishery Management Authority (COTFMA).

The overall management objective for Lake Huron is to:

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 an annual harvest of 8.9 million kg.

The target of 8.9 million kg represents the average historic commercial harvest from Lake Huron from 1912 to 1940 and is considered the best current measure of long-term harvest potential of Lake Huron. Historic commercial harvests are, at best, minimum estimates of the weight of fish removed from the lake because not all fish caught were reported.

An alphabetical list of common fish names and their corresponding scientific names are given in Table 1. The table lists all fish species referred to throughout this publication.

Table 1. Common and scientific names of fishes (American Fisheries Society 199 1) referenced in this report. An asterisk indicates that a species is extinct in Lake Huron.

Common name	Scientific name
Indigenous species	
Cold water:	
Bloater	*Coregonus hoyi*
Blackfin cisco*	*Coregonus nigripinnis*
Brook trout	*Salvelinus fontinalis*
Deepwater cisco*	*Coregonus johannae*
Deepwater sculpin	*Myoxocephalus thompsoni*
*Kiyi**	*Coregonus kiyi*
Lake herring	*Coregonus artedi*
Lake trout	*Salvelinus namaycush*
Lake whitefish	*Coregonus clupeaformis*
Longnose sucker	*Catostomus Catostomus*
Round whitefish	*Prosopium cylindraceum*
Shortjaw cisco*	*Coregonus zenithicus*
Shortnose cisco*	*Coregonus reighardi*
Cool water:	
Burbot	*Lota lota*
Crass pickerel	*Esox americanus vermiculatus*
Johnny darter	*Etheostoma nigrum*
Lake sturgeon	*Acipenser fulvescens*
Logperch	*Percina caprodes*
Longnose dace	*Rhinichthys cataractae*
Muskellunge	*Esox masquinongy*
Northern pike	*Esox lucius*
Ninespine stickleback	*Pungitius pungitius*
Sand shiner	*Notropis stramineus*
Slimy sculpin	*Cottus cognatus*
Spottail shiner	*Notropis hudsonius*
Trout-perch	*Percopsis omiscomaycus*
Walleye	*Stizostedion vitreum vitreum*
Yellow perch	*Perca flavescens*

Continued on next page

Table 1, *continued*

Common name	Scientific name
Warm water:	
Black crappie	*Pomoxis nigromaculatus*
Bluegill	*Lepomis macrochirus*
Bullheads	*Ictalurus* spp.
Gars	*Lepisosteus* spp.
Channel catfish	*Ictalurus* punctatus
Freshwater drum	*Aplodinotus grunniens*
Green sunfish	*Lepomis cyanellus*
Largemouth bass	*Micropterus salmoides*
Longear sunfish	*Lepomis megalotis*
Pumpkinseed	*Lepomis gibbosus*
Rock bass	*Ambloplites rupestris*
Smallmouth bass	*Micropterus dolomieu*
White crappie	*Pomoxis annularis*
White sucker	*Catostomus commersoni*
Non-indigenous species	
Cold water:	
Atlantic salmon	*Salmo salar*
Brown trout	*Salmo trutta*
Chinook salmon	*Oncorhynchus tshawytscha*
Coho salmon	*Oncorhynchus kisutch*
Kokanee salmon	*Oncorhynchus nerka*
Pink salmon	*Oncorhynchus gorbuscha*
Rainbow smelt	*Osmerus mordax*
Rainbow/steelhead trout	*Oncorhynchus mykiss*
Sea lamprey	*Petromyzon marinus*
Cool water:	
Alewife	*Alosa pseudoharengus*
Threespine stickleback	*Gasterosteus aculeatus*
Warm water:	
Gizzard shad	*Dorosoma cepedianum*
Common carp	*Cyprinus carpio*

This report was prepared by the Lake Huron Technical Committee (LHTC), which is charged with providing technical advice and recommendations for management of fish communities in Lake Huron to the LHC. Membership of the LHTC is composed Of

- two fishery biologists each from the staffs of the COTFMA, the Michigan Department of Natural Resources (MDNR), the Ontario Ministry of Natural Resources (OMNR), and the National Biological Service-Great Lakes Science Center (NBS);

- one biologist each from the sea lamprey control staffs of the Department of Fisheries and Oceans Canada (DFO) and the United States Fish and Wildlife Service (USFWS); and

- additional staff from the GLFC, OMNR and USFWS to serve as liaisons to the LHTC.

The LHTC was charged with producing a report on the state of Lake Huron on a regular basis. Fish-community objectives for Lake Huron serve as the basis for this state of the lake report that describes the present status of fish stocks in the Lake. The purpose of the report is to provide the mechanism by which the LHC can measure progress toward the objectives and, based on the differences between the present status of fish stocks and the long-term objectives, develop management strategies for achieving the objectives.

The time between state of the lake reports will be used by the LHTC to consolidate, analyze, and evaluate the most recent information being generated regarding the Lake Huron fish community. This report represents the first attempt at consolidating current biological information from different fishery-management agencies on a lakewide basis for the purpose of assessing the current status and dynamics of Lake Huron fishes. Berst and Spangler (1973) provided an excellent overview of the ecology of the Lake Huron fish community through 1970, and Spangler and Collins (1992) described the fishery-community structure of Lake Huron between 1958 and 1968, but no comprehensive review has been done since then. This report is intended to provide a broad overview that can be understood by both scientists and the general public.

Measuring progress toward achieving specific objectives will require a knowledge of:

- fish-population statistics and dynamics,
- food-web dynamics and energy transfer,
- commercial and sport harvests,
- allocation of fish mortality among natural, sea lamprey-induced, and fishing components, and
- habitat inventory.

The LHTC will be responsible for providing this to the LHC and the Great Lakes community.

Background

Description of the Lake Huron Basin

Lake Huron lies in the center of the Great Lakes and receives the discharge of both Lakes Superior and Michigan (Fig. 1). It is the third largest of the Great Lakes with a total volume of 3,540 km^3 and a surface area of 59,596 km^2 (Table 2). Three-quarters of the Lake's shoreline and two-thirds of the drainage area are in Canada. Manitoulin Island and the Bruce Peninsula divide the lake into three discrete basins:

- the North Channel,
- Georgian Bay, and
- the main basin of Lake Huron.

The main basin of the lake also includes the extensive shallow-water area of Saginaw Bay. Lake Huron receives the outflow from Lake Michigan through the Straits of Mackinac and the outflow of Lake Superior via the St. Marys River (Berst and Spangler 1973).

Table 2. Morphometry and hydrology of Lake Huron. Data from Herdendorf et al. (1992), Berst and Spangler (1973), and Beeton and Chandler (1966).

Parameter	Metric units	English units
Maximum length	332km	206mi
Maximum breadth	295km	183mi
Shoreline length	6,157km	3,848mi
Lake volume	3,540km^3	850 mi^3
Surface area	59,596km^2	23,020 mi^2
Drainage area	190,900h^2	73,738 mi^2
Maximum depth	229 m	751ft
Mean depth	59m	195ft
Mean discharge	5,036 m^3/s	177,900 cfs

Lake Huron lies within three distinct geologic formations. Along the North Channel and northeastern side of Georgian Bay the bedrock is composed mainly of Precambrian Shield. A Niagara limestone formation extends northwest from the Bruce Peninsula through Manitoulin Cockburn, and Drummond Islands to the Straits of Mackinac. The remainder of Lake Huron lies mainly within the Paleozoic rock formation. The northern portion of the Lake Huron watershed is forested land; the lower portion is farmland (Berst and Spangler 1973). The Lake Huron basin ranks second lowest of all the Great Lakes in number of human inhabitants (2.69 million). The Saginaw Bay basin contains 37% of the inhabitants (1 million).

Lake Huron is classified as an oligotrophic lake. Total dissolved solids (TDS) average approximately 110 ppm and these levels are intermediate between Lake Superior (<60 ppm) and Lake Ontario (>180 ppm) (Francis et al. 1979). Water clarity varies among and within the three basins of Lake Huron, but visibility in the open waters is 10-11 m (Johnson et al. 1987). Thermal stratification of the water column occurs in each of the three basins and in outer Saginaw Bay. The main basin of Lake Huron usually remains ice free in the winter except near shore. Pack ice covers Georgian Bay, and the North Channel freezes completely. Historic fish production from Lake Huron averaged 1.6 kg/ha (Berst and Spangler 1973).

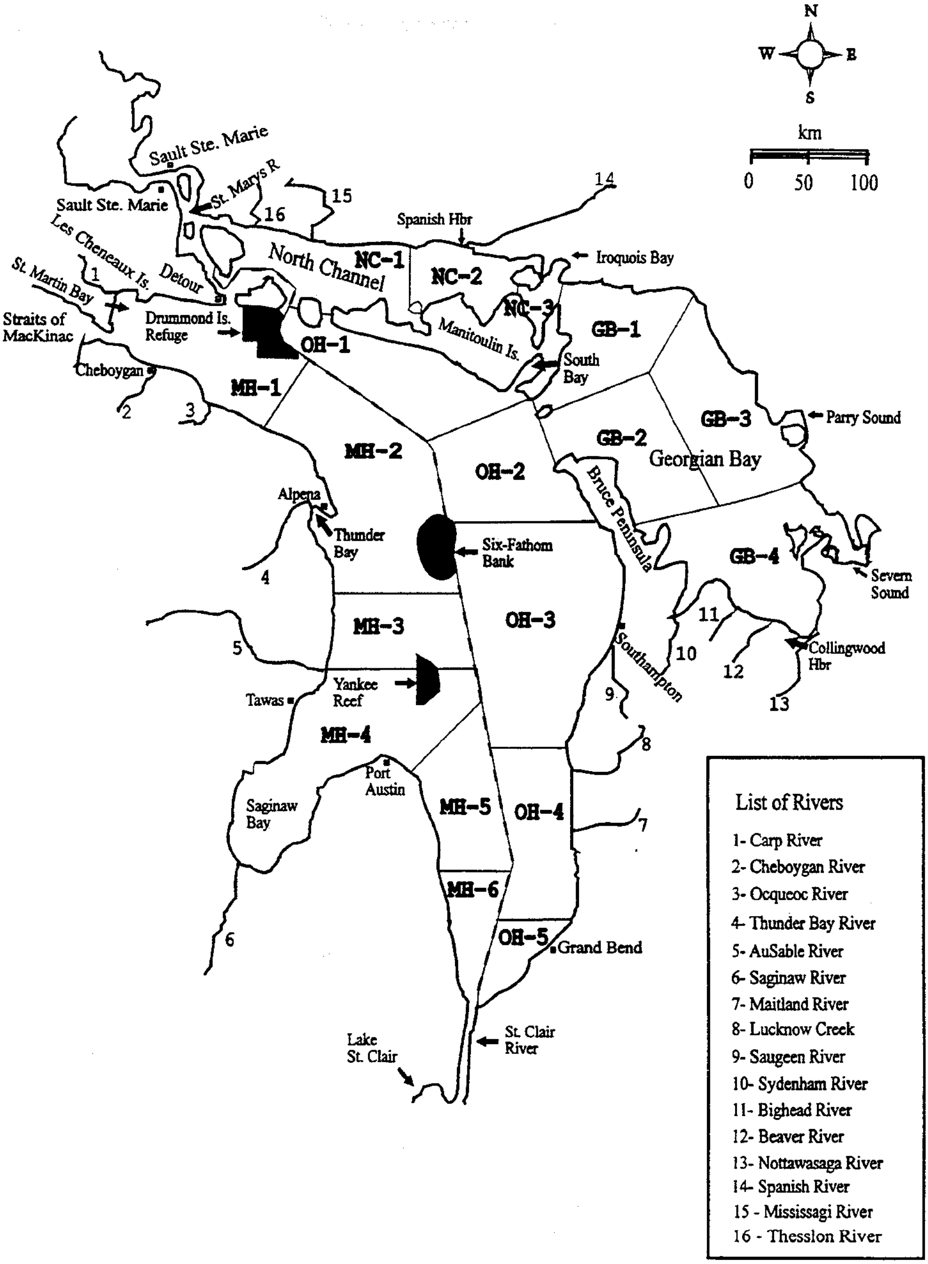

Fig. 1. Lake Huron basin with statistical districts in bold.

Historic Fish Community

The original fish community of Lake Huron was diverse with abundant populations of cold-water and cool-water species, and lesser amounts of warm-water fish (Table 1).

- Cold-water species like the lake trout, lake whitefish, deepwater ciscoes, burbot, longnose sucker, and deepwater sculpin were the predominant, deepwater fish species in all three basins of Lake Huron.

- Walleye, northern pike, lake sturgeon, muskellunge, and yellow perch were the abundant cool-water species inhabiting each basin.

- Smallmouth bass, largemouth bass, bullheads, rock bass, pumpkinseed, white crappie, white sucker, and freshwater drum were the principal warm-water fish species of the Lake and inhabited mainly the near-shore, warmer areas of the open lake and the bays.

During the early period of European settlement in North America, various Native American tribes depended upon the abundant fish species in Lake Huron as a source of food and trade. Accounts of Native American fishing activities in the Straits of Mackinac in 1695 (Kinietz 1940) described catches of

> *a large number of trout, that weigh up to fifty livres and that the sturgeon, pike, carp* [suckers], *herring, dory, and a hundred different kinds of fish abound there.*

The lake whitefish was reported to be very abundant in the rapids of the St. Marys River at Sault Ste. Marie (Fig. 1) and the size of the run there attracted a large number of people to the banks of the stream.

Composition and abundance of the Lake Huron fish community have changed dramatically in this century (Smith 1968, 1972; Berst and Spangler 1973; Hartman 1988). Native American tribes were involved in some form of commercial fishing as early as the 1700s but large-scale non-Indian commercial fishing did not begin until the mid-1800s (Kinietz 1940; Berst and Spangler 1973). The annual commercial harvest from Lake Huron was fairly constant from the early 1900s through 1930-averaging approximately 9 million kg (Fig. 2). Lake trout, whitefish, lake herring, lake sturgeon deepwater ciscoes, and walleyes were the primary targets of the fishery during the early 1900s. From 1930 to 1966, total commercial harvests declined continuously from a high of 11 million kg to a low of 3.6 million kg. By 1966, lake trout were extinct in Lake Huron except for two small populations in Canadian waters. Four species of deepwater ciscoes had become extinct in the Lake (Bailey and Smith 1981), and populations of whitefish, lake herring, and walleyes were all severely depressed by the 1960s (Berst and Spangler 1973). Exotic species like the rainbow smelt and alewife thrived in Lake Huron as a result of the demise of the indigenous species (Berst and Spangler 1973).

The dramatic changes in the Lake Huron fish community in this century were the result of excessive fishing, habitat deterioration, and invasions and introduction of exotic species. Overexploitation was implicated in the decline or extinction of sturgeon deepwater ciscoes, whitefish, lake trout, and lake herring (Van Oosten et al. 1946; Berst and Spangler 1973; Brown et al. 1987; Eshenroder et al. 1992). Habitat loss, combined with overfishing, was instrumental in the collapse of lake herring and walleye populations in Saginaw Bay (Keller et al. 1987). Loss of access to spawning grounds also contributed to the demise of sturgeon.

The final insult to the Lake Huron fish community was the invasion or introduction of exotic species like the sea lamprey, alewife, and rainbow smelt. These three species were ocean-dwelling fish that gained access to Lake Huron during this century either:

- as a result of construction of the Welland Canal that bypasses Niagara Falls (sea lamprey and alewife), or

- from intentional introduction (rainbow smelt).

Population sizes of these exotic species increased tremendously and resulted in direct or indirect interaction with indigenous species that were under considerable stress because of overfishing and habitat loss. The sea lamprey was first observed in Lake Huron in 193 1 (Smith and Tibbles 1980). By the 1960s, sea lamprey predation was considered the leading cause of the collapse of most fish species in the Lake (Berst and Spangler 1973; Coble et al. 1990) - although the debate is not over (Eshenroder et al. 1992). The collapse of the lake trout and burbot populations from sea lamprey predation drastically reduced predation pressure on the alewife and rainbow smelt, and the two prey species flourished. The rainbow smelt and alewife have been implicated in the demise of whitefish, ciscoes, and yellow perch through predation and/or competition with young fish (Smith 1970).

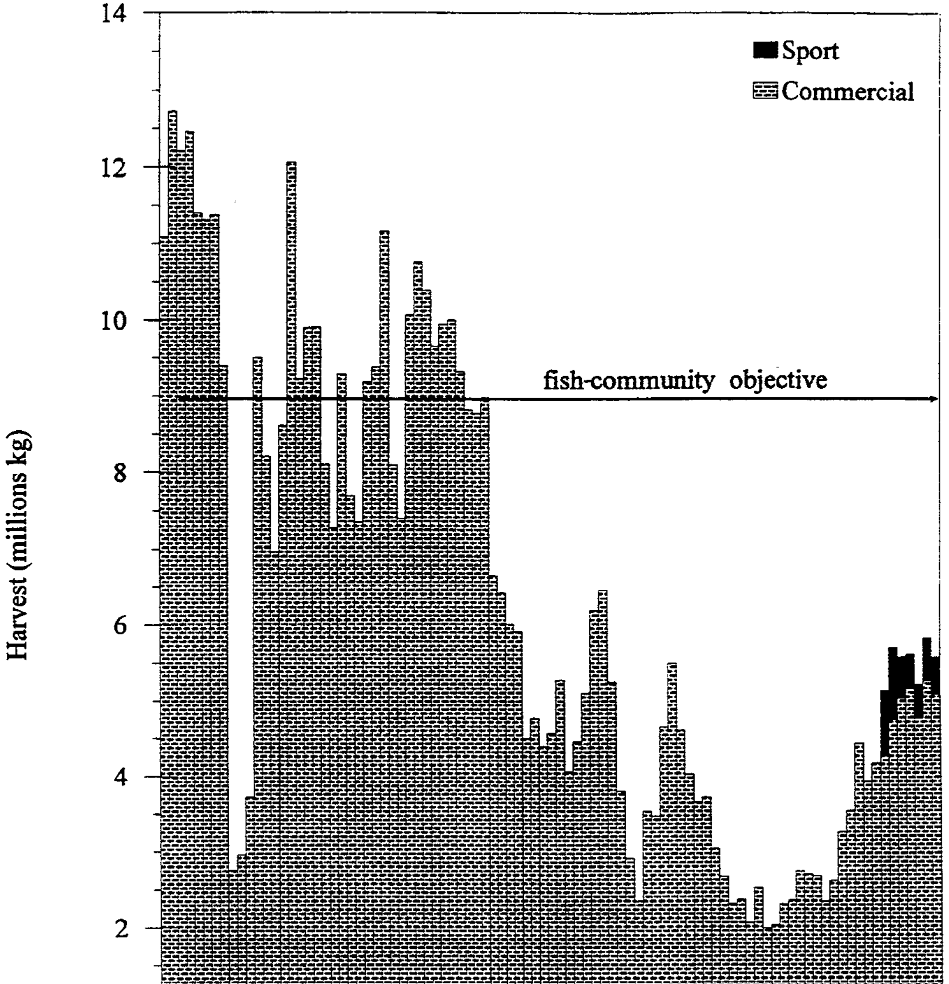

Fig. 2. Annual fish harvests from Lake Huron by commercial and sport fisheries, 1901-92 (some data for 1909-11 are missing).

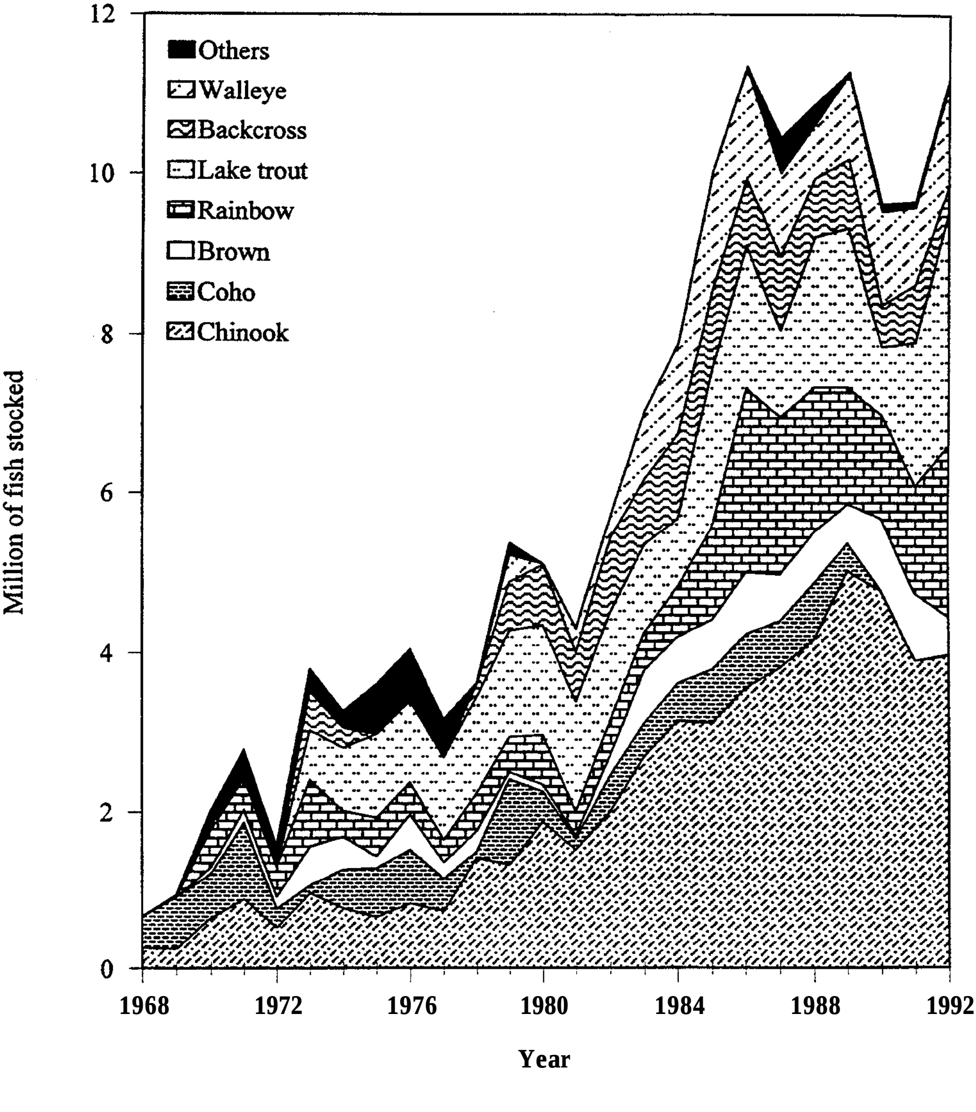

Fig. 3. Predatory fish of various species stocked annually in Lake Huron, 1968-92.

Active fishery management was begun in the late 1960s in response to the deterioration of the Lake Huron fish community. Sea lamprey control lakewide was begun in 1970 (Smith and Tibbles 1980). Commercial fisheries were severely restricted, both as to number of licenses and areas of operation, by the state of Michigan (Keller et al. 1987) and the Province of Ontario. Massive stockings of, first, coho salmon and then, chinook salmon (Fig. 3) were undertaken to control expanding populations of rainbow smelt and alewives. The process of rehabilitating lake trout populations to self-sustainability began with the stocking of hatchery-reared fish in 1973 (Appendix).

STATUS OF THE COLD-WATER FISH COMMUNITY IN 1992

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Salmonine Community

The present salmonine community of Lake Huron includes lake trout, chinook salmon, coho salmon, pink salmon, Atlantic salmon, rainbow trout, brown trout, and brook trout. Lake trout and brook trout are the only salmonines indigenous to Lake

Huron-all the others were introduced. The kokanee salmon, a freshwater form of sockeye salmon, was stocked in Ontario waters of Lake Huron from 1965 to 1972 (Collins 1971), but there have been no confirmed sightings of kokanees in the lake in the last 10 yr.

The fishery objective is to establish a diverse salmonine community that can sustain an annual harvest of 2.4 million kg, with lake trout as the dominant species and anadromous (stream-spawning) species also having a prominent place. The reported total harvest of salmonines from Lake Huron in 1992 was 1 million kg and represents 42% of the fishery objective. Lake trout made up only 13% of the total salmonine harvest in 1992.

Lake Trout

The lake trout is envisioned as being the most abundant predacious salmonine species present in the future Lake Huron fish community. It was the dominant predator in Lake Huron before the collapse of various stocks during the 1940s because of a combination of overfishing and sea lamprey predation. By the 1960s, only two remnant populations of lake trout survived in the Lake:

1) in Iroquois Bay in the North Channel,

2) in Parry Sound in Georgian Bay (Fig. 1).

Present populations of lake trout in Lake Huron are supported almost entirely by stocking of hatchery-reared fish.

Stocking

After the onset of sea lamprey and fishery controls in the late 1960s, state, federal, and provincial fishery agencies began promoting the rehabilitation of lake trout populations in Lake Huron by annually stocking yearling and fingerling fish. Since 1969, the following forms have been stocked into Lake Huron (Appendix):

- 27.6 million pure lake trout,

- 3.6 million splake (male brook trout x female lake trout), and

- 11.6 million backcrosses (splake x lake trout).

Lake trout have been stocked into Michigan waters at an annual rate of approximately 1.2 million fish. More than 600,000 splake, lake trout, and backcrosses have been stocked annually into Ontario waters of Lake Huron since 1978-principally in waters of the North Channel and Georgian Bay. Little to no stocking has been done in the main basin of Ontario waters. The stocking of splake in Ontario waters of Lake Huron has been discontinued and annual stockings of backcrosses have been declining since 1984.

A comprehensive lakewide-management plan for rehabilitation of lake trout in Lake Huron was developed in 1985 to promote interagency coordination for the rebuilding of self-sustaining lake trout populations. A fundamental part of the rehabilitation plan was the establishment of a stocking protocol within prioritized areas of the Lake (Fig. 4).

- High-priority units are to be stocked at 1.5 lake trout/acre of water <73 m deep.

- Low-priority areas are to be stocked at 1 fish/acre.

Deferred rehabilitation units are not stocked with lake trout. A maximum of 4.64 million lake trout (2.85 million for Michigan waters and 1.8 million for Ontario waters) is to be stocked in Lake Huron annually under the rehabilitation plan. Stocking goals called for in the rehabilitation plan have never been met because of difficulties in producing enough hatchery-reared fish for stocking.

A second part of the rehabilitation stocking plan was evaluation of how well various strains, or forms, of lake trout survive and reproduce in Lake Huron.

- A refuge was established along the southern shore of Drummond Island in northern Lake Huron for evaluating the effects of exceptionally high sea lamprey predation on an unfinished population of lake trout.

- A second special rehabilitation area was created around Six Fathom Bank in central Lake Huron (Fig. 1) to evaluate the ability of various strains of lake trout to survive and reproduce on an historically used, offshore, very large spawning reef.

The various strains of lake trout stocked in the refuge and at Six Fathom Bank have been marked with coded-wire tags to aid in identification of each strain when the fish are caught later.

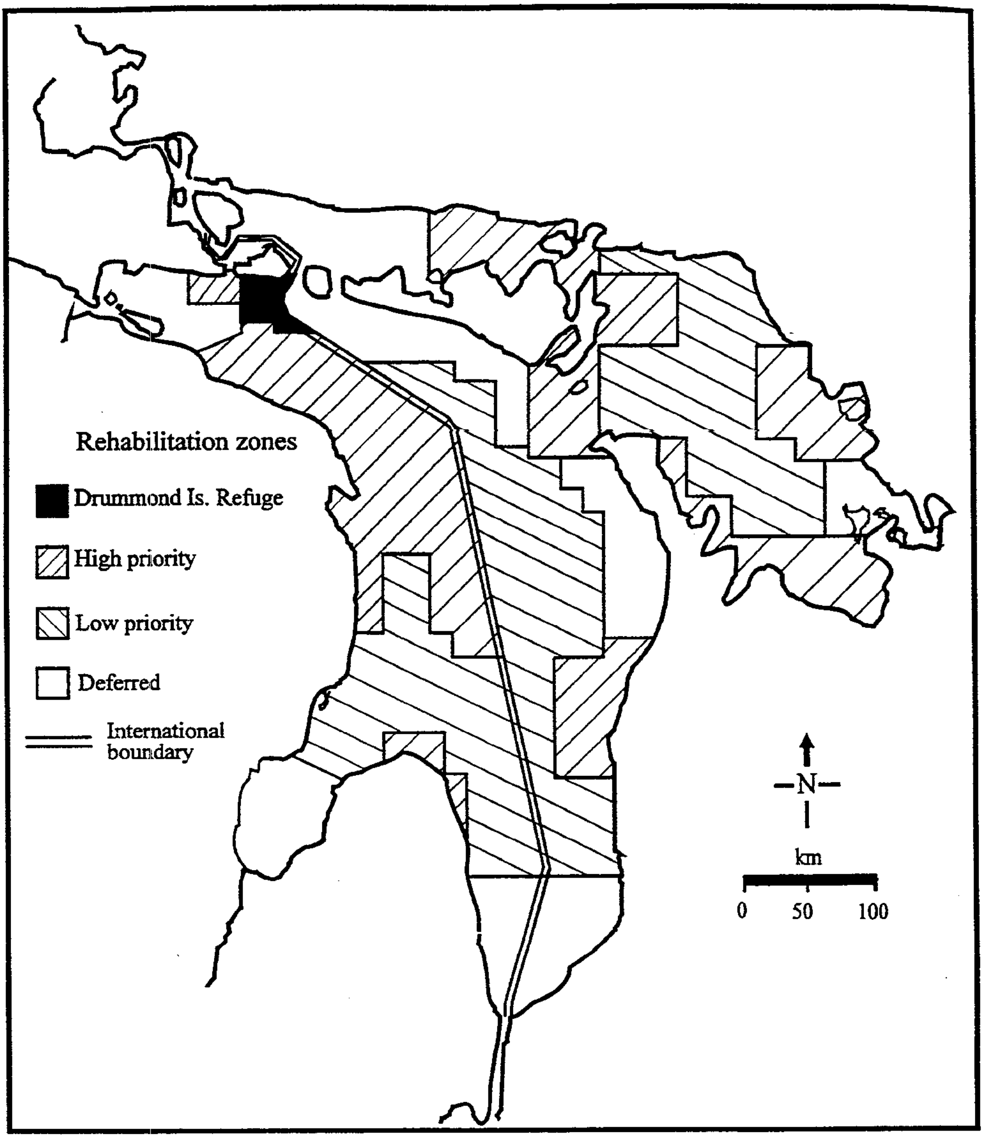

Fig. 4. Lake trout-rehabilitation zones in Lake Huron and priority classification of each zone.

Harvest

The future lake trout population of Lake Huron is expected to be capable of sustaining yields approaching 1.4 to 1.8 million kg-approximately two-thirds of the historic commercial harvest, which averaged 2.4 million kg between 19 12 and 1940 (Baldwin et al. 1979; Hartman 1988). The lake trout harvest from Lake Huron averaged 204,000 kg in 1986-92-20% of the lake trout-rehabilitation goal and 10% of the historical harvest. Data on the recreational harvest from Michigan and Ontario waters are, however, incomplete-actual harvests are, therefore, greater than reported here.

The structure of the lake trout fishery has changed considerably since the late 1960s, which makes historic and current harvests not directly comparable. During the early part of this century, commercial fisheries licensed by the state of Michigan and Province of Ontario were almost the only fisheries for lake trout from Lake Huron. Currently, fish are harvested by:

- Ontario and Michigan Native American (mostly commercial) fishers,
- Province of Ontario licensed commercial fishers, and
- Michigan and Ontario recreational fishers.

Michigan's state-licensed commercial fishery is not permitted to harvest lake trout. In addition, current commercial fisheries are greatly reduced in size compared with the fisheries that existed between 1912 and 1940. In addition, there are limits on the number of lake trout that can be harvested.

Abundance

Progress of lake trout rehabilitation is assessed by all agencies through index netting and monitoring of the recreational and commercial fisheries. Index gillnet fishing for lake trout (Fig. 1) is conducted annually by the:

- OMNR in the southern portion of Georgian Bay,

- MDNR at four stations from MH-1 through MH-4,

- NBS at Six Fathom Bank and Adams Point, and

- COTFMA in the Drummond Island Refuge.

Abundance of fish caught by index gillnets is expressed as the number of fish caught per 1,000 m of net lifted.

Changes in abundance of lake trout in the Lake are influenced by stocking, fishing, sea lamprey predation, and survival of stocked fish before vulnerability to sea lampreys or the fisheries. Abundance of lake trout throughout Michigan waters has been declining at approximately 12% per year since 1977-although stocking of this species has remained at approximately 1.2 million fish annually (Fig. 5). Abundance of lake trout in Georgian Bay waters (GB-4) has been highly variable and appears to be related to the number of lake trout stocked in Ontario waters.

Factors influencing abundance of lake trout vary among areas in Michigan waters of Lake Huron. To evaluate the effects of stocking hatchery-reared lake trout on subsequent abundance, the 3-yr average catch rate (fish/305 m of net) was examined in relation to average stocking rates for the previous 10 yr. In northern waters (MH-1), abundance of lake trout declined from 198 1 to 1992 even though numbers of fish stocked remained constant (Eshenroder et al., in press), which suggests that sea lamprey-induced and fishing-related deaths are high in the north. In central waters (MH-2), abundance of lake trout was not related to number of fish stocked there since 198 1, which may indicate that either survival of recently stocked hatchery lake trout is poor or that large numbers of fish move out of the area. MDNR index gillnet fishing in the early 1970s indicated movement was substantial from MH-2 into MH-1. In south-central areas (MH-3 and 4), abundance of lake trout appears to correlate well with stocking of hatchery-reared fish (Eshenroder et al., in press).

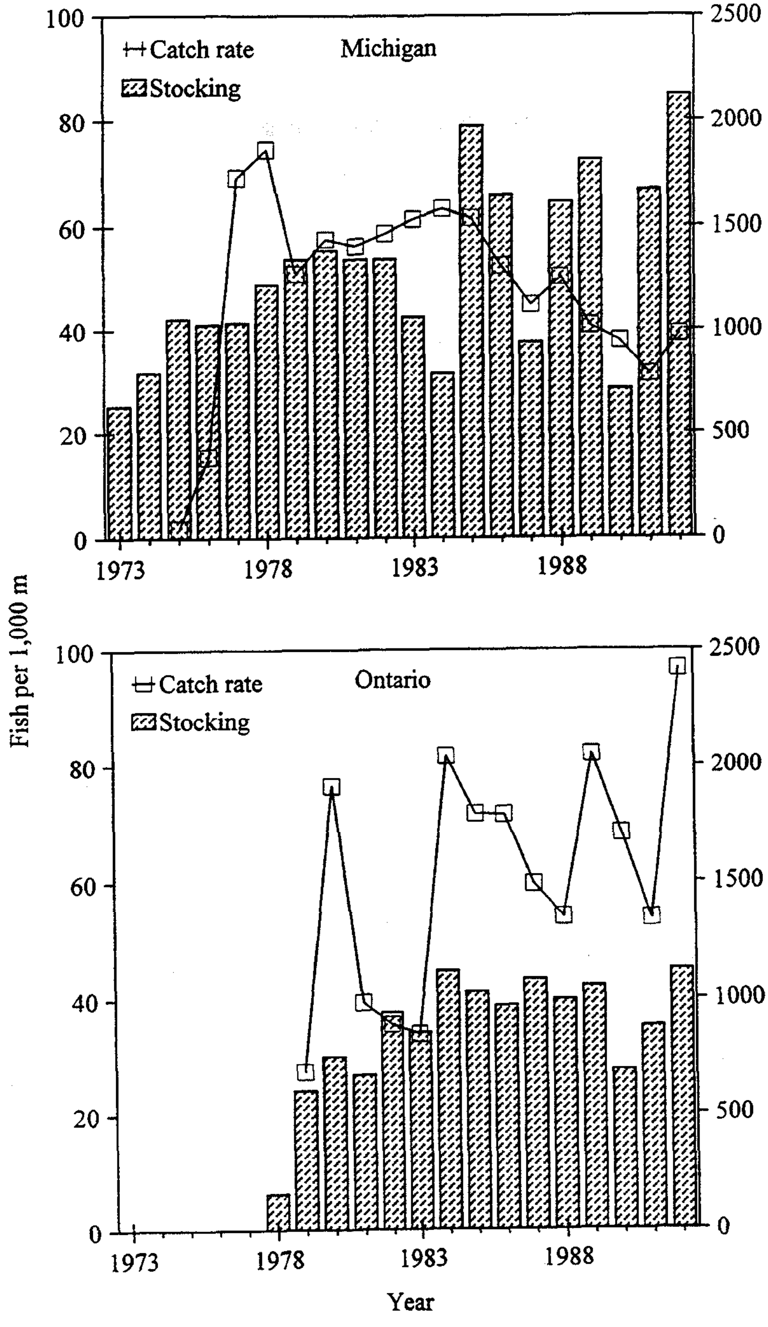

Fig. 5. Relative abundance of lake trout caught during index gillnet surveys **and the** number of lake trout stocked annually in Michigan and Ontario waters of Lake Huron, 1973-92.

Survival

Survival of lake trout in Michigan waters of Lake Huron increases from northern to southern areas. In MH-1, lake trout survive well to age 4 but not beyond. In MH-3 and 4, lake trout age 5 and older have been well represented in gillnet catches (Fig. 6). Survival is evidently relatively high for younger fish in the north but it declines rapidly with age.

The low survival of lake trout in northern Michigan waters and high survival of fish in southern waters is reflected in computations of total annual mortality (proportion of the population dying annually). The lake trout-rehabilitation plan states that total annual mortality of lake trout in Lake Huron should not exceed 40% in areas where sea lamprey wounding is less than 5% and should not exceed 45% in areas where sea lamprey wounding exceeds 5%. Estimated mortality rates in most areas of the Lake, except southern waters, are in excess of 45% and increase from southern to northern waters (Table 3).

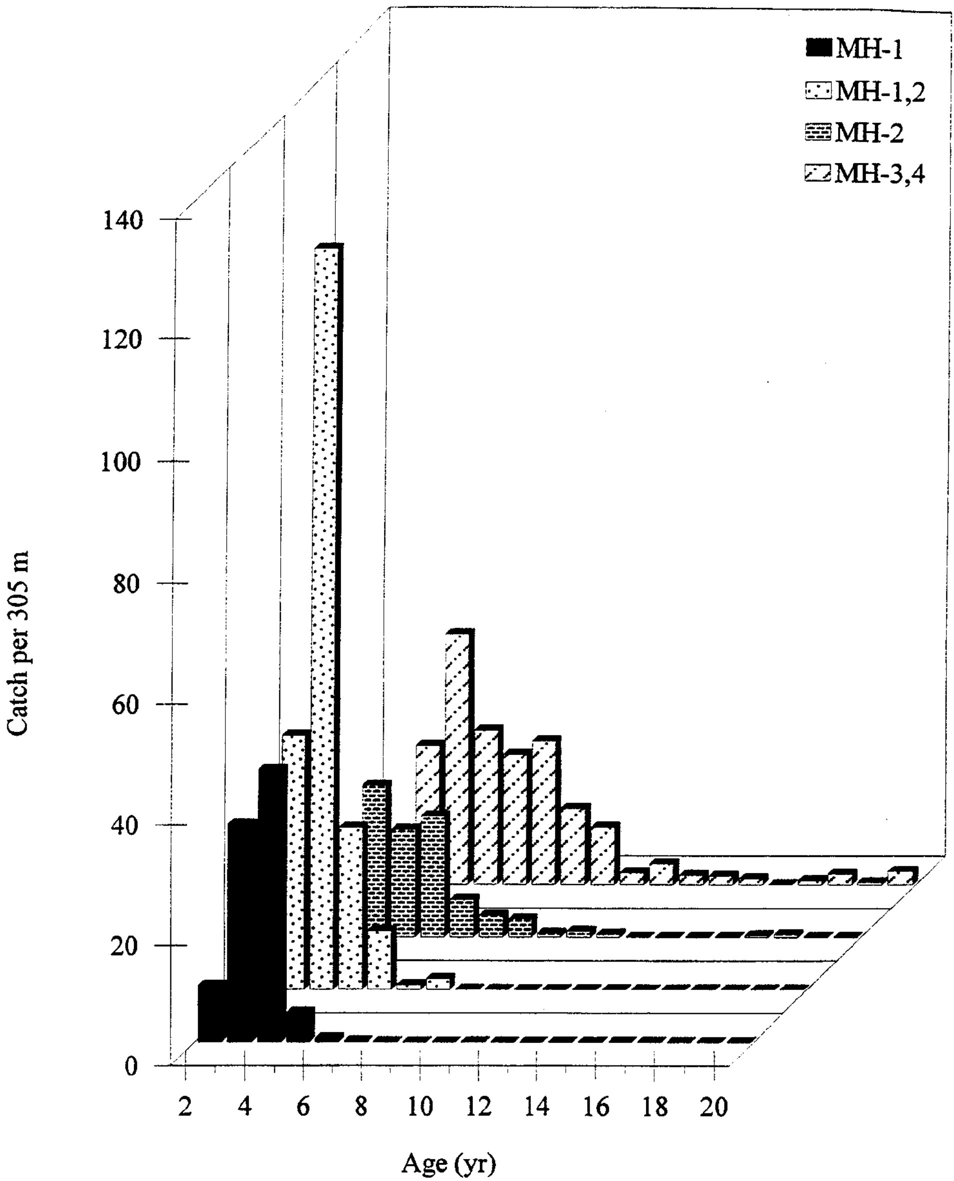

Fig. 6. Age composition of lake trout caught during index gillnet surveys in selected statistical districts from Michigan waters of Lake Huron, 1990-92.

Table 3. Total annual mortality (%) of lake trout in statistical districts of Lake Huron, 1982-92.

Yr	MH-1	MH-2	MH-3	MH-4	GB-4	NC-3
1982-86	76	49	42	28		
1984-85	-	-			64	100
1985-86					49	83
1986-87	87			36	73	
1987-88	76			40	76	53
1988-89	89	52	43	37	43	75
1989-90		52	47	46	78	48
1990-91	>70	35	43	31	71	
1991-92					27	
Mean	>70	47	44	36	60	60

Growth

Growth of lake trout in Michigan waters of Lake Huron also changes from north to south. Lengths at age 5, averaged during the last 3 yr of survey data, were:

- 48 cm in MH-1,
- 53 cm in northern MH-2,
- 55 cm in central MH-2,
- 58 cm in offshore areas of MH-2, and
- 59 cm in MH-3 and 4.

Long-term growth (expressed as length at age in the index gillnet fishery) declined somewhat from 1977 to 1987 but has increased slightly or not changed noticeably since 1988 (Fig. 7). This pattern suggests that lake trout populations are not approaching carrying capacity.

Length-weight relations were used to compute the weight of an average lake trout 60 cm long at various gillnet sites. The computed weights averaged approximately 2.2 kg. The computed weight of a backcross 60 cm in length was approximately 2.5 kg, which is greater than the computed weight of a lake trout-backcross have a more robust condition than lake trout.

Food Habits

Alewives and rainbow smelt are the preferred foods of lake trout in Lake Huron, but other food items (sculpins, trout-perch, sticklebacks, whitefish, deepwater ciscoes (chubs), other salmonines, crustaceans, and other invertebrates) are also found in the lake trout diet. Alewives and rainbow smelt have made up approximately 90% of the identifiable food items found in the stomachs of lake trout caught in spring gillnet surveys in Michigan since 1981. Since 1989, however, alewives have made up a larger proportion of the lake trout diet than smelt. From 1981 to 1988, rainbow smelt made up 57% and alewives 34%, by number, of the diet of lake trout in Michigan waters. After 1989, alewives made up 57% and rainbow smelt 34% of the diet of lake trout.

The degree to which lake trout use rainbow smelt and alewives varies from northern to southern Michigan waters of Lake Huron. Alewives made up:

- 88%, by number, of the lake trout diet in southern Michigan waters (MH-3 and 4),
- 78% in central Michigan waters (MH-2), and
- 41% in northern Michigan waters in 1992.

The proportion of rainbow smelt in the diet increased from 12% in southern Michigan waters, to 22% in central waters, and 49% in northern waters. Slimy and deepwater sculpins, trout-perch, and ninespine sticklebacks all made significant contributions to the diet of lake trout from northern Michigan waters.

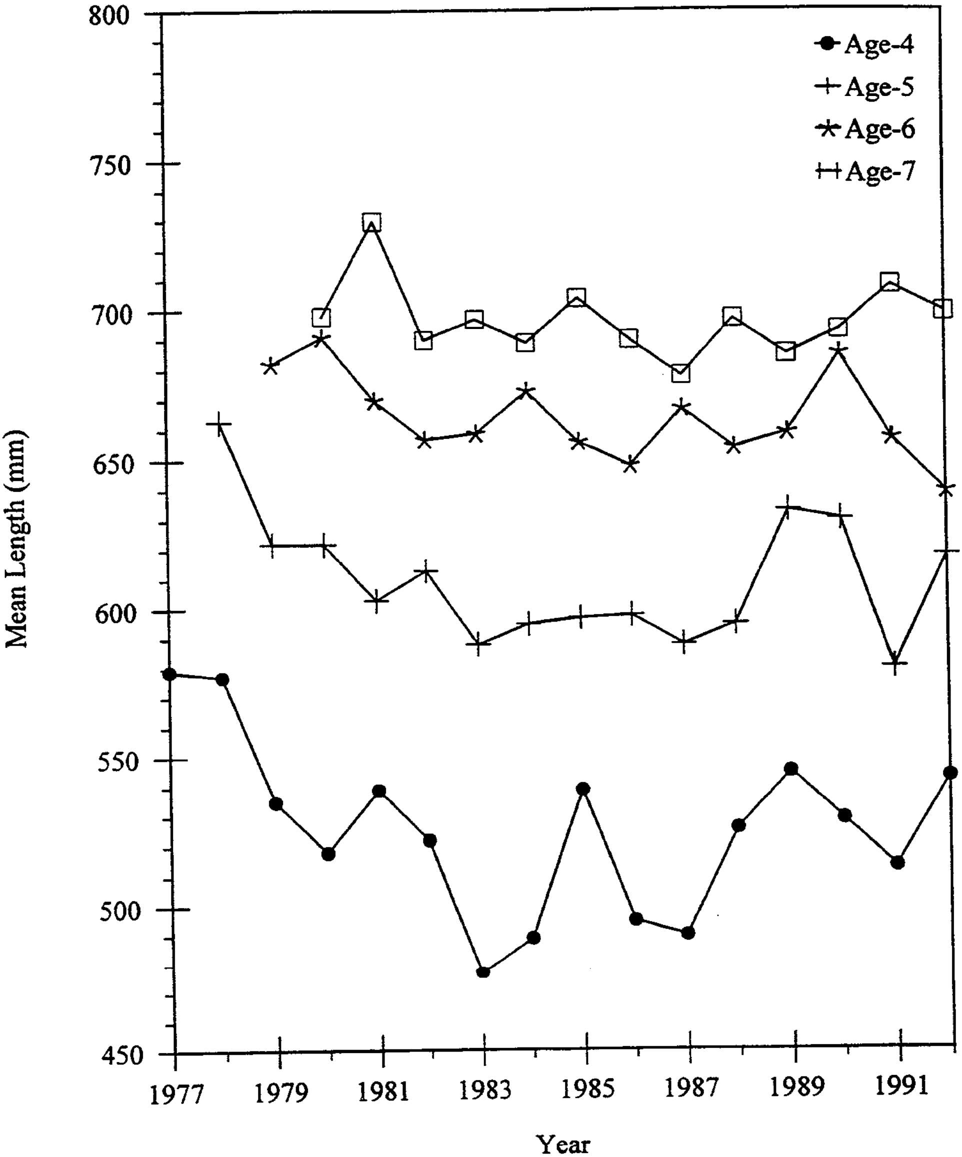

Fig. 7. Mean length at age of lake trout captured during index gillnet surveys in southern Michigan waters of Lake Huron, 1977-92.

Reproduction

Information on natural reproduction of lake trout in Lake Huron has been collected through:

- bottom trawling,
- index gillnet fishing, and
- monitoring of recreational and commercial fisheries.

Sizes and ages at which lake trout reach full sexual maturity in Lake Huron vary by sex-averaging approximately 59 cm, total length, for males and 70 cm for females. Full sexual maturity begins at approximately age 7 for male lake trout and age 9 for female lake trout. Fish from southern waters mature at an earlier age than fish from northern waters because of faster growth rates in southern waters.

The first evidence of lake trout reproduction in Lake Huron was obtained in the spring of 1981 when fertilized eggs were found near Rockport north of Alpena, Michigan (Nester and Poe 1984). In 1983, 5 age-2 unclipped lake trout were taken in the same area. Since 1984, age-0 lake trout have been taken regularly by bottom trawls in the Thunder Bay area. Nearly all of the lake trout reproduction occurring in Michigan waters of Lake Huron is centered in the Thunder Bay area, despite the presence of more abundant adult populations in southern areas of the lake (MH-3 and 4). Measurable year-classes of age-0 lake trout were produced in MH-2 by very small populations of fish spawning for the first time (Eshenroder et al., in press). Catch rates of age-0 lake trout near Thunder Bay declined from 2.6 fish/trawl tow for the 1986 year-class to 0.2 fish/trawl tow for the 1991 year-class.

Spawning lake trout can be found on various reefs in Lake Huron, but only one spawning reef is known to contain wild fish. Increasing numbers of wild lake trout in spawning condition were caught during gillnet surveys on a reef near the center of Thunder Bay in 1991 and 1992. Several other reefs near Thunder Bay sampled in 199 1 and 1992 were either unoccupied or were occupied only by hatchery-reared lake trout.

Appreciable numbers of lake trout in spawning condition have also been captured on Six Fathom Bank and in the Drummond Island Refuge, but these were nearly all fish of hatchery origin. Catch rates of spawning lake trout averaged:

- 9 fish/305 m in the Drummond Island Refuge, 199 l-92, and

- 40 fish/305 m on Six Fathom Bank in 1992.

Large numbers of spawning lake trout also concentrate on an artificial reef near Tawas, Michigan. Lake trout eggs and emergent fry have been collected on this reef (Foster and Kennedy, in press).

Some reproduction of lake trout is also occurring in South Bay, Manitoulin Island (Fig. 1). Emergent fry traps caught 0.5-3.5 age-0 fish/trap annually before 1992. In 1992, trap catches increased to 8.6 age-0 fish/trap, or approximately 20.1 fry/m of sampled spawning substrate. Bottom trawling in South Bay has also taken age-0 to age-3 wild lake trout. Wild age-0 lake trout have been found in the stomachs of stocked yearling lake trout in South Bay. An estimated 3,000-4,000 wild lake trout are produced each year in South Bay.

Sea Lamprey Wounding

The incidence of sea lamprey wounds on lake trout in Lake Huron is derived from observed numbers of Type A, Stages I-III sea lamprey marks (Ring and Edsall 1979) per 100 lake trout caught. Sea lamprey wounding of lake trout is measured on fish caught:

- in spring gillnet surveys,

- in commercial harvests and monitored, or

- in fall gillnet surveys.

In Michigan waters, sea lamprey wounding of lake trout declines from northern to southern areas, and wounding increases with the size of the fish (Table 4). Sea lamprey wounding of lake trout in Ontario waters has not been as high as in Michigan waters, but wounding on lake trout from Ontario's southern zone is equal to wounding of fish from Michigan's south-central basin. Wounding of lake trout generally increases with host size and is most pronounced on fish >61 cm total length. The pattern of increased sea lamprey wounding on larger lake trout conforms with laboratory observations by Swink (1991).

Sea lamprey-induced mortality of lake trout from Michigan waters of Lake Huron was determined from a statistical relation between sea lamprey wounding and the probability of surviving an individual sea lamprey attack (Koonce and Pycha 1985). The probability (Swink 1990) of surviving a single sea lamprey attack is:

- 0.35 for fish <53 cm long,
- 0.45 for fish 53-73 cm long, and
- 0.55 for trout >73 cm long.

Annual sea lamprey-induced mortality (Table 4) ranged from 24% for lake trout >73 cm in MH-2,3, and 4 to 56% on lake trout >73 cm at Drummond Island (MH-1). Sea lamprey-induced mortality on lake trout >53 cm averaged 30% throughout Michigan waters of Lake Huron in 199 l-92.

Table 4. Sea lamprey wounding of lake trout and weighted mean lamprey-induced mortality rates in Michigan waters of Lake Huron, 199 l-92. MH-1 data were collected in October from within the Drummond Island Refuge. MH-2, 3, and 4 data were collected in April and May.

District	Size group (cm)	No. of fish	Probability of survival	Wounds per fish	Lamprey mortality[1] (A_L)
MH-1	43-53	54	0.35	0.093	16%
	53-63	63	0.45	0.270	28%
	63-73	68	0.45	0.353	35%
	>73	8	0.55	1.000	56%
MH-2	43-53	120	0.35	0.046	8%
	53-63	139	0.45	0.172	19%
	63-73	113	0.45	0.338	34%
	>73	13	0.55	0.334	24%
MH-3 and 4	43-53	54	0.35	0.032	6%
	53-63	108	0.45	0.230	25%
	63-73	234	0.45	0.314	32%
	>73	105	0.55	0.335	24%

[1] $A_L = 1 - \exp(-M_i(1 - P_i)/P_i)$, where M is the marks per fish, P is the probability of surviving a single lamprey attack, and i is the size-class of fish.

Lake trout-population parameters, sea lamprey wounding data, and estimates of lamprey-induced mortality were used to model lake trout-stock *size*, harvest, and sea lamprey-induced deaths within Michigan waters of Lake Huron (Technical Fisheries Review Committee 1992). The model was used to predict future stock size and allocation of lake trout deaths based on the history of the fishery.

Two management scenarios were developed for years beyond 1992:

1) Stock lake trout according to the rehabilitation plan, reduce fishing mortality enough to bring total annual mortality to 45%, and maintain current levels of sea lamprey control.

2) Stock according to the rehabilitation plan reduce fishing, and increase sea lamprey control to bring wounding of lake trout down to 5%.

Sea lamprey predation accounted for 3 8% of all lake trout deaths in 1980-92 because many fish were taken by the fishery before they could be killed by sea lampreys. Maintaining current levels of control and reducing fishing mortality to control total mortality would result in sea lamprey predation accounting for 59% of all lake trout deaths after 1992 (Fig. 8). Losses of lake trout to sea lamprey predation would be most severe in northern Lake Huron. In the second scenario, the model predicted that with enhanced control of the sea lamprey, harvests of lake trout from MH-1,2, and 3 would approach 450,000 kg by the year 2001 (Fig. 8). Without additional sea lamprey control, the harvest of lake trout would be only 250,000 kg. Predictions after 1992 were made by maintaining current lake trout-stocking levels and reducing total annual mortality to 45% beginning in 1993 (Fig. 8).

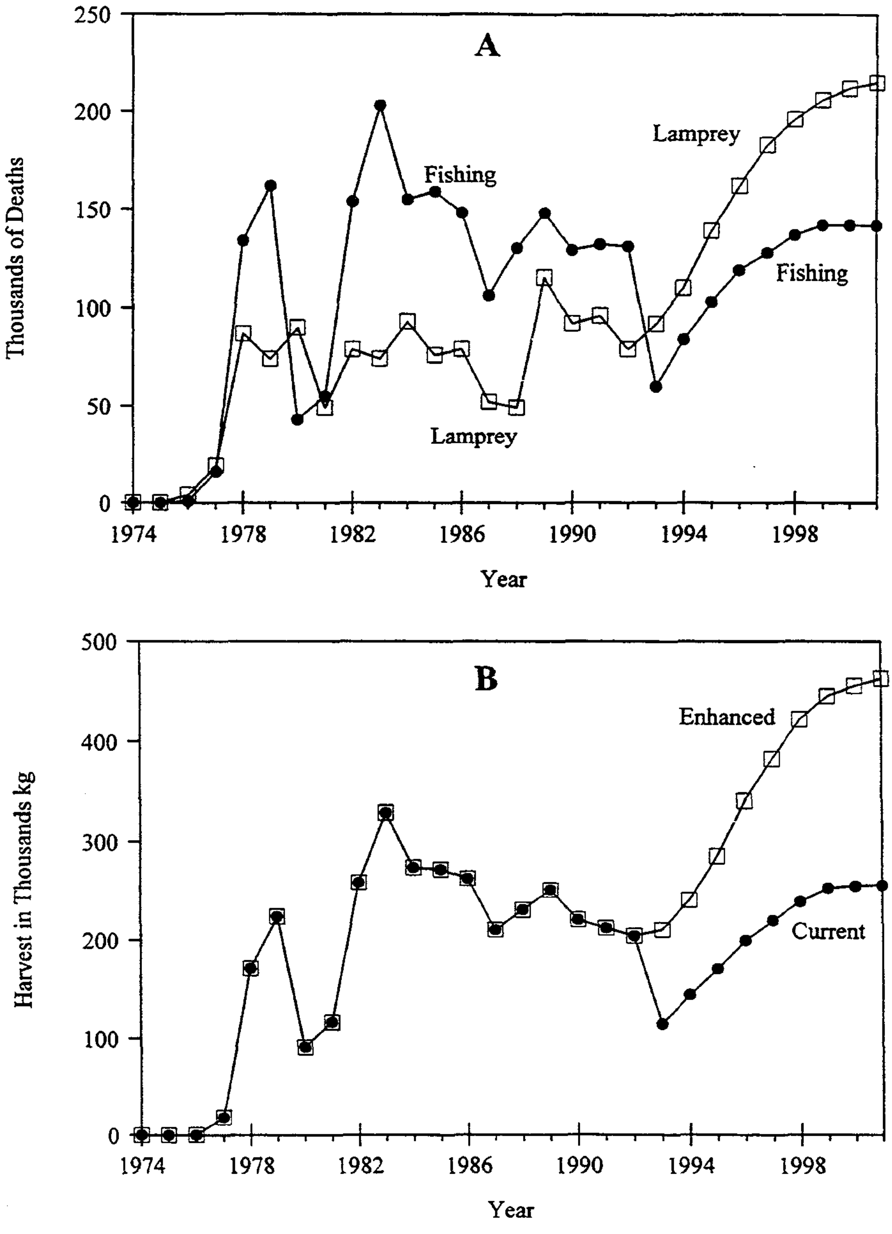

Fig. 8. Allocation of lake trout deaths (A) and harvest of lake trout (B) at current (1974-92) and enhanced (1993-2000) levels of sea lamprey control as predicted through modeling lake trout-population characteristics in Michigan statistical districts MH-1,2, and 3.

Chinook Salmon

No specific objective for chinook salmon is in the fish-community objectives for Lake Huron. Fishery agencies anticipate, however, that chinooks will be widely distributed throughout the lake and will have an important position in the future fish community.

Stocking

Chinooks were first stocked in Lake Huron in 1968 by the MDNR. Since the mid-1980s, the MDNR annually stocked approximately 3.5 million chinook salmon fingerlings into Lake Huron. The first stocking of chinooks in Ontario waters of Lake Huron was made in 1985 and was done by the Community Fisheries Involvement Program of the OMNR. Stocking since then has increased annually (Appendix). Chinooks are typically stocked at 4 mo of age when they weigh approximately 4-5 g each. Many of the fish in Ontario waters, however, are stocked as old as 9 mo and weigh an average of 10 g. Currently, the number of chinooks to be stocked lakewide has been capped at the 1990-91 levels of 4 million fish until a sound, ecologically based model capable of determining optimum stocking levels in relation to available food resources can be applied to the Lake.

Harvest

The estimated lakewide harvest of chinooks has remained fairly stable at 780,000 kg since 1986 (Fig. 9). The sport fishery accounted for nearly 50% of the chinook harvest during the mid-1980s. By the early 1990s, however, only 26% of the total harvest was made by the sport fishery. The Native American commercial harvest of chinooks from northern waters (MH-1), which consists of 99% sexually mature fish, has increased from <1% of the total harvest in 1986 to nearly 40% of the chinook harvest in 1992. The Native American harvest has increased substantially because more fish have been stocked in the area that the fishery operates in and because returns of chinook salmon to the sport fishery in southern waters of Lake Huron have apparently declined despite constant stocking in southern waters (Rakoczy 199 1). The chinook harvest at weirs and fishways in rivers and streams has fluctuated with no apparent trend in 1986-92.

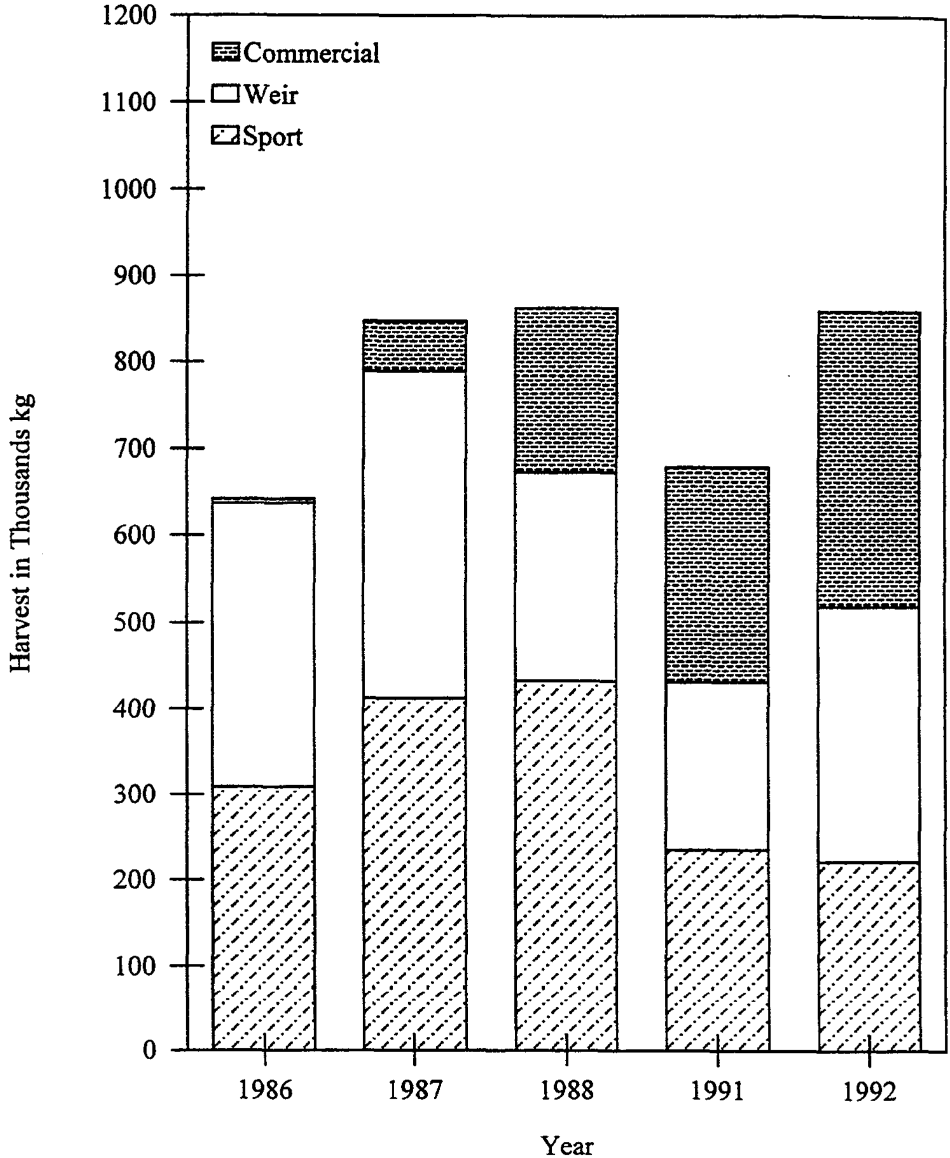

Fig. 9. Commercial, weir, and sport-fishery harvests of chinook salmon from Lake Huron, 1986-92.

No data are available to determine the sport harvest of chinook from most of the Ontario waters of Lake Huron, but a chinook sport fishery exists in the North Channel, Manitoulin Island, and Bruce Peninsula areas. The sport harvest of chinooks from southern Georgian Bay ranged from 13,600 fish in 1992 to 18,000 in 199 1. Estimates of the sport harvest from Michigan waters of Lake Huron are incomplete for several years, but creel surveys were conducted at all important ports and sport-fishing areas in 1986-88. During that time, the sport harvest of chinooks ranged from 84,390 fish in 1986 to 105,406 fish in 1988 (Rakoczy 1991).

Abundance

No data have been collected to describe abundance of chinooks in Lake Huron. The harvest of chinooks at weirs and fishways may represent the best measure of total lakewide abundance.

Survival

Survival of chinooks in Lake Huron is best described by returns to the fishery. No age-specific survival information exists for chinooks in Lake Huron. The return of chinooks to the Michigan sport fishery decreases from north to south (Rakoczy 199 1) stockings in the north contribute the largest proportion to the entire Michigan sport fishery. Marking studies indicate that chinooks provide the greatest returns to the area in which they are stocked. Returns to all Lake Huron fisheries during the life cycle of the 1984 year-class were 60 fish/1,000 stocked (Rakoczy 1991). Returns of the 1988 year-class to the gillnet fishery in northern Lake Huron were 90 fish/1,000 stocked. The rate of return of individual age classes to the sport fishery ranged from 0.3% at age 4 to 4.8% at age 1.

Growth

Most of the information on chinook growth has been obtained from fisheries that harvest sexually mature fish just before they enter rivers and streams to spawn. Mean weight of sexually mature chinooks returning to spawn in the Au Sable River did not change much between 1970 and 1980 (Fig. 10). Mean weight of the 1988 year-class returning to St. Martin Bay (MH-1) to spawn was the same as for earlier year-classes at the Au Sable River during the 1970s. The age at sexual maturity has, however, increased which suggests that lipid levels have declined since the 1970s. During the 1970s, nearly all fish reached sexual maturity by age 3. In the 1990s, however, 20% become sexually mature at age 4.

The average size of chinooks harvested from Lake Huron varies depending upon the fishery surveyed to collect the information. Lakewide average weight at age in Lake Huron is:

- 1.8 kg at age 1,
- 5.2 kg at age 2,
- 7.2 kg at age 3, and
- 8.1 kg at age 4.

The 1988 year-class of chinook salmon harvested by the commercial fishery in St. Martin Bay in 1989-92 was 33%-67% larger at a given age than was the 1984 year-class harvested by the sport fishery in Michigan waters of Lake Huron in 1985-88. Chinooks caught in the commercial fishery tend to be larger than fish caught in the sport fishery because the commercial fishery harvests only returning sexually mature fish in August, September, and October. The sport fishery harvests sexually mature fish, but also immature fish throughout the entire open-water season.

Food Habits

No systemic surveys have been done of food preferences of chinooks in Lake Huron. We believe that the alewife and smelt probably provide the basis of most chinook salmon growth after their first several months in the Lake. Rainbow smelt made up 90% of identifiable food items found in the diet of chinooks measuring 286-487 mm total length caught incidentally in the whitefish gillnet fishery between Detour and St. Ignace in 1993-94. Sticklebacks made up the majority of items found in the stomachs of adult chinook salmon from St. Martin Bay in August, 1991 (M. Ebener, Chippewa-Ottawa Treaty Fishery Management Authority, 186 East Three Mile Road, Sault Ste. Marie, MI, 49783, pers. commun.), but sticklebacks probably do not contribute much to chinook salmon growth.

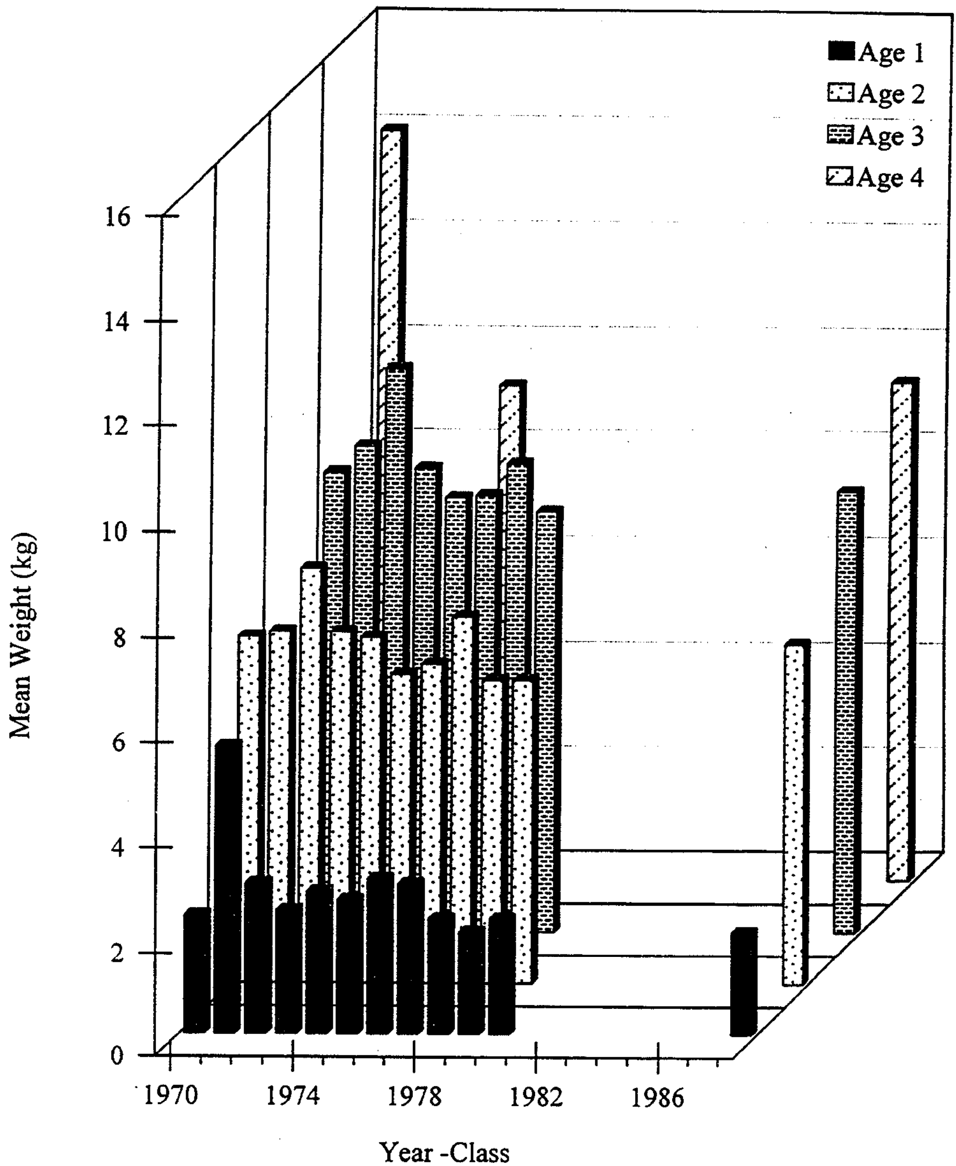

Fig. 10. Mean weight at age of the 1970-80 year-classes of chinook salmon caught during index gillnet surveys near the Au Sable River, and mean weight of the 1988 year-class of chinook harvested by the Native American gillnet fishery in St. Martin Bay, 1989-92.

Reproduction

Before the 1980s, no reproduction of chinooks was detected in Michigan tributary waters of Lake Huron (Carl 1982). Large numbers of adult chinooks have been reported in nearly all Ontario streams that have natural reproduction of steelheads. In recent years, information has been collected on natural reproduction of chinooks in Michigan tributaries. Naturally reproduced age-0 fish were captured near the Carp River in St. Martin Bay in May, 1991. These fish ranged from 35 to 55 mm in total length (M. Ebener, Chippewa-Ottawa Treaty Fishery Management Authority, 186 East Three Mile Road, Sault Ste. Marie, MI, 49783, pers. commun.). Naturally produced chinook young have also been found in the Chippewa River-a tributary to the Saginaw River (J. Baker, Michigan Department of Natural Resources, 503 N. Euclid Ave., Bay City, MI, 48706, pers. commun.). Also, preliminary results from a study of natural reproduction of chinooks near Thunder Bay, Lake Huron indicate that the contribution from natural reproduction may range from 10% to 30% of the number stocked.

Sea Lamprey Wounding

Sea lampreys may inflict significant mortality on chinooks in Lake Huron, especially in northern waters.

- In 1988-92, sea lamprey wounding ranged from 18 to 33 marks/100 chinooks caught in the Native American gillnet fishery in MH-1.

- Sea lamprey wounding of chinooks caught in a Georgian Bay fishway ranged from 16 to 20 wounds/100 fish in 1989-92.

- The incidence of sea lamprey attachments to chinooks caught in the Michigan charterboat fishery of Lake Huron ranged from 14 sea lampreys/100 fish in 1992 to 19 sea lampreys/100 fish in 1990.

- In 1992, Ontario salmon derbies reported attachment rates of 19 sea lampreys/100 chinooks in the main basin and 9 sea lampreys/l 00 chinooks in Georgian Bay.

Research is needed to describe the contribution of sea lamprey predation to chinook mortality in Lake Huron in order to quantify the actual loss of chinook salmon.

Rainbow Trout

Fishery agencies foresee rainbow trout having a prominent role in the future salmonine fish community of Lake Huron. No specific fishery-management objective exists for rainbow trout. Fish-community objectives simply state that rainbow trout will be managed for self-sustainability where stream-spawning habitat is satisfactory (DesJardine et al. 1995). The rainbow trout has established itself in virtually all streams where conditions suitable for natural reproduction exist. Data from Dodge (1972) illustrated that distinct stocks of rainbow trout have already been established in southwestern Georgian Bay.

Three different types of rainbow trout exist in Lake Huron:

1) domestic rainbow trout,

2) steelhead trout, and

3) Skamania.

Domestic refers to a strain that spends its entire life living in the open lake and does not enter tributaries to spawn. In Michigan, domestic rainbow trout are stocked in areas of the main basin that have no large rivers. Domestics have been cultivated in the hatchery system for approximately 100 yr and are stocked in harbors and off breakwalls to provide angling opportunities but very limited prospects of natural reproduction. The term steelhead refers to those strains of rainbow trout that spend most of their adult life in the Great Lakes but spawn in tributaries. The first steelheads, stocked in the Great Lakes in 1876, originated from the state of California. Currently, the state of Michigan uses Lake Michigan winter-run steelhead as the strain for stocking in Lake Huron. Skamania is a type of steelhead that moves up rivers earlier and spawns earlier than other steelheads.

Stocking

The first known stocking of rainbows in the Lake Huron watershed was in the Au Sable River, Michigan, in 1876 (MacCrimmon 197 1). Subsequent stockings resulted in the establishment of wild populations in many areas of Lake Huron by 1930 (Berst and Spangler 1973). Biette et al. (198 1) credited the success of rainbow trout in the Great Lakes to good luck rather than good management and suggested that the use of a diverse gene pool was a contributing factor to the success of the first stockings.

Annual stockings (1970-92) of rainbow trout in Lake Huron have ranged from 300,000 to 2.3 million (Appendix). Since 1986, an average of 1.85 million rainbow trout (including domestic, steelhead, and Skamania) has been stocked in the Lake and these stockings have increased significantly in the last 10 yr. Currently, approximately 750,000 fry and fingerling rainbow trout are stocked annually in Ontario waters. The MDNR annually stocks approximately 1.15 million yearling rainbow trout at all major ports in their jurisdiction. Recent studies in Lake Michigan have shown poor survival of fry and fingerling rainbows (Seelbach and Whelan 1988). Consequently, beginning in 1993, yearling and fingerlings will be replaced by large smolts (where possible) in Michigan waters of Lake Huron.

The Skamania strain was first stocked in Lake Huron by the state of Michigan in 1983, but the MDNR terminated Skamania stocking in 199 1. Stocking was terminated because of concerns over the possible effects of genetic interactions between Skamania and other rainbow strains, and because of concern that summer water temperatures in Michigan streams were too warm when Skamania enter to spawn. The OMNR began stocking Skamania in Georgian Bay in 1988, but these stockings provided little initial return to the fishery. The ultimate success of these stockings is still unknown.

Harvest

Despite high stocking levels in Michigan waters of Lake Huron the sport-fishery harvest of rainbow trout has been disappointing. Rainbow trout accounted for only 2% to 3% of the total sport harvest from Michigan waters in 1986-88 (Rakoczy and Rogers 1987, 1988, 1989). The sport-fishing harvest of rainbow trout of all types from Michigan waters of the Lake has ranged from 2,100 fish in 1988 to 5,300 fish in 1987. Angler catch rates during the same years ranged from 0.13 to 0.43 fish/100 h. Traditionally, the rainbow sport fishery in Michigan waters of the Lake has been an important seasonal fishery with only occasional offshore opportunities. Nearly one-half of the total rainbow trout harvest from Michigan waters is from the Au Sable River.

Sport-fishery-harvest data on rainbow trout are limited from the Ontario side of the Lake. Only two of the larger rivers in the area have had recent creel surveys.

- An estimated 869 rainbow trout were caught in 32,105 angler hours of fishing on the Saugeen River from September 3, 1989 to November 7,1989-a catch rate of 3.2 rainbow trout/100 h (Tarandus Associates Ltd. 1989).

- In the Bighead River (Fig. l), an estimated 1,722 rainbow trout were caught from June 12, 1991 to December 15, 1991 a catch rate of 16.1 rainbow trout/100 h (Nickerson 1992).

- Based on an open-water creel survey, an estimated 6,572 rainbow trout were harvested from southern Georgian Bay in 1992 (Ontario Ministry of Natural Resources, 611 Ninth Avenue East, Owen Sound, Ontario, Canada, N4K 3E4, unpubl. data).

Abundance

A decline in abundance of wild, naturally reproducing populations of rainbow has been observed in southwestern Georgian Bay and the Bruce Peninsula area. The total number of rainbow trout caught from the Saugeen River and Lucknow Creek, tributary to the eastern main basin of the Lake has remained stable or increased from 1972 to 1992 (Fig. 11). The proportion of wild rainbow trout using these rivers has decreased each year. The proportion of wild fish among rainbow migrants in the Saugeen River in the spring declined from 97% in 1985 to 82% in 1992. At Lucknow Creek, wild fish declined from 94% in 1989 to 70% in 1992. The number of rainbow trout using fish ladders on the Sydenham and Beaver Rivers in southwestern Georgian Bay declined in 1983-92 (Fig. 11). As the overall numbers have declined, the proportion of stocked fish using these rivers has increased in recent years. Catches of rainbow trout from the Nottawasaga River in southern Georgian Bay have remained fairly constant from 1977 to 1992.

Food Habits

Information on the food habits of rainbow trout in Lake Huron is minimal. Most of the rainbow trout stomachs from adult fish caught in St. Martin Bay during the spring and fall, 199 1 and 1992 were empty, but several fish contained mayfly (Ephemeroptera) larvae (M. Ebener, Chippewa-Ottawa Treaty Fishery Management Authority, 186 East Three Mile Road, Sault Ste. Marie, Michigan, 49783, pers. commun.)

Reproduction

Rainbow trout do reproduce naturally within the Lake Huron basin and sensitive headwater areas of tributaries are important reproductive habitats (Alexander and MacCrimmon 1974). The extent of reproduction in Lake Huron is, however, uncertain. The Ontario side of the Lake has the majority of tributaries that support rainbow trout runs.

Eight traditional rainbow trout streams entering Georgian Bay were surveyed in 1992 to document the amount of natural reproduction occurring in rivers that show a decline in rainbow abundance, and to compare reproductive success with information collected during the 1980s. With one exception, all the rivers contained juvenile, wild rainbow trout at levels comparable to those found in the 1980s. Current declines in spawning numbers may be the result of poor year-classes produced in the late 1980s when low stream flows and high water temperatures probably limited survival in streams.

Tributaries that support substantial spawning populations of rainbow trout on the Michigan side of Lake Huron are limited and no evaluation of spawning populations has been done. The Au Sable and Carp Rivers (Fig. 1) are two of the better-known rainbow trout streams in Michigan waters and a large rainbow trout population spawns in the St. Marys River.

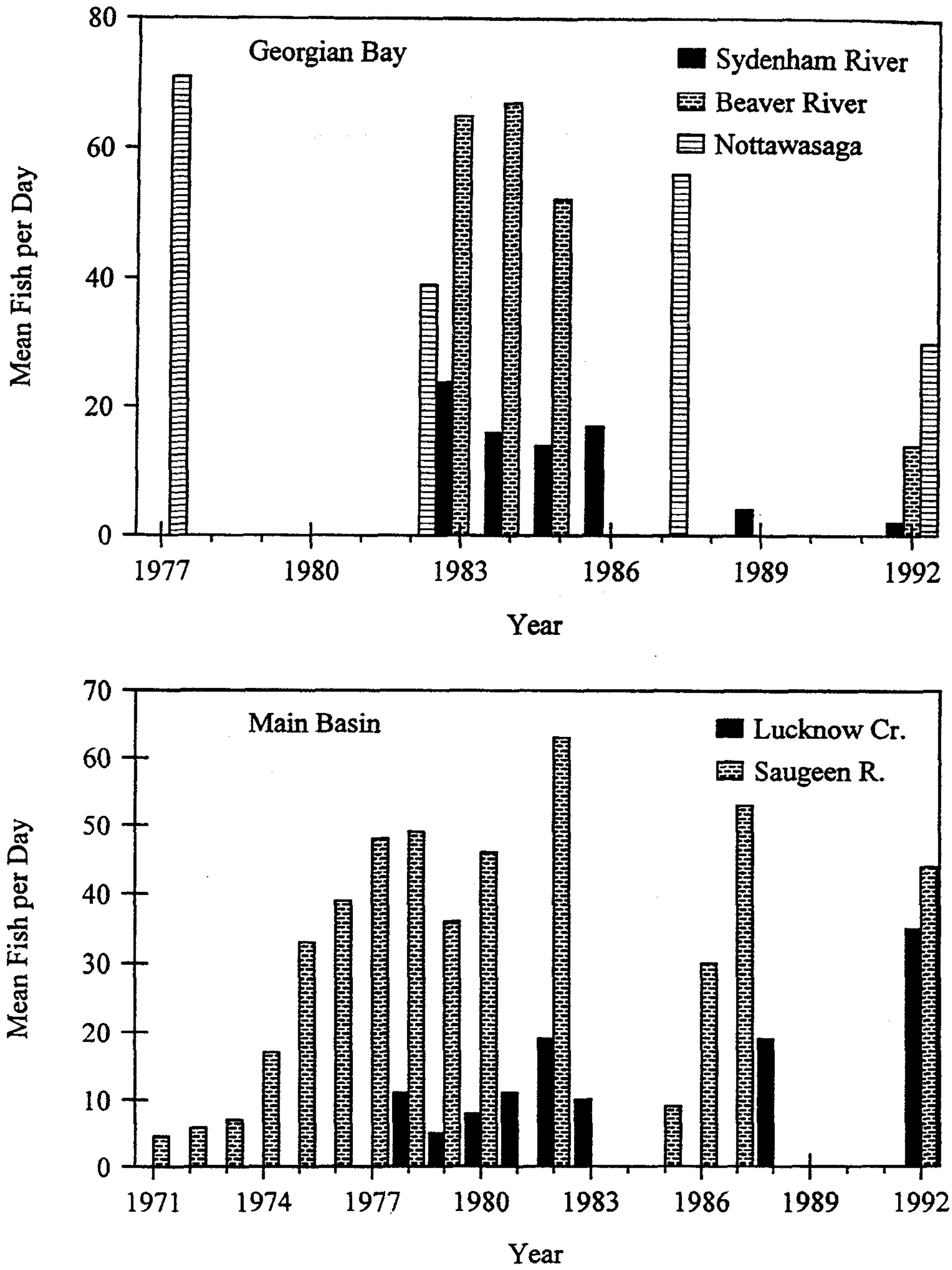

Fig. 11. Average number of rainbow/steelhead caught at fish ladders on Ontario tributaries in southwestern Georgian Bay and the main basin, 1971-92. All data are for spring migrations, except the Sydenham River, which is a fall run.

Sea Lamprey Wounding

The incidence of sea lamprey wounds on rainbow trout is much lower in the southern waters of Lake Huron than in the northern waters. Sea lamprey wounding of rainbow trout caught during the spring in the Saugeen River ranged from 7 marks/l 00 fish in 1977 to 0.5 marks/100 fish in 1985. In comparison, the average sea lamprey marking rate on rainbow trout caught during the spring in St. Martin Bay was 16 marks/100 fish in 1991 and 29 marks/100 fish in 1992 (M. Ebener, Chippewa-Ottawa Treaty Fishery Management Authority, 186 East Three Mile Road, Sault Ste. Marie, Michigan, 49783, pers. commun.).

Coho Salmon

No specific objective has been set for coho salmon in Lake Huron. Fish-community objectives simply state that coho may persist based solely on the strength of limited natural reproduction or immigration. Cohos will not be stocked in Lake Huron (DesJardine et al. 1995) because of

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

Cohos are currently present in Lake Huron at very low levels.

Stocking

An average of 509,000 yearling cohos were stocked annually in Lake Huron by the MDNR in 1968-89 (Appendix). Despite the stocking of almost 1 million cohos in some years, the return to the angling fishery has been poor, and cohos have not played a major role in the Lake's sport fishery for many years (Rakoczy and Rogers 1989). Because of the poor return to the sport fishery and concerns over interactions with other riverine species, stocking of coho salmon was terminated in Lake Huron in 1989.

Sea Lamprey Wounding

No information currently exists on the effect of sea lamprey predation on the remaining coho population in Lake Huron, but sea lamprey predation on these fish was historically very high. In 1969, nearly 73% of mature cohos entering Michigan tributaries of Lake Huron bore sea lamprey marks compared with a 4% sea lamprey marking rate on fish in Lake Michigan (Great Lakes Fishery Commission 1970). In 1970, 58% percent of the cohos returning to Michigan streams of Lake Huron bore sea lamprey scars and/or fresh wounds (Great Lakes Fishery Commission 1972).

Pink Salmon

No specific fishery-management objective exists for pink salmon. The fish-community objectives recommend that pink salmon be managed as self-sustaining populations where habitat proves satisfactory. This species was first introduced into Lake Superior in 1956 at Thunder Bay, Ontario (Scott and Crossman 1973), and was first discovered in a Lake Huron tributary in the Carp River in 1969 (Parsons 1973). The successful establishment of pink salmon was probably enhanced by the depressed state of populations of lake trout, lake herring, and alewives (Collins 1975).

Stocking

Pink salmon were never stocked in Lake Huron.

Harvest

The pink salmon sport-fishery harvest biennially fluctuates greatly. The contribution of this species (Rakoczy and Rogers 1988, 1989; Weber 1988) to the sport harvest from Michigan waters was:

- 35% in 1985,
- <1% in 1986,
- 16% in 1987, and
- 2% in 1988.

The numbers of pink salmon harvested in the Michigan sport fishery ranged from 139 in 1986 to 29,500 in 1987.

No recent studies of pink salmon in Ontario waters of Lake Huron have been done. Pink salmon returns from fishway operations and sport-fishery harvests in southern Georgian Bay and the central eastern shore of Lake Huron are limited and indicate that population levels are low in those waters. Only 42 pink salmon were caught in 32,000 angler hours on the Saugeen River in the fall of 1989 (Tarandus Associates Ltd. 1990), and 16 were caught in 43,000 angler hours on the Bighead River of southwestern Georgian Bay in the summer and fall of 199 1 (Nickerson 1992). Some of the streams in the Bruce Peninsula area do provide an angler harvest of pink salmon during odd-numbered years, but the species is not actively sought (J. Morton, Ontario Ministry of Natural Resources, 611 9th Avenue East, Owen Sound, Ontario, N4K 3F4, pers. commun.).

Abundance

Information on abundance of pink salmon in Lake Huron is minimal. Kocik et al. (199 1) estimated the number of spawning pink salmon in three northern Lake Huron tributaries in 1984-88. The number of spawning pink salmon (Kocik et al. 1991) ranged from:

- 0 in 1988 to 11,422 in 1985 in Albany Creek,
- 0 in 1984, 1986, and 1988 to 31,500 in 1985 in the Carp River, and
- 0 in 1986 and 1988 to 1,120 in 1985 in the Black Mallard River.

Survival

Survival of pink salmon in the open waters of Lake Huron has not been determined. Kocik et al. (199 1) estimated survival of pink salmon from egg deposition to outmigrating fry from Albany Creek in northern Lake Huron to be:

- 0.15% in 1985 and 1986, and
- 0.44% in 1987 and 1988.

Growth

Information on growth of pink salmon is also limited. Pink salmon males are consistently longer and heavier than females regardless of collection method, year, or site (Kocik and Taylor 1987; Kocik et al. 199 1). Mean length and weight of both male and female pink salmon from northern Lake Huron tributaries were greater in even-numbered years than in odd-numbered years (Kocik et al. 199 1). Kocik et al. (199 1) also reported that average length of fish in odd-numbered years showed an apparent association with abundance. Average lengths initially increased as populations within Lake Huron expanded and decreased as populations decreased.

Food Habits

Kocik and Taylor (1987) documented a northward movement of pink salmon from the St. Clair River in late spring to the Straits of Mackinac by late August. They found that the adult diet was mainly smelt (45% by weight) and alewives (38%). Adult stages of aquatic and terrestrial insects (5%) and zooplankton were both relatively unimportant (<1%) in the diet of pink salmon. Kocik and Taylor (1987) concluded that:

- the diet of pink salmon overlaps those of other salmonines in the Great Lakes, and

- abundant year-classes of pink salmon may adversely affect the growth and abundance of other species in the Great Lakes.

Reproduction

Naturally reproducing populations of pink salmon are currently evident in many locations in Lake Huron tributaries. Pink salmon are known to spawn in the St. Marys River, Albany Creek, Carp River, and the Black Mallard River (Kocik et al. 1991; A. Dupont, Ontario Ministry of Natural Resources, Aerodrome Building, P. 0. Box 130, 69 Church Street, Sault Ste. Marie, Ontario, Canada, P6A 565, pers. commun.). Nine age-0 fish ranging in length from 38 to 57 mm were captured off the mouth of the Cheboygan River in 1992 which suggests that pink salmon may also be reproducing in that river. Odd-year spawning runs are very prominent in the Lake Huron basin, but even-year spawning runs of pink salmon have been observed-although in relatively low numbers (Collins 1988). Collins (1988) suggested that alternate-year pulses in abundance of adult and juvenile pink salmon could, in the extreme, have a destabilizing effect on the pelagic fish community of the Great Lakes. This effect would be reduced if substantial even-year spawning stocks should became established.

Sea Lamprey Wounding

Kocik et al. (199 1) reported that some pink salmon bore sea lamprey-attack marks in odd-numbered years in Lake Huron tributaries, but these marking rates were low and ranged from 0.3 to 2.5% in 1985 and 1987. Only one pink salmon of 50 caught in a weir on Nunns Creek in northern Lake Huron in 199 1 bore a sea lamprey mark.

Brown Trout

Very little emphasis is placed on the brown trout in Lake Huron except to stress that it will continue to be a part of the Lake Huron salmonine community. Brown trout were first stocked in the Great Lakes in a Lake Michigan tributary in 1883 (Berst and Spangler 1973). Initial stockings were made with fish from Germany and Loch Leven, Scotland-various strains continue to be stocked in Lake Huron. A study in Thunder Bay is currently being done to assess the difference in success of a German strain versus a Wisconsin strain of brown trout.

Stocking

Current stocking levels are approximately 200,000 brown trout in Ontario waters and 400,000 brown trout in Michigan waters (Appendix). The majority of the fish stocked are yearlings. Yearling brown trout have shown better survival than fry or fingerlings-96% of the Thunder Bay harvest of this species from 1985 to 1987 was composed of fish stocked as yearlings (Weber 1988). Because of the higher survival rates, the MDNR is now stocking yearling brown trout exclusively. Stocking of brown trout in the Thunder Bay area by the MDNR has been delayed until June in recent years so that predation by walleyes on recently stocked fish would be buffered by the high abundance of young alewives. Stocking of brown trout in Ontario waters has been concentrated in the North Channel, southern Georgian Bay, and the main-basin areas near the Saugeen and Maitland Rivers.

Harvest

The total catch of brown trout in Lake Huron is relatively minor compared with that of Pacific salmon or lake trout, but in certain areas of suitable habitat (for example, in Thunder Bay) stocked brown trout support fisheries that last the entire open-water season (Weber 1988). Brown trout have accounted for 2-7% by number of the salmonid harvest from Michigan waters of Lake Huron (Rakoczy and Rogers 1987; 1988; 1989). Creel-survey returns from eight index ports in Michigan waters indicated a general downward trend in harvest and catch rates of brown trout from 1986 to 1992. The number of brown trout harvested by the Michigan sport fishery declined from 15,100 in 1986 to 3,300 in 1992 (Rakoczy and Rogers 1987, 1988, 1989). Catch rates of brown trout in the Michigan sport fishery declined from 0.86 fish/100 h in 1986 to 0.32 fish/100 h in 1992.

In Ontario waters, brown trout are harvested by anglers in the St. Marys *River, the* North Channel, and in certain areas of southern Georgian Bay. A creel survey of the Saugeen River in 1989 estimated 4 brown trout were harvested after 32,105 angler hours of effort (Tarandus Associates Ltd. 1989). On the Bighead River in 1991, no brown trout were harvested in an estimated 43,549 angler hours (Nickerson 1992). An open-water and shore creel survey conducted in southern Georgian Bay in 1992 estimated that 1,507 brown trout were harvested (Ontario Ministry of Natural Resources, 611 Ninth Avenue East, Gwen Sound, Ontario, Canada, N4K 3E4, unpubl. data). The results indicate that the main brown trout harvest is taken by boat and shore anglers on the bay, not by stream fisheries.

Survival

The available evidence suggests that survival of brown trout has declined in Lake Huron. Numbers of brown trout harvested by angling and returns at fish ladders in both southern Georgian Bay and the eastern main basin indicate that either survival rates are low in these locations or the fish are not remaining in or returning to the area to spawn.

In Michigan waters, returns of stocked fish to the creel averaged 6.3% in 1986-88, but in recent years these returns have declined to approximately 2%. Declines in the brown trout harvest from Michigan waters have been attributed to predation on stocked fish by walleyes, burbot, channel catfish, brown trout, and piscivorous birds at the time of stocking.

Reproduction

Wild populations of brown trout do occur in many tributaries of Lake Huron as a result of introductions (MacCrimmon and Marshall 1968). Brown trout abundance, however, has never rivaled rainbow or steelhead abundance in the lake. Most of the natural reproduction of brown trout is limited to the Ontario side of the lake where there are a large number of suitable spawning streams. Natural reproduction on the Michigan side of the lake has been almost negligible (Weber 1988). The reasons for lack of homing and in-stream recruitment of brown trout are unclear but, as has been suggested for Lake Michigan brown trout (Keller et al. 1990), they may be related to:

- genetics,
- lack of imprinting of stocked fish, and
- competition from salmon, resident trout, and steelhead for spawning sites and rearing habitats.

Sea Lamprey Wounding

Brown trout appear to be less susceptible to sea lamprey wounding than species such as the lake trout or rainbow trout. Sea lamprey wounding on brown trout was less than 2 wounds/100 fish in the fall of 1992, based on fish-ladder monitoring in Ontario waters.

Brook Trout

The brook trout is not addressed in the objectives for the Lake Huron fish community, so it will receive little attention here. There have been historic reports of brook trout in certain areas of Lake Huron. Several silver-colored fish were taken in Michigan waters in the early 1970s, (R. Eshenroder, Great Lakes Fishery Commission, 2100 Commonwealth Blvd., Suite 209, Ann Arbor, Michigan, 48105-1563, pers. commun.). No new sightings have been reported since that time. Brook trout were reportedly taken occasionally in Georgian Bay in the early 1900s, but those fish were considered to have strayed from streams in the area (Bensley 1915).

Stocking of brook trout in Lake Huron was begun in 1984 when the MDNR stocked fish at Rogers City. The purpose of this stocking was to provide a diversity of fishing opportunities to anglers. owing to the poor return to the sport fishery, stocking of brook trout in Michigan waters of Lake Huron was terminated in 1991.

Tributaries to Lake Huron on the Ontario side of the lake support native populations of brook trout, but these fish are usually restricted to headwater areas and are segregated from anadromous salmonines by stream barriers such as man-made dams and natural waterfalls.

Atlantic Salmon

The Atlantic salmon is foreseen to be a minor part of the future salmonine community of Lake Huron and as such may be used for experimental introductions (DesJardine et al. 1995).

Atlantic salmon were first stocked in the Au Sable River by the MDNR in 1972. Initial stockings consisted of 9,000 *age-2* fish from a Quebec strain. Atlantic salmon stocked since 1987 have been from landlocked, marine, and sea-run sources. No stocking of Atlantic salmon has been done in the Ontario waters of Lake Huron.

The numbers of Atlantic salmon stocked have varied from 8,000 to 30,000. From 1987 to 1992, all stocking was done in the St. Marys River. In 1992, Atlantic salmon were also stocked in the Carp River. Future plans of the MDNR are to stock 65,000 yearlings in the St. Marys River and 25,000 yearlings in the Carp River annually.

Return rates for Atlantic salmon, adjusted for tag loss, have been 4%-6% (S. Scott, Michigan Department of Natural Resources, P. 0. Box 77, Newberry, Michigan, 49868, pers. commun.). Most of the tags have been recovered from the St. Marys River where some fish appear to remain after stocking. Other Atlantic salmon are probably harvested in this area when they return to spawn. The second-largest area of return is from the main basin of Lake Huron. Other tag returns have come from Lake Superior, Lake Erie, and Lake Michigan.

Coregonines

The fishery objectives for coregonines are to:

- maintain the present diversity of coregonines,
- manage stocks of lake whitefish and ciscoes at levels capable of sustaining annual harvests of 3.8 million kg, and
- restore lake herring to a significant level and protect, where possible, rare deepwater ciscoes.

The goal of 3.8 million kg is equivalent to the average harvest of coregonines from 19 12 to 1940 when the coregonine fish community appeared to be stable.

The whitefish subfamily of fishes (Coregoninae) is prominent in the fish community of Lake Huron and has been a mainstay of the commercial-fishing industry on the lake for many years. Bailey and Smith (198 1) listed 9 members of this subfamily among the native fish fauna of Lake Huron.

- The whitefish, the round whitefish, and the cisco (or lake herring) are generally found at depths <35 m and occur in all three basins of the lake.
- A second group, the deepwater ciscoes or chubs, occupies the deeper regions (>35 m) of the main basin of the lake, Georgian Bay, and some small pockets of deeper water in the North Channel.

Extinctions have occurred among this second group. The deepwater cisco, shortjaw cisco, blackfin cisco, and kiyi have been lost (Bailey and Smith 198 1). The shortnose cisco may soon be added to this list. The last known occurrence of the shortnose cisco in the lake was in Georgian Bay in the 1970s where it was present in low numbers. The shortnose cisco was absent from commercial catches in the 1990s, and special efforts to locate this species in 1992 were unsuccessful. The bloater is the only remaining deepwater cisco and it is abundant.

The harvest of coregonines, although variable, was without noticeable trend from 19 12 to 1939 (Fig. 12), but a period of fluctuation in catches followed. Severe lows in the mid- 1940s, mid-1950s and the late 1960s were interspersed with short-lived peaks that matched or approached the earlier harvest levels. The harvest of coregonines began to rise again in the mid- 1970s and has continued to rise through the first half of the 1980s. Recovery has proceeded to a point where the harvest objective for this subfamily is slightly exceeded (average 3.5 million kg in 1990-92). The 1992 harvest of 3.75 million kg met the coregonine objective.

Striking changes have occurred in the species composition of the coregonine harvest. The lake herring, which contributed 2 million kg or 53% of the coregonine harvest during the baseline period, has accounted for <1% of the coregonine harvest since the 1960s (Baldwin et al. 1979). Conversely, the whitefish, which historically accounted for 35% of the harvest, now accounts for 82%. The commercial harvest of deepwater ciscoes has increased from 12% of the coregonine harvest during the baseline period (19 12-40) to 17% of the harvest in 1990-92. The contribution of round whitefish to the total harvest was never very large (1%) and has changed little.

The higher annual coregonine harvest in recent years has occurred within a regulatory framework that has allowed some tight controls to be put in place. Since 1984, the OMNR has imposed quotas on commercial coregonine fisheries. The MDNR likewise has limited permissible catches of whitefish in trapnet fisheries authorized under permits. The COTFMA has regulated harvests by limiting effort, number of licenses, and boat size that help keep the harvests within total allowable catches (Technical Fisheries Review Committee 1992). Unquestionably, these controls have prevented the coregonine harvest from going higher in recent years. The regulatory regime also appears to have led to some of the stability that has marked the coregonine fisheries during the last decade.

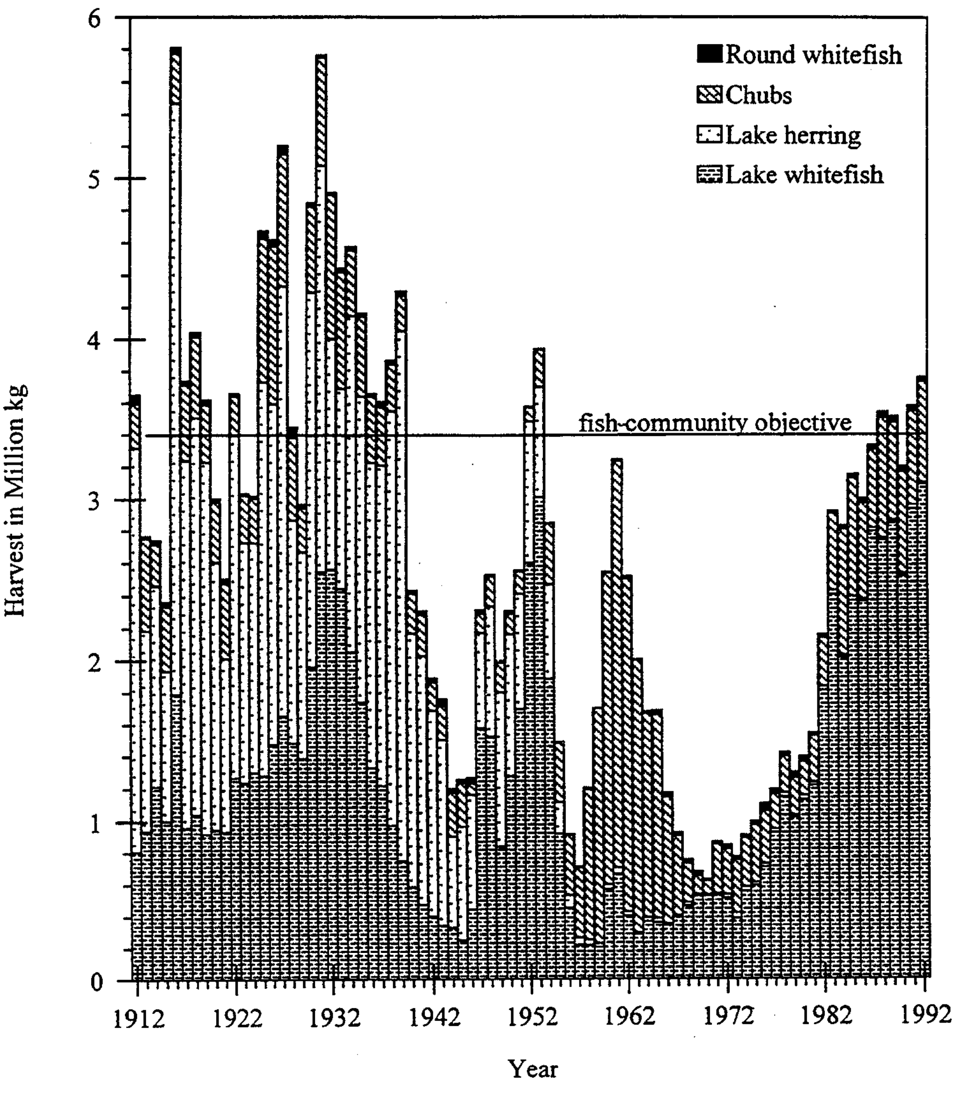

Fig. 12. Annual commercial harvests of coregonines from Lake Huron, 1912-92 (1922-77 data from Baldwin et al. (1979)).

Lake Whitefish

Ample evidence now exists from mark-recapture studies and population characteristics that whitefish in Lake Huron occur as a collection of spatially differentiated stocks (Budd 1957; Cucin and Regier 1966; Casselman et al. 1981) that differ phenotypically and genotypically (Casselman et al. 198 1) (Fig. 13). Although straying among stocks occurs, the stocks function largely as discrete populations and should be managed as such.

Harvest

The history of whitefish landings has been one of dramatic change in quantities of fish and in the distribution of the catches among and within basins (Baldwin et al. 1979; Hartman 1988). Landings were relatively stable at 1.4 million kg in 1922-29 but escalated to 2.5 million kg in 193 1 and 1932 because of increased catches in Michigan waters of the main basin that were attributed largely to the introduction of deep trapnets (Van Oosten et al. 1946). Within a decade, the Michigan fishery virtually collapsed. In Ontario waters of the main basin, whitefish catches increased in the 1930s but never increased to more than 155,000 kg. The fisheries for whitefish in Georgian Bay and the North Channel were relatively stable until about 1940, after which those fisheries became part of a widespread whitefish decline. During the baseline period of 19 12-40, the average annual harvest of whitefish throughout the lake was 1.5 million kg. A phenomenal 1943 year-class enabled harvests to reach peaks of 1.4 million kg in Michigan waters in the late 1940s and 2.8 million kg in Georgian Bay in the early 1950s (Hile and Buettner 1959; Cucin and Regier 1966). The lakewide harvest fell to 13% of the 1912-40 baseline level in the late 1950s and, on average, reached only 29% of the baseline harvest during the 1960s. Since 1975, the trend in commercial whitefish harvests has been upward with the total in 1992 exceeding 3 million kg.

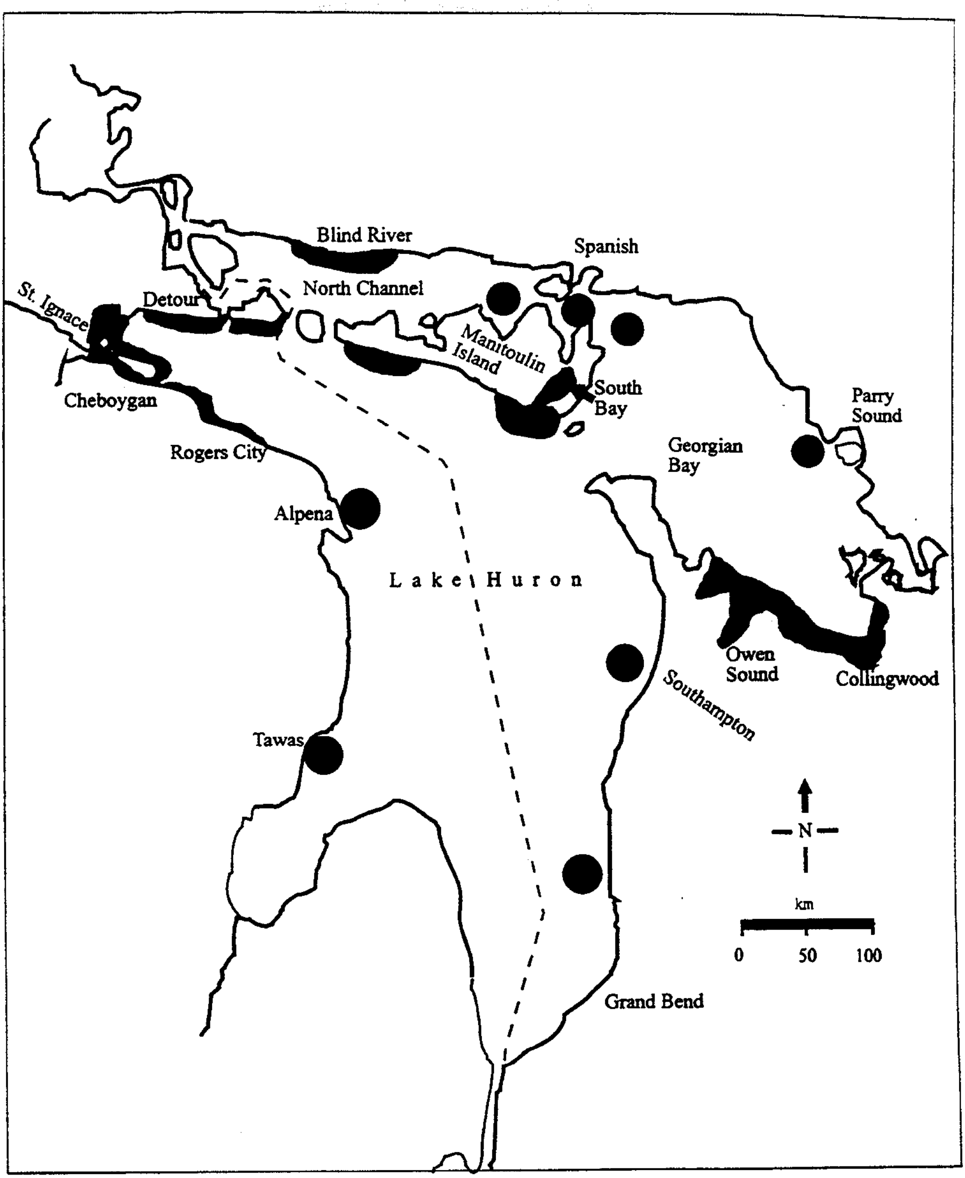

Fig. 13. Geographic centers of known or suspected lake whitefish stocks in Lake Huron.

The recent increase in lake whitefish harvest has occurred chiefly in the main basin and the North Channel and has drastically altered the distribution of the lakewide catch among basins. The Georgian Bay portion of the whitefish harvest changed from 35% in 1912-40 to 4.2% in 1992. Conversely, the contribution from Ontario waters of the main basin has gone from 6% to 49%. The main basin now accounts for 90% of the total lake whitefish landings in Lake Huron compared with 5 1% earlier.

Abundance

The abundance of whitefish in the main basin of Lake Huron is the result of consistently strong recruitment. In 1978-91, whitefish year-class recruitment in Ontario's main basin (OH-3) varied no more than fivefold and no truly weak year-classes were produced (Fig. 14). Consistently strong recruitment of whitefish has also characterized Michigan waters of Lake Huron, but year-class strengths differ from those in Ontario waters. The 1986 and 1987 year-classes of whitefish were abundant in Ontario's main basin, but the 1989 year-class was exceptionally abundant in northern Michigan waters (National Biological Service-Great Lakes Center, 145 1 Green Road, Ann Arbor, Michigan 48 105, unpubl. data).

In contrast, in Georgian Bay (GB-4) where whitefish stocks have recovered slower, recruitment has been much less regular (Fig. 14). Strong year-classes tended to occur at 5-yr intervals from 1972 to 1987, and these were interspersed with relatively weak year-classes. Since 1987, however, a series of strong year-classes has been produced and early indications are that at least some of these may be basinwide. The one part of the lake where whitefish production has fallen short of historic values also appears to be recovering.

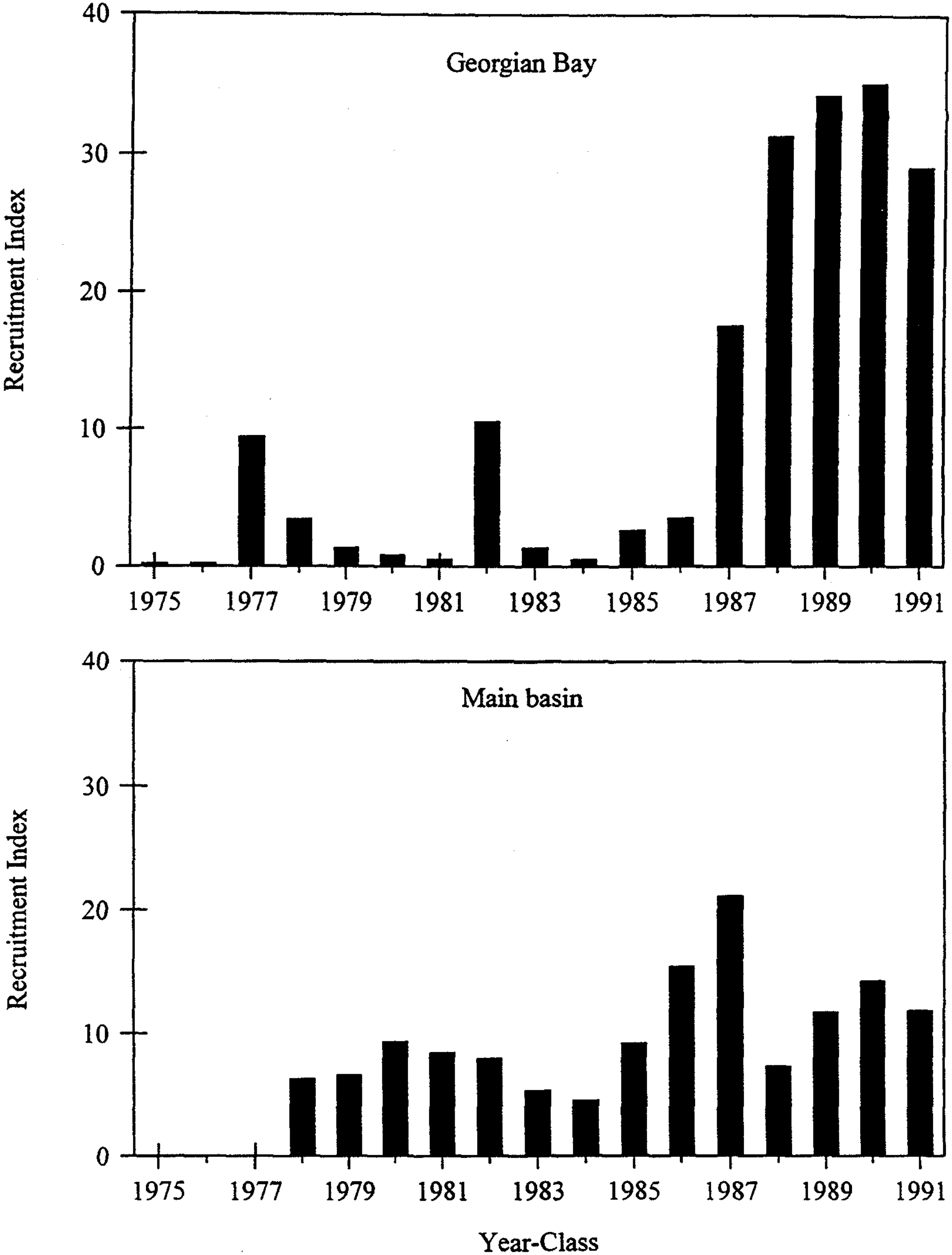

Fig. 14. Indices of relative abundance of year-classes of lake whitefish caught during gillnet surveys in southern Georgian Bay (GB-4) and main basin (OH-3) of Ontario waters of Lake Huron.

Growth and Survival

Growth and survival of whitefish (measured by mean length at age and total annual mortality) are similar among most statistical districts (Table 5). Total annual mortality rates range from 45% in OH-4 and OH-5 to 65% in MH-1, and they are generally higher in the north than in the south. Since the sea lamprey is more abundant in northern Lake Huron, a north-south cline in mortality rates is not unexpected. Wounding rates on adult lake whitefish have, however, not been high enough to attribute all of the difference to sea lamprey predation. Differing rates of fishing mortality are also a factor.

Table 5. Total annual mortality (%), mean age of the catch, and total length (in mm) at age 5 for whitefish caught commercially in various statistical districts of the main basin and the North Channel, 1989-92.

	Statistical district					
Parameter	MH-1	OH-l	OH-2	OH-3	OH-4,5	NC-1
Total mortality	65	60	57	53	45	59
Mean age	6.3	4.7	4.7	4.9	5.1	4.3
Total length at age 5	467	520	518	513	532	537

Age at recruitment to the fishery differs around the lake, but in virtually all areas whitefish are fully vulnerable at age 5. The total length of whitefish at this age differs little throughout Ontario waters of the main basin and the North Chamiel (range, 5 13-537 mm), but age-5 fish are smaller in northern Michigan waters of MH-1. Slower growth of whitefish in MH-1 results in at least a 1-yr delay in recruitment to the fishery and accounts for the higher mean age of the catch in MH-1 than other areas, despite a higher total mortality rate. In MH-1, 65% is the target total mortality rate for whitefish. In Ontario waters, a total mortality no greater than 60% is favored.

Sea Lamprey Wounding

Results of a study of a whitefish population in northern Lake Huron in 1964-68 indicated that sea lamprey predation is an important component of both natural and total mortality (Spangler 1970). Spangler's results support Smith's (1968) conclusion that the sea lamprey could have been partly responsible for decreasing whitefish abundance in the early 1940s and for Hile and Buettner's (1959) contention that the sea lamprey accelerated the disappearance of the strong 1943 year-class. Spangler and Collins (1980) showed that survival rates of whitefish increased substantially in the main basin and the North Channel after sea lamprey control was extended to Lake Huron in the early 1960s. Whitefish abundance increased concurrently in those areas, but neither response occurred in Georgian Bay.

Sea lamprey wounding on whitefish declines from north to south in Lake Huron. Average wounding rates on whitefish caught in the commercial fishery during the 1987-91 open-water season ranged from 3.8 marks/l00 fish in the North Channel to 0.46 marks/100 fish in southern Lake Huron. A dramatic change from the 1987-91 average wounding rate was observed in 1992 when most rates doubled. The North Channel rate, for example, increased 2.5-fold to 9.4 wounds/100 fish in that year. These rates rank with those in pre-control years (Spangler and Collins 1980).

Deepwater Ciscoes (Chubs)

Deepwater ciscoes serve as prey for salmonine predators in Lake Huron. Their contribution to the prey base in the lake will be discussed later in the section entitled "Status of Prey Fishes in 1992."

The early fishery for chubs was selective for the larger species of deepwater ciscoes and reduced different species in order of their size (Smith 1972). The complete disappearance of most species in this group came after invasion of the lake by the sea lamprey, alewife, and rainbow smelt. Various views have been expressed on possible interactions that might have caused the decline in chubs (Christie 1972; Smith 1968, 1972; Brown et al. 1987; Crowder et al. 1987).

Harvest

Annual harvests of all species of chubs during the 19 12-40 baseline period varied widely about a mean of 0.47 million kg but then declined to a mean of 0.20 million kg through the 1940s (Baldwin et al. 1979; Hartman 1988). When released from predation by lake trout and burbot, chubs increased in abundance through the 1950s and the harvest increased to a record 2.5 million kg in 196 1. At that time, most chubs were taken in the main basin By the late 1960s, the chub fishery in the main basin had collapsed and it remained in that state until a strong year-class in 1977 provided for a turnaround.

Demand for the more darkly pigmented chubs from Georgian Bay was created when stocks in the main basin failed. Throughout the 1970s, landings from Georgian Bay averaged 0.22 million kg, but toward the end of the decade stocks were declining.

Recoveries of the bloater in both basins have contributed to combined harvests averaging 0.63 million kg during the past 10 yr. The resurgence in chub stocks has occurred in the absence of state-licensed chub fisheries and as a result of market condition requirements for only large-sized chubs.

Abundance

Bloater populations in Lake Huron have undergone a dramatic recovery (Fig. 15):

- beginning in the late 1970s,
- proceeding rapidly through the 1980s, and
- leveling off or subsiding in the early 1990s.

The longer time series offered by the commercial fishery shows the peaks in abundance but is biased high during the period of collapse because of the practice of fishing token amounts of gillnet at only optimal times and places. The systematic trawling surveys of prey fish carried out by the NBS better represent the change during the last two decades. The slight offset in the recent pattern of abundance (Fig. 15) is probably the result of gear selectivity. Changes show first in assessment trawls followed by changes in commercial gillnets. Catch rates from commercial fisheries are now greater than were recorded during the late 1950s and early 1960s when catches were high, but changes in commercial gillnet efficiency prevent a direct comparison.

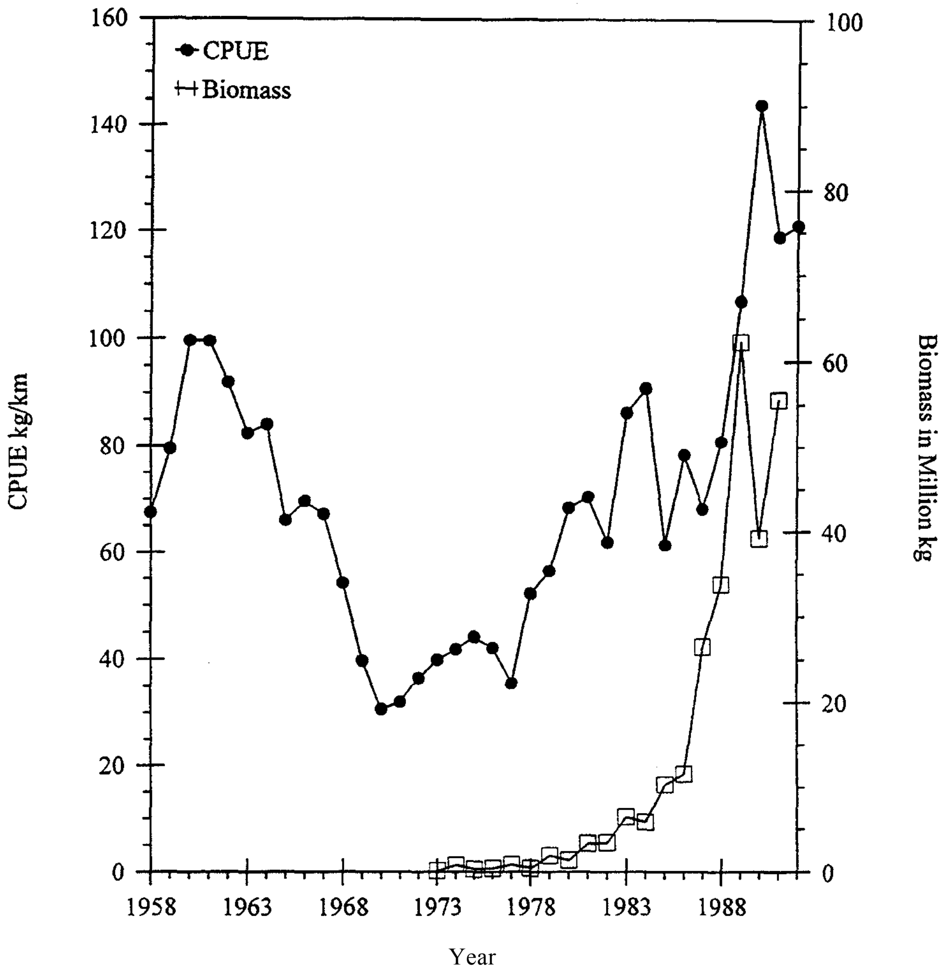

Fig. 15. Relative abundance (catch per effort) of chubs caught by the Canadian commercial fishery from all basins of Lake Huron, 1958-92, and biomass of bloaters as indexed through bottom trawling in Michigan waters of Lake Huron, 1973-9 1.

Sea Lamprey Wounding

Chubs are subject to attack by small sea lampreys, but wounds from attacks are seldom seen on chubs in Georgian Bay and throughout the southern two-thirds of the main basin. In northern Lake Huron (OH-l), more wounds are seen on chubs than elsewhere, but even there the wounding rates fall below 0.5 marks/100 fish. Striking exceptions, however, suggest that in localized areas the effect of sea lamprey parasitism may be considerable. Of 369 chubs sampled in the vicinity of Cockburn Island in 1992, 13% bore sea lamprey wounds. Nearly one in five (23.2%) of the 125 chubs examined in this area in the spring were wounded. In 1990, a wounding rate of 4.2 marks/100 fish was reported for a sample of 2,055 chubs taken in June and July from the adjoining MH-1 waters. These waters lie close to the False Detour Passage that forms the connection of the North Channel with the main basin and are probably on the route of sea lampreys dispersing from the North Channel.

Lake Herring

Interviews with retired fishermen suggest that the lake herring was widespread and far more abundant in Georgian Bay and the North Channel than historic harvest records would indicate. Stocks declined in the 1940s and early 1950s and have been of little commercial consequence since then (Baldwin et al. 1979; Hartman 1988).

Although the lakewide harvest of lake herring is relatively stable, considerable variability occurs within basins. Some recovery was evident in Georgian Bay in the 1970s and very recently, signs of a resurgence in the North Channel were evident. A decline in the catch in Georgian Bay after 1987 is apparently related to fishing activity. The lake herring remains scarce in the main basin of Lake Huron and little, if any, fishing is directed at them.

The relegation of lake herring to a minor role in the coregonine community is presumably the consequence of invading exotic fish species. Smith (1970, 1972) attributed the decline of lake herring to the introduction of the alewife and rainbow smelt, but he also noted that the inner region of Saginaw Bay may have become unsuitable for lake herring because of water pollution. A nucleus of lake herring remains in all three basins of Lake Huron and they may increase in abundance if exotic planktivores are suppressed through predation by recovering salmonines.

Round Whitefish

Round whitefish never had high marketability and appear in the commercial harvest mainly as bycatch. Major shifts in round whitefish abundance during the last 20 yr are not evident. Round whitefish appear in good numbers and the harvest has been slightly above the 19 12-40 average.

STATUS OF COOL-WATER FISHES IN 1992

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Walleye

The fishery objective for walleye is to reestablish and maintain this species as the dominant cool-water predator in its traditional area with a population capable of sustaining a harvest of 0.7 million kg (DesJardine et al. 1995). Historically, walleye was the dominant nearshore predator and an economically important species to both commercial and sport fisheries of Lake Huron. Recent management efforts have focused on rebuilding, where possible, naturally reproducing walleye stocks. Reckahn and Thurston (199 1) reported that there were as many as 14 different stocks of walleyes in the Ontario waters of Lake Huron, but several have become extinct. In addition, walleyes from Lake Erie and the St. Clair River move into Lake Huron and contribute to the Lake Huron harvests of this species (Mrozinski et al. 1991; Reckahn and Thurston 1991).

Stocking

The rebuilding of walleye stocks in Lake Huron was begun by stocking fingerlings:

- the MDNR began stocking fingerling walleyes in Saginaw Bay in 1978,
- the OMNR began stocking the North Channel and Georgian Bay in 1984, and
- the COTFMA began stocking northern Lake Huron in 1985.

Since 1983, an annual average of approximately 1.1 million walleye fingerlings has been stocked in Lake Huron (Appendix). Some walleye fry have been stocked, but the success of these is unknown.

Harvest

The annual walleye harvest ranged from as high as 1.6 million kg in the early part of this century to as low as 35,000 kg in 1972 (Baldwin et al. 1979; Hartman 1988). The walleye population in Saginaw Bay regularly supported annual harvests ranging from 450,000 to 900,000 kg before it collapsed in the late 1940s because of poor reproduction and other factors (Mrozinski et al. 1991). Licensed commercial harvesting of walleyes was halted in Michigan when zone management of fisheries was started in 1970. Lakewide harvests of walleyes from Lake Huron averaged just under 329,000 kg in 1987-92. This harvest represents approximately 50% of the fish-community objective, although the sport-fishery harvest of walleyes is underestimated because there is not a creel survey throughout the Lake Huron basin. Current walleye harvests are split equally between sport and commercial fisheries, but the walleye sport harvest from Michigan waters exceeds the total Lake Huron commercial harvest in some years.

Abundance

More than 8.5 million walleye fingerlings have been stocked in Saginaw Bay since 1978, and the sport harvest of walleyes there has increased from almost ml in the 1970s to 105,000 in 1988 (Mrozinski et al. 1991). Based on tagging experiments and a creel census, an estimated 1-2 million adult walleyes inhabited Saginaw Bay as of 1989 (Mrozinski et al. 1991). Mrozinski et al. (1991) reported that more than 250,000 adult walleyes may spawn in the Tittabawassee River, a tributary to Saginaw Bay. The number of sexually mature adult walleye inhabiting St. Martin Bay between April and May was estimated as:

- 5,200 in 1990,
- 6,300 in 1991, and
- 1,100 in 1992.

Survival

Some estimates of survival of walleyes in Lake Huron are available. The annual survival of walleyes in Saginaw Bay has been estimated at 63% (Mrozinski et al. 1991). Angler exploitation of walleyes in Saginaw Bay was reported as approximately 5% by Mrozinski et al. (1991). Based on trapnet catches, survival in St. Martin Bay was 49% for fish 4 to 6 yr old in 1990 and 33% for fish 4 to 7 yr old in 199 1.

Growth

Growth of walleyes in Lake Huron, based on length-at-age analysis, has shown little change through time but varies among areas of the lake. In Saginaw Bay, growth of walleyes is rapid and fish there grow to the minimum size limit (38.1 cm total length) for harvest after only two growing seasons (Mrozinski et al. 1991). Very little change has been observed in the average length of age-3, age-5, and age-7 walleyes from Saginaw Bay in 1981-92, even though population abundance has increased substantially. Only the length of age-3 walleyes has shown some decline over time (Fig. 16). The walleyes captured from St. Martin Bay were smaller at a given age than fish from either Saginaw Bay or central Lake Huron near Thunder Bay. Growth of walleyes from Thunder Bay and Saginaw Bay was very similar.

Food Habits

Food preferences of walleyes from Michigan waters of Lake Huron change with size of fish and locality. Age-O walleyes captured in July and August, 1992 in St. Martin Bay ate zooplankton, various fish including johnny darters, amphipods, and insects. Adult walleyes in St. Martin Bay prefer rainbow smelt. Adult walleyes caught with gillnets in the Detour area of Lake Huron in September and October, 1991 and 1992 consumed rainbow smelt and alewives almost exclusively.

Walleyes in Saginaw Bay consume a wide variety of prey, but they prefer alewives and gizzard shad (Haas and Schaeffer 1992). Yellow perch were also important in the diet of age-2 and age-3 walleyes from Saginaw Bay in 1988, but Haas and Schaeffer (1992) noted that these fish ate yellow perch only because of delayed recruitment of alewives and gizzard shad.

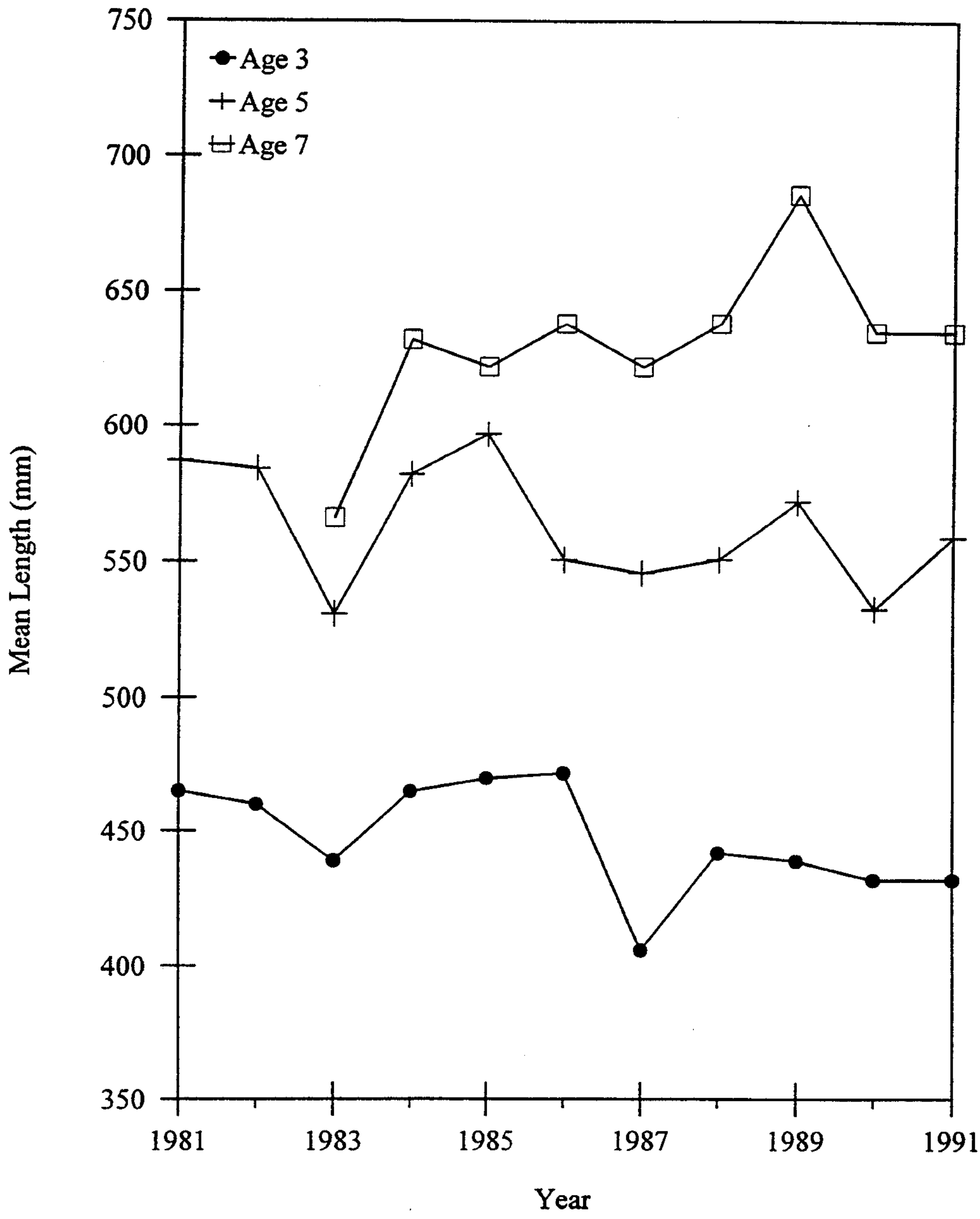

Fig. 16. Mean lengthat age of'walleyes caught during surveys in Saginaw Bay, 1981-91.

Reproduction

Naturally reproducing populations of walleyes are found throughout the Lake Huron basin including the St. Marys River. Munuscong Bay is a very large and important spawning area within the St. Marys River and fish from the bay inhabit both United States and Canadian waters upstream of Drummond Island (Reckahn and Thurston 1991). Walleyes also spawn below the dam on the Cheboygan River (Fig. 1). Natural reproduction of walleyes has been documented in the Saginaw River system-a tributary to Saginaw Bay (Mrozinski et al. 199 1; Jude 1992). Jude (1992) reported that 3 to 28 million walleye larvae passed by his study area in the Saginaw River in 1987 and 1988, respectively, but concluded that environmental or biological factors may be preventing successful recruitment of these fish to the Saginaw Bay sport fishery. In Ontario, walleyes are known to reproduce in the Nottawasaga, Severn, Moon, Shawanaga, Magnetawan, French, Spanish, and Mississagi Rivers, but reproductive success is low in many of these rivers (Reckahn and Thurston 199 1).

Sea Lamprey Wounding

Walleyes in Lake Huron are susceptible to predation by sea lampreys, but wounding rates are generally 6%. Sea lamprey wounding of walleyes from St. Martin Bay averaged 2 marks/l 00 fish in 199 1 and 1992 with annual rates ranging from 1 mark/100 fish in 1991 to 3 marks/100 fish in 1992.

Yellow Perch

The fishery objective for yellow perch is to maintain this species as the dominant nearshore omnivore while sustaining a harvestable annual surplus of 0.5 million kg. The yellow perch is widely distributed in Lake Huron, and is an important component of the sport and commercial hat-vests. In Ontario waters, most of the perch are taken from the main basin and fewer are harvested in Georgian Bay and the North Channel. In Michigan waters of the Lake, most perch are harvested from Saginaw Bay and fewer are taken from the St. Marys River, Detour-Drummond Island, the Les Cheneaux Islands, and other nearshore areas.

Harvest

Most historical records are from the commercial harvest. Harvests of yellow perch from Lake Huron have ranged from 144,000 kg to 2.1 million kg since 19 12 (Baldwin et. al. 1979; Hartman 1988). The commercial harvest has remained fairly steady since 1920 and averaged approximately 370,000 kg annually through 1992 (Baldwin et. al, 1979). The current commercial and sport harvest of perch from Lake Huron exceeds the fish-community objective of 0.5 million kg.

Creel surveys are limited to specific United States areas that include Saginaw Bay, Les Cheneaux Islands, St. Marys River, Detour-Drummond Island, and others. The estimated sport harvest of yellow perch from Michigan waters of the Lake ranged from 200,000 fish in 1989 to 1 million fish in 1987. These figures are low because creel surveys are not done basinwide nor is the ice fishery always surveyed.

Abundance

Estimates of yellow perch abundance in Lake Huron are limited to the Les Cheneaux Islands and Saginaw Bay areas. Lucchesi (1988) estimated that there were between 524,000 and 1.8 million yellow perch ≥ 18 cm in the Les Cheneaux Islands area of northern Lake Huron in 1985-86. Abundance of perch in the Les Cheneaux Islands area appears to have changed very little from 1986 to 1993, based on gillnet catch rates. However, analysis of catch rates indicates abundance since 1986 is substantially lower than pre-1985 levels.

Yellow perch populations in Saginaw Bay have varied widely in abundance since 1986. Haas and Schaeffer (1992) estimated, based on trawl catches, that the biomass of yearling and adult perch was approximately 100 kg/ha in 198688, but abundance declined to 40 kg/ha in 1989. Preliminary indications are that the decline has continued to the present (R. Haas, Michigan Department of Natural Resources, 33 135 S. River Road, Mt. Clemens, Michigan, 48045, pers. commun.).

Survival

Survival of yellow perch has been estimated in several areas of Lake Huron. In the Les Cheneaux Islands, survival of adults was estimated at 38%-42% in 1985 and 1986 based on fykenet catches. Exploitation by the sport fishery was 28% of the population of fish ≥ 18 cm (Lucchesi 1988). Annual survival in 1991 was determined to be 54% for 8- to 10-yr-old yellow perch from St. Martin Bay and 60% for 4- to 9-yr-old fish from the Cheboygan area (M. Ebener, pers. commun.). Survival in Saginaw Bay was reported at 41%-48% for 1- to 3-yr-old fish and 3 1%-41% for 4- to 8-yr-old fish (Haas and Schaeffer 1992). Haas and Schaeffer (1992) concluded that yellow perch in Saginaw Bay suffered high natural mortality because of the lack of food for adult fish in 1986-88.

Growth

Growth of yellow perch in Lake Huron, based on length at age, has fluctuated among areas over time. These fluctuations may reflect management policies, food availability, and competitive interactions with other species. Growth in Saginaw Bay has declined through time because of the loss of large mayfly larvae (Hexagenia spp.) due to the eutrophic conditions in the bay (Haas and Schaeffer 1992). As a result, perch from Saginaw Bay currently grow slower than fish from other areas of Lake Huron. During the late 1920s, yellow perch from Saginaw Bay grew well and reached sizes exceeding 30 cm in total length. Eutrophication and the associated depressions in dissolved oxygen (DO) in Saginaw Bay during the following decades essentially eliminated *the* large burrowing mayfly *Hexagenia* from the bay and caused the growth of yellow perch to decline (Fig. 17). Both Salz (1989) and Haas and Schaeffer (1992) concluded that adult yellow perch from inner Saginaw Bay suffer severe depletion of body fat and energy content that ultimately reduces growth rate.

Yellow perch from other areas of Lake Huron appear to have normal growth rates. Length at age has generally increased in the Les Cheneaux Islands since 1986, and growth rate of fish from Detour-Drummond Island was slightly less in 1987 than in 1979 (Grimm 1989). The 1992 length-at-age data from the Les Cheneaux Islands and 1987 data from Detour-Drummond Island showed that fish from both areas were growing near Michigan's statewide average. Size at age and apparent growth rates of perch from St. Martin Bay are greater than for fish from other areas, possibly because size-selective sport and commercial fisheries are nearly absent in the area, and population densities are low.

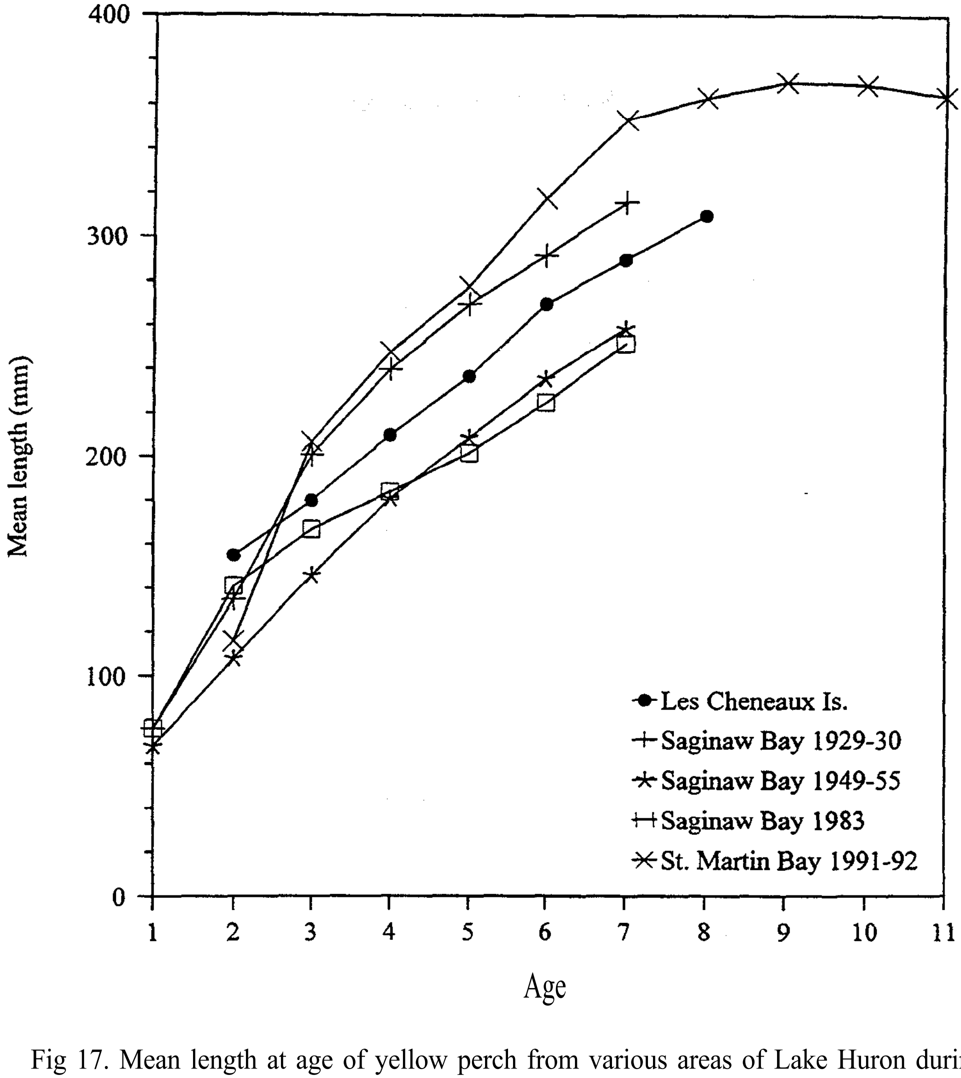

Fig 17. Mean length at age of yellow perch from various areas of Lake Huron during different time periods (Les Cheneaux and Saginaw Bay data from Lucchesi (1988)).

Food Habits

The food preferences of yellow perch from Saginaw Bay were documented because of the poor growth of fish from inner Saginaw Bay (Salz 1989; Haas and Schaeffer 1992). Haas and Schaeffer (1992) reported that perch from Saginaw Bay consumed mainly zooplankton and chironomid larvae, and rarely fed on other fish.

Esocids

The fishery objectives (DesJardine et al. 1995) for esocids are to:

- maintain the northern pike as a prominent predator throughout its natural range,

- maintain the muskellunge in numbers and at sizes that will safeguard and enhance its species status and appeal, and

- sustain a harvestable annual surplus of 0.1 million kg of these esocids.

Three species of esocids inhabit Lake Huron: northern pike, muskellunge, and grass pickerel. The grass pickerel is a minor component of the esocid population of the Lake because it is found only in tributaries of southern Lake Huron and Georgian Bay (Scott and Crossman 1973).

Northern Pike

Harvests

Large commercial fisheries for northern pike existed in Lake Huron early in this century and reported commercial harvests were more than 136,000 kg in 1921. Thereafter, the harvest declined almost annually (Baldwin et al. 1979). Habitat loss throughout the Lake's watershed is thought to have contributed to the decline of northern pike. Over half of the historic commercial harvest came from Canadian waters of the North Channel and Georgian Bay. Commercial harvest of northern pike from Michigan waters was halted in 1966. Commercial harvests from Ontario waters in 1988-92 averaged 6,700 kg, but the harvest no longer reflects abundance.

Annual sport-fishery harvests from Michigan waters in 1986-91 ranged from 35 to 44,000 fish of which 95% came from the St. Marys River-Drummond Island area (Fig. 1). Unfortunately, sport-harvest data are incomplete because creel surveys are not conducted throughout the lake or in every year in many areas.

Abundance

Sizable populations of northern pike exist in the St. Marys River system, the North Channel, the Les Cheneaux Islands, Georgian Bay, and Saginaw Bay (Fig. 1). Abundance in Saginaw Bay appears to be increasing and the increases there may be related to high lake levels in 1985 and 1986. Stocking of pond-reared fall fingerlings of northern pike in Saginaw Bay is scheduled to begin in 1993. The MDNR has been trying to pass northern pike through a fishway from the St. Marys River into a flooded waterfowl area on Drummond Island to bolster natural reproduction there, but this project has met with only limited success. In addition, road construction on Drummond Island has, in one instance, blocked northern pike from reaching a traditional spawning marsh (S. Scott, Michigan Department of Natural Resources, P. 0. Box 77, Newberry, Michigan, 49868, pers. commun.).

Limited information is available on northern pike abundance or status in Lake Huron, and most of those data have been collected as part of studies directed at other fish species. Abundance of northern pike has been monitored in the Les Cheneaux Islands area as part of a study evaluating yellow perch populations. Abundance in the area has been variable, but appears stable based on gillnet catches during the month of October, 1983-91.

Muskellunge

The muskellunge is most abundant in Georgian Bay, but reproducing populations of this species also occur in the North Channel and the St. Marys River. A naturally reproducing population of muskellunge exists in Lake Nippissing, which is a tributary to the North Channel (Scott and Crossman 1973). Two naturally reproducing populations of muskellunge are present in Lake St. Clair, but based on recaptures of tagged fish, they do not move into Lake Huron (Bryant and Smith 1988). Information on muskellunge abundance, population statistics, sport harvest, and incidental catch in commercial fisheries is scarce and mainly anecdotal.

Lake Sturgeon

The fishery objectives for this species are:

- to increase the abundance of lake sturgeon to the extent that the species is removed from its threatened status in United States waters, and

- to maintain or rehabilitate populations in Canadian waters.

The sturgeon is listed as either endangered or threatened by 19 of the 20 states encompassing the original range within the United States-Wisconsin is the only exception (Auer 1991). Protection in Canada is provided under the Federal Fisheries Act by the province where the sturgeon population is located (Houston 1987). Protection of sturgeon populations in the Ontario waters of Lake Huron consists of closed seasons, size limits, creel limits, and gear restrictions. In 1991 and 1992, a commercial harvest of 4,600 and 5,300 kg, respectively, of sturgeon was taken from Ontario waters.

Native American tribes inhabiting the Lake Huron basin depended heavily upon sturgeon and fished for them in the Mississagi River (a tributary to the North Channel) and the islands of Lake Huron (Kinietz 1940). Sturgeon were considered to be a nuisance by early commercial fishermen until its flesh and roe became marketable and their value soared. Lakewide commercial landings from Lake Huron exceeded 453,000 kg in 1885-80% of that originating in Canadian waters.

Overharvesting from commercial fishing and the construction of dams on rivers historically used for spawning were the key contributors to the rapid decline of sturgeon in Lake Huron (Ono et al. 1983). Sturgeon were known to spawn at certain locations within Saginaw Bay (Organ et al. 1979) and in the Au Sable River (Goodyear et al. 1982). They still spawn in the St. Clair River, and this population may be the source of sturgeon that are currently caught in southern Lake Huron by Ontario commercial fishermen. The lower 32 km of the Mississagi River is unobstructed and may be the source of sturgeon currently harvested in the North Channel. Documentation of sturgeon spawning populations in Ontario waters has not begun.

No active management plans exist for sturgeon in Lake Huron, but management agencies are interested in recovery and restoration of the sturgeon in the Lake. Inventory and protection of remnant stocks, as well as restoration and rehabilitation of habitat are the main focus of the activities. The MDNR has a work group assembled to pursue sturgeon restoration in all the Great Lakes, and the USFWS is in the early stages of prelisting and developing recovery activities for protection and restoration of the sturgeon.

STATUS OF WARM-WATER FISHES IN 1992

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Channel Catfish

The fishery objective for channel catfish is to maintain this species as a prominent predator throughout its natural habitat while sustaining a harvestable surplus of 0.2 million kg. Channel catfish inhabit mainly nearshore areas such as Saginaw Bay and are relatively uncommon in the deeper, colder, more sterile waters of the main basin. Nearly 90% of the harvest of channel catfish in Lake Huron is from Saginaw Bay. Most of the commercial harvest from Ontario waters is in the main basin and a lesser amount is harvested from the North Channel and Georgian Bay.

Commercial harvests of channel catfish from Lake Huron have ranged from 54,000 kg to 368,000 kg since 1952 (Baldwin et al. 1979). No harvests of channel catfish were recorded from Canadian waters before 1952. The commercial harvest was fairly steady from 1952 to 1977 and averaged 130,000 kg. An average of 287,000 kg has been taken annually since. 1977. The increase in harvest may be attributable to changes in the market price for channel catfish rather than changes in population abundance. The current harvest average of 287,000 kg is greater than the fish-community objective.

The sport fishery for channel catfish has not been closely monitored. An estimated 22,040 channel catfish were caught in Michigan waters of Lake Huron in 1992, mostly from Saginaw Bay. Sport-fishery potential may be limited because the Michigan Department of Public Health recommends that anglers should not consume channel catfish taken from Saginaw Bay and its tributaries because of high polychlorinated biphenyl (PCB) levels in this species from the bay.

Little information is available on the biology of channel catfish in Lake Huron with the exception of Saginaw Bay. Lorantas (1982) described population dynamics including growth, mortality, and yield. Size and age distributions of channel catfish varied within Saginaw Bay and appeared to be related to habitat preferences among fish of different ages. Smaller and younger channel catfish were more abundant in the extensive shallower areas of Saginaw Bay than were larger, older fish (Lorantas 1982).

Total annual mortality of channel catfish was 51% in Saginaw Bay and is comparable to that in other waters (Lorantas 1982). Haak (1987) found that mortality of channel catfish in Saginaw Bay declined to 36% in 1985. The commercial fishery accounted for the bulk of the mortality in Saginaw Bay. Both Lorantas (1982) and Haak (1987) suggested the minimum size limit for channel catfish in the commercial fishery should be increased.

Centrarchids

The fishery objective for centrarchids is to sustain smallmouth and largemouth bass and the remaining assemblage of sunfishes at recreationally attractive levels over their natural range.

Smallmouth Bass

The smallmouth bass is widely distributed throughout the nearshore area of Lake Huron, and is probably the single most important species to the sport fishery of Ontario waters. In Michigan waters, this species is one of the top ten fish caught by sport anglers. The annual sport harvest of smallmouth bass ranged from 7,700 to 15,800 fish in Michigan waters in 1986-9 1.

Researchers have shown that year-class strengths of smallmouth bass and subsequent yields to the sport fishery are influenced mainly by water temperatures and not abundance of adult fish (Fry and Watt 1957; Coble 1975; Latta 1975; Shuter et al. 1980). Reproductive success of smallmouth bass (Shuter et al. 1980) is reduced when:

- water temperatures drop below 12 °C during the period from egg fertilization to the free-swimming age-0 fish, and

- the mean July air temperature isotherm is below 18.3 “C.

Summer water temperatures influence growth of smallmouth bass in Lake Huron (Coble 1967) and northern Lake Michigan (Latta 1975) and may be related to reproductive success the following year (Shuter et al. 1980).

Only limited biological data exist on smallmouth bass in most areas of Lake Huron because this species is not given much attention by the management agencies. In the Cheboygan Michigan area, smallmouth bass ages 2-8 and 178-45 1 mm in total length were represented in trapnet assessment catches in 1991. Based on catch-curve analysis, total annual mortality of age-4 to -8 smallmouth bass at Cheboygan was 50%-a rate similar to mortality reported by other investigators on Lake Huron and the adjacent area of Lake Michigan (Coble 1975; Latta 1975).

Largemouth Bass

Abundance and distribution of largemouth bass are very restricted in Lake Huron. It is, however, locally important to the sport fishery in Saginaw Bay. Virtually no information is available on the biological status of largemouth bass in Lake Huron.

Other Centrarchids

Other members of the Lake Huron centrarchid community include rock bass, pumpkinseed, bluegill, black crappie, white crappie, green sunfish, and longear sunfish. Rock bass made up 75% of the harvest of all centrarchids from Michigan waters of Lake Huron in 1986-88. The pumpkinseed is common in the sport fishery of Saginaw Bay.

STATUS OF PREY FISHES IN 1992

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The fishery objective is to maintain a diversity of prey species at population levels matched to primary production and to predator demands (DesJardine et al. 1995). The fish community that occupies all parts of the Lake Huron basin and serves as food for its predators include: the rainbow smelt, bloater, slimy sculpin, deepwater sculpin, alewife, threespine stickleback, ninespine stickleback, trout-perch, and shiners (Berst and Spangler 1973; Stedman and Bowen 1985). Abundance of individual prey species fluctuates considerably from year to year. Fish-community objectives, therefore, envision constant change in the prey-species composition. The idea is to maintain diversity and self-regulation of the prey community.

Since 1973, the NBS has conducted fall surveys of the major prey-fish stocks in Lake Huron (Argyle 1982). These surveys are specifically used to measure:

- relative abundance,
- size and age structure, and
- condition of key planktivorous fishes that are important as prey.

Annual assessments have been conducted with a 12 m bottom trawl since 1973 and a 2 1 m wing trawl since 1992 at five principal areas. All trawl tows are made along depth contours ranging from 10 to 110 m at each site.

Rainbow Smelt

Rainbow smelt populations have fluctuated in abundance because of changes in year-class strength. They have, however, been relatively stable compared with alewives and bloaters throughout the 1970s and 1980s. From the mid-1970s until the mid-1980s, the rainbow smelt was the dominant planktivore in Lake Huron (Brown et al. 1987). Standing stocks of rainbow smelt in the fall were large and numerical abundance indices based on fall catch rates of adult rainbow smelt were high (Fig. 18).

The adult population has been generally smaller since 1987 when the bloater became the dominant planktivore in Lake Huron.

Catches of age-0 rainbow smelt (<10 cm total length) each fall were erratic from 1973 to 199 1 but show some relation to the strength of subsequent year-classes (Fig. 18). In general, strong year-classes were produced from 1979 to 1986, but since then year-classes have been weaker. The rainbow smelt was more abundant in Lake Huron when alewives and bloaters were at lower densities, which suggests that intraspecific competition may exist among the three species.

The rainbow smelt population in Lake Huron is currently dominated by young fish, and stability is therefore dependent upon the production of consistently strong year-classes. The adult population is 90% age- 1 and age-2 fish; age-3 fish make up the bulk of the remaining adults. Since 1978, age-l fish have made up approximately 50% of the adult population. Total annual mortality of rainbow smelt was estimated at 80% in 1973-91.

Alewife

The alewife is the least abundant of the three major prey species in Lake Huron, but it is an important component in the diet of predatory fish. Abundance of adult alewives was relatively high in 1973-79 but then declined to low levels in 1980 (Fig. 18). Adult alewife abundance remained low during the early 1980s, began to recover slightly in the mid-1980s, and declined steadily in 1987-91. Lakewide alewife abundance in 199 1 was nearly as low as in the early 1980s.

Catches of subadult alewives (42 cm total length) have fluctuated widely since 1973 (Fig. 18). In many years, catches of subadults represent age-0 fish and provide a preview of year-class strength. Alewife year-class strength, therefore, appeared to fluctuate substantially. High variability in catch rates may be because of other factors such as time of sampling or environmental conditions. Year-class indices based on subadult catches should, therefore, be viewed with caution. For example:

- The 1979 year-class appeared to be relatively weak as age-0 fish (Fig. 18) but later proved to be fairly strong.

- The 1984 year-class initially appeared to be weak but later proved to be very strong.

Trawling indicated that alewife biomass was relatively high in 1973-8 1 and generally lower thereafter (Argyle 1982). Large year-classes resulted in increased lakewide biomass in 1987 and 1988, but the higher levels were not maintained. Since 1990, the alewife relative biomass has been low-similar to that seen in the early 1980s.

Along with the general decline in alewife populations during the past decade, substantial changes in stock structure occurred. The age composition of alewives changed substantially in 1973-91. Alewife populations were made up of older individuals in 1973-84, but younger fish predominated after 1985. The mean age of alewives declined from 3.1 yr in 1973 to 2.1 yr in 1991 and reached a low of 1.4 yr in 1984 (age-0 fish were not included because of their high catch variability). In 1985-92, the annual mean age was consistently less than the 1973-91 mean of 2.5 yr.

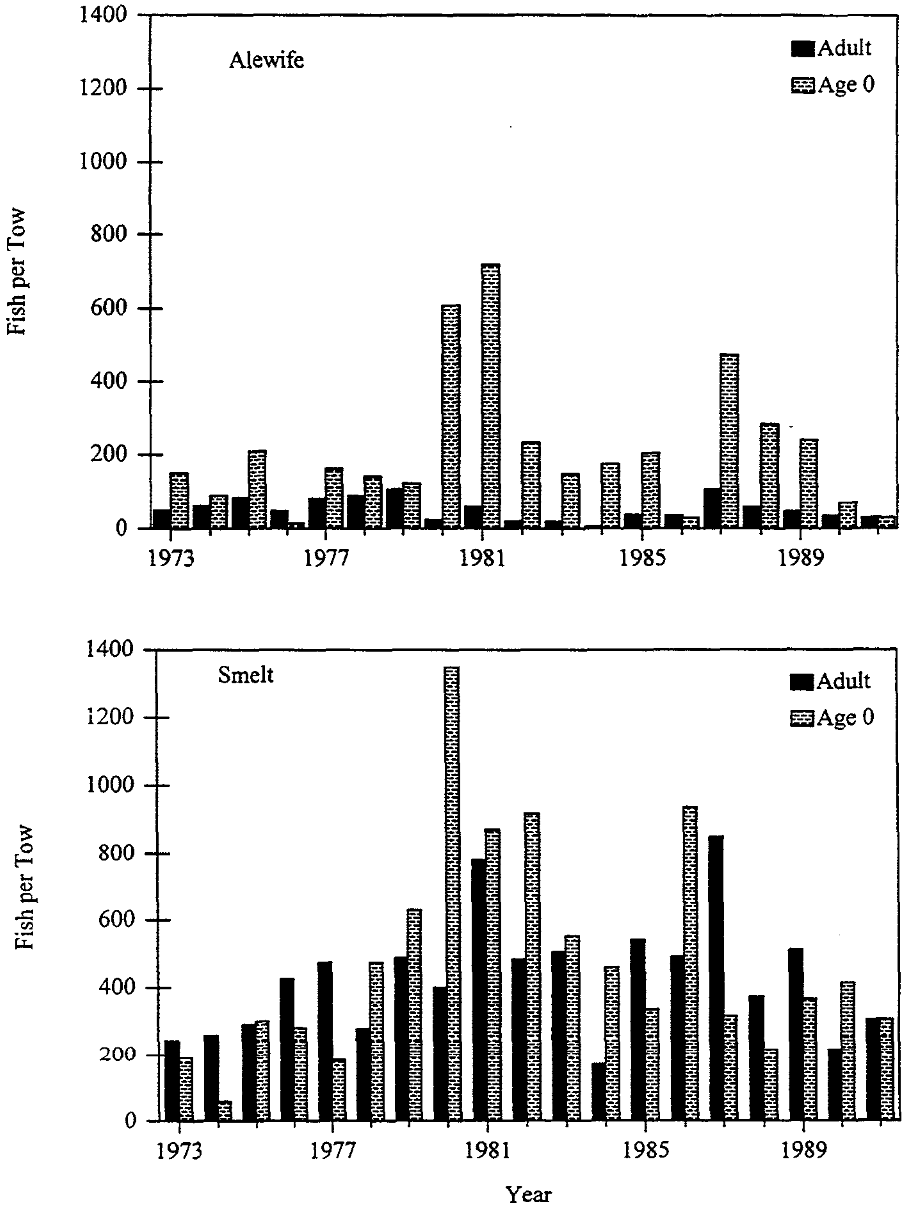

Fig. 18. Relative abundance of adult and age-0 rainbow smelt and alewives caught during fall bottom-trawl surveys in Lake Huron, 1973-9 1.

Bloater

In the early 1970s, bloaters were very scarce in Michigan waters of Lake Huron (Brown et al. 1987). Numbers of young fish began to increase in 1977 and 1978 and catches of this species increased throughout the 1980s (Fig. 19). Bloater catches peaked in 1989 because of the large 1988 year-class and then declined. The decline in the weight of bloaters caught since 1989 was not as drastic as the decline in numbers.

By the end of the 1980s, the biomass of bloaters in United States waters eclipsed that of the rainbow smelt and alewife (Fig. 20). A comparison of catch rates by depth showed that bloaters were more abundant in deeper waters, with the largest concentrations occurring at depths of ≥ 46 m. Catches of age-0 and age- 1 bloaters of the same year-class provide indices of year-class size. Year-class size increased in the early 1980s and the 1983 and 1984 year-classes were very large. These strong year-classes were followed by several smaller year-classes, especially that of 1987. Another very large year-class of this species was produced in 1988, but this year-class was followed by progressively smaller year-classes-particularly in 1990-92. The adult population of bloaters will decline substantially in abundance in the near future as a result of poor recruitment from the 1990-92 year-classes.

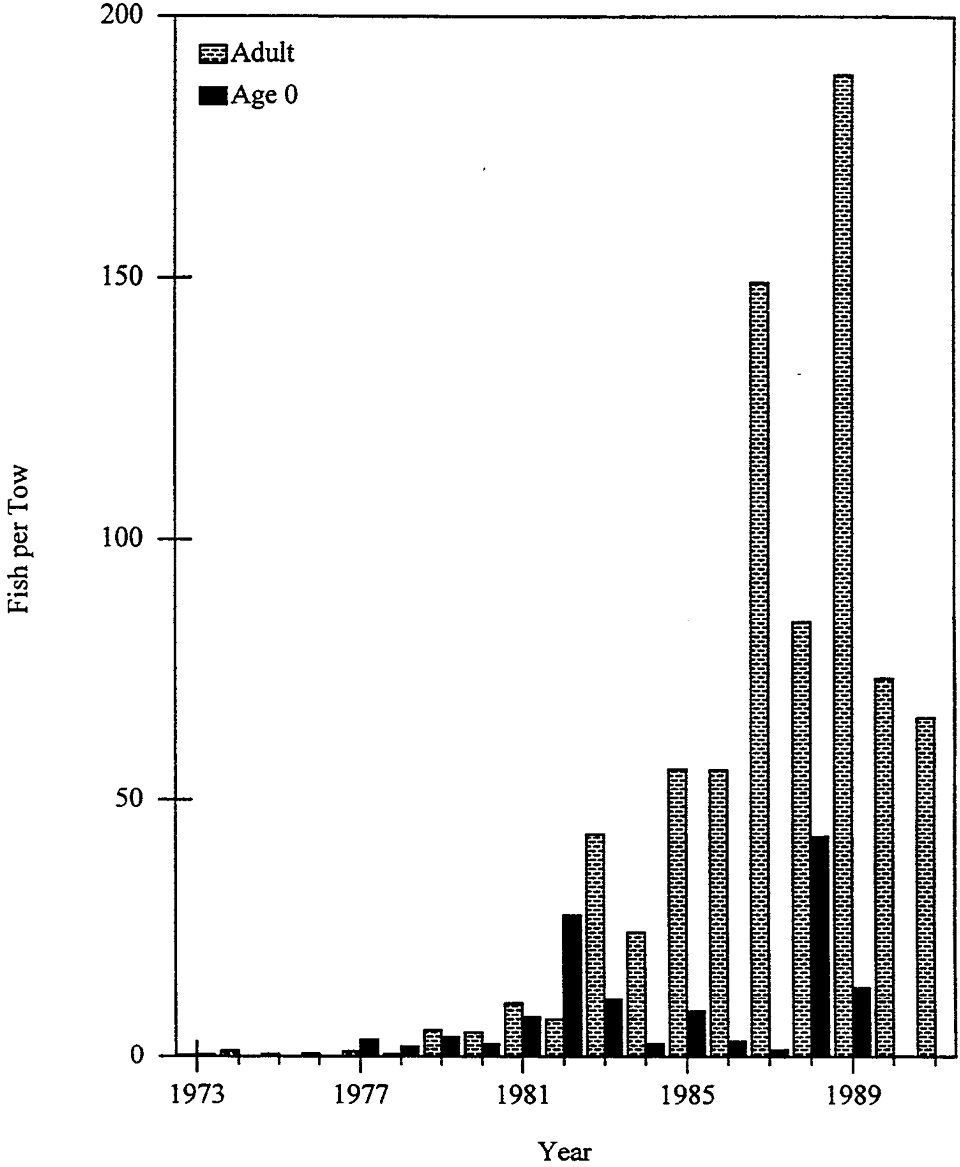

Fig. 19. Relative numerical abundance of adult and age-0 bloaters caught during fall bottom-trawl surveys in Lake Huron, 1973-9 1.

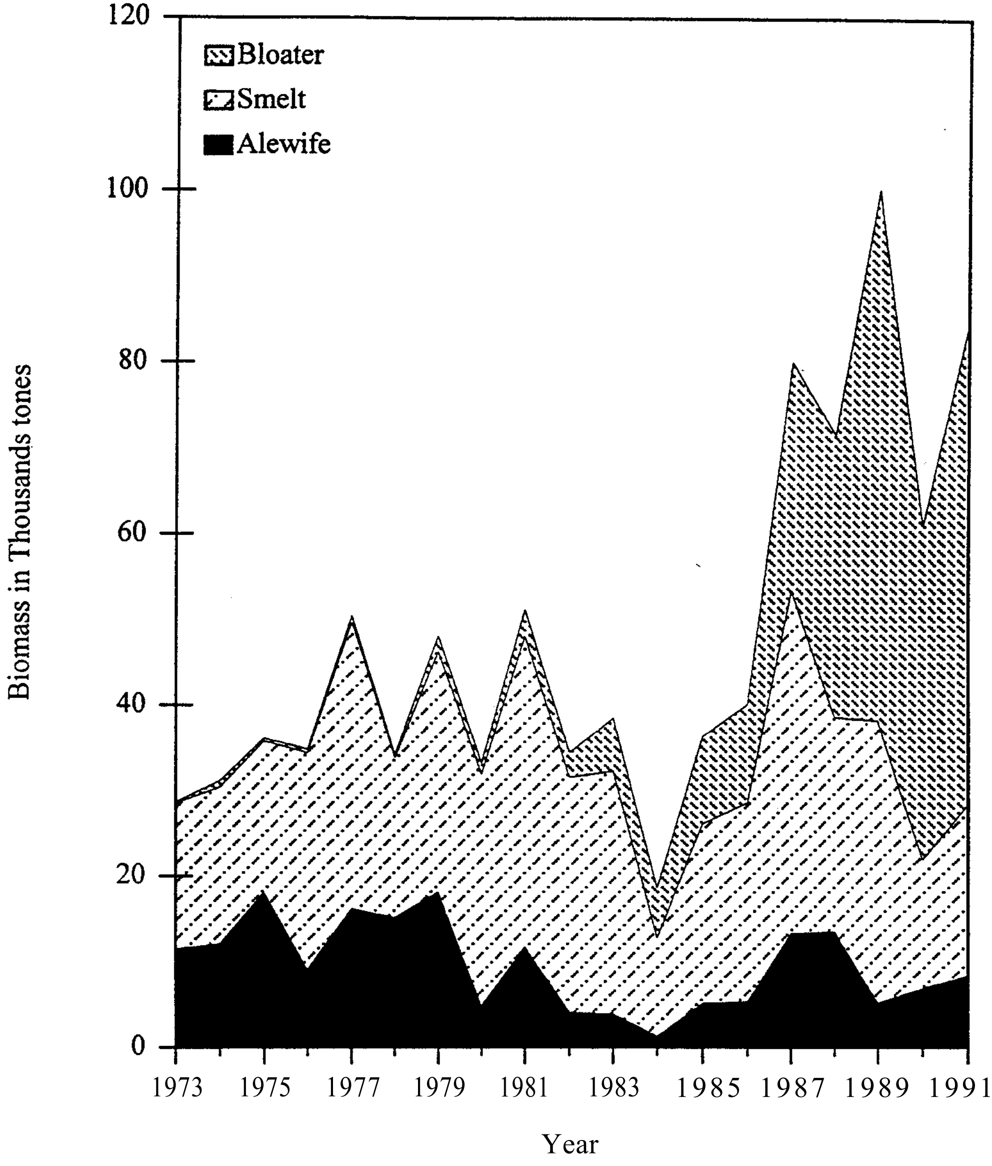

Fig. 20. Biomass of bloaters, rainbow smelt, and alewives in Michigan waters of Lake Huron based on fall bottom-trawl surveys, 1973-9 1.

Other Prey Species

The other principal prey species include the deepwater sculpin, trout-perch and ninespine stickleback. Deepwater sculpin abundance generally increased in 1973-79 and remained relatively high in 1979-82 (Fig. 21). Since 1982, deepwater sculpin catches have been lower but relatively stable. Trout-perch catches have increased since the early 1980s and have stabilized at higher levels than in 1973-84. Catches of ninespine sticklebacks fluctuated greatly in 1973-91, although much of the annual variability may be due to availability of this species to the trawl rather than to changes in population abundance. Catches of slimy sculpins in the trawl gear are typically very small and few inferences can be drawn from the catch data.

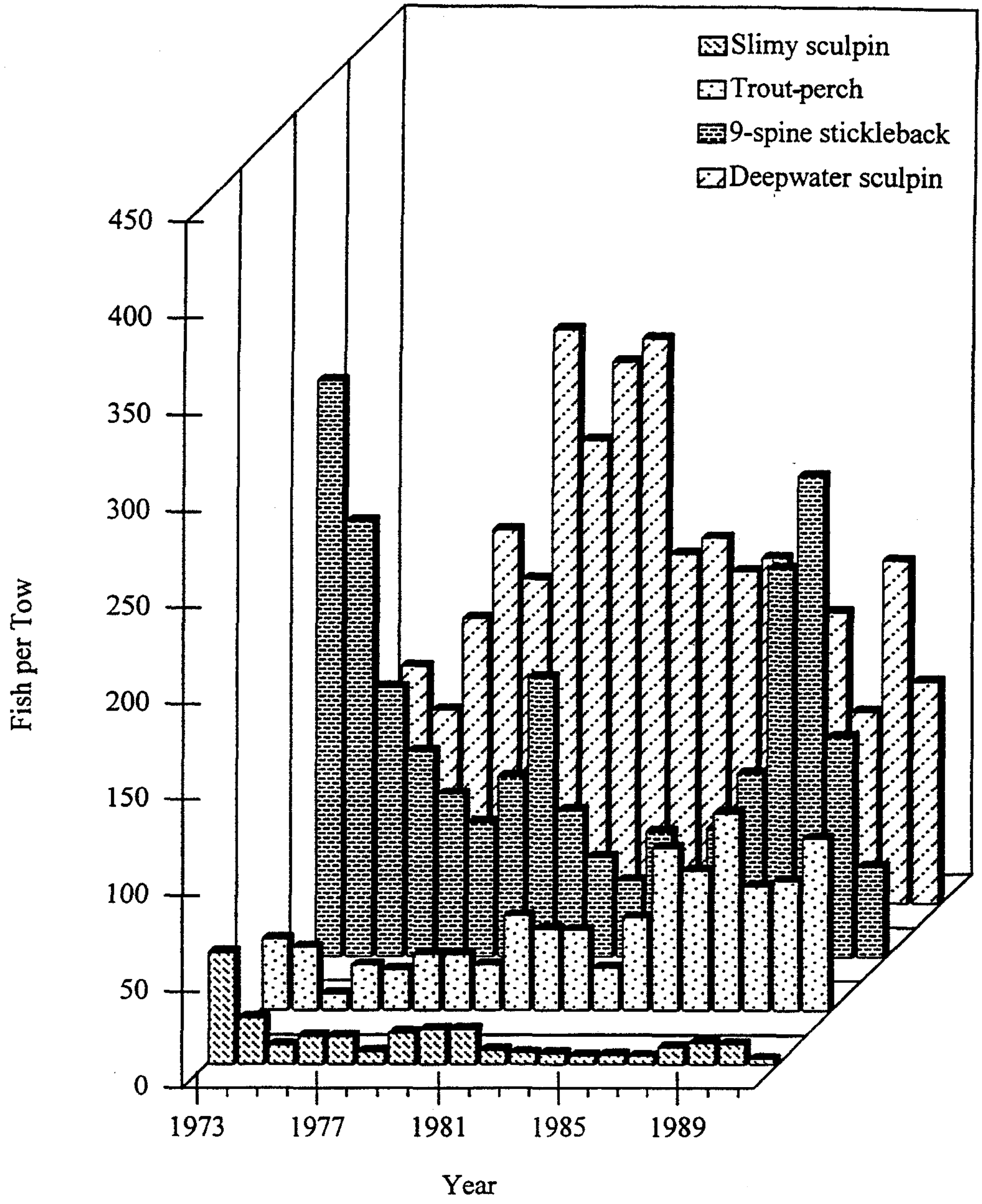

Fig. 2 1. Relative abundance of slimy sculpins, trout-perch, ninespine sticklebacks, and deepwater sculpins caught during fall bottom-trawl surveys in Lake Huron, 1973-9 1.

STATUS OF SEA LAMPREY POPULATIONS IN 1992

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The fishery objectives for the sea lamprey in Lake Huron are to:

- reduce abundance to allow the achievement of other fish-community objectives, and

- obtain a 75% reduction in parasitic sea lampreys by the year 2000 and a 90% reduction by the year 20 10.

Applegate (1950) reported the first sea lamprey from Lake Huron in 1937 when a spawning migration was noted in the Ocqueoc River, Presque Isle County, Michigan. Early attempts at controlling sea lampreys in Lake Huron involved mainly the use of mechanical and electromechanical weirs operated on 11 tributaries in 1964 (Smith and Tibbles 1980). These barriers were discontinued because they:

- washed out during floods,
- were dangerous to humans and wildlife,
- were costly to maintain, and
- were labor intensive.

By 1980, all but the Ocqueoc River weir were discontinued.

The Control Program

In 1960, the GLFC initiated a program to control the sea lamprey in Lake Huron tributaries with the chemical 3 trifluoromethyl-4-nitrophenol (TFM). In 1960-62, TFM was applied to 21 tributaries in Canada and 3 streams in the United States. Because of financial constraints, the GLFC terminated sea lamprey control in Lake Huron in 1963-65. Since 1966, streams with routinely reestablished larval populations have been treated with TFM approximately every 4 yr.

A total of 527 lampricide applications has been made on 110 Lake Huron tributaries (5 1 in Canada and 59 in the United States) since 1960. Approximately 20% of these streams required treatment only once, but some were treated as many as 28 times. During the last 10 yr, treatments have been conducted regularly on 20 tributaries in Ontario and 26 in the United States. In addition to stream treatments, 5 lentic areas (3 in Ontario, 2 in Michigan) have been treated with 2', 5-dichloro-4'-nitro-salicylanilide, or granular Bayer 73.

Sea Lamprey Abundance

The GLFC monitors abundance of sea lampreys in Lake Huron by collecting parasitic adults from 10 Canadian commercial fishermen and by trapping mature spawning adults on 4 index tributaries. The number of adult sea lampreys caught at the Ocqueoc River weir and 4 Canadian tributaries decreased 85% from 1949 to 1970 following treatments of all the known lamprey-producing tributaries in Lake Huron. The number of juvenile (parasitic-phase) lampreys collected from the 10 commercial fishermen remained stable in 1972-82 (Fig. 22). Beginning in 1983, the population of juvenile sea lampreys began to increase-a probable result of untreated larvae in the St. Marys River and a possible increase in survival of juveniles in Lake Huron.

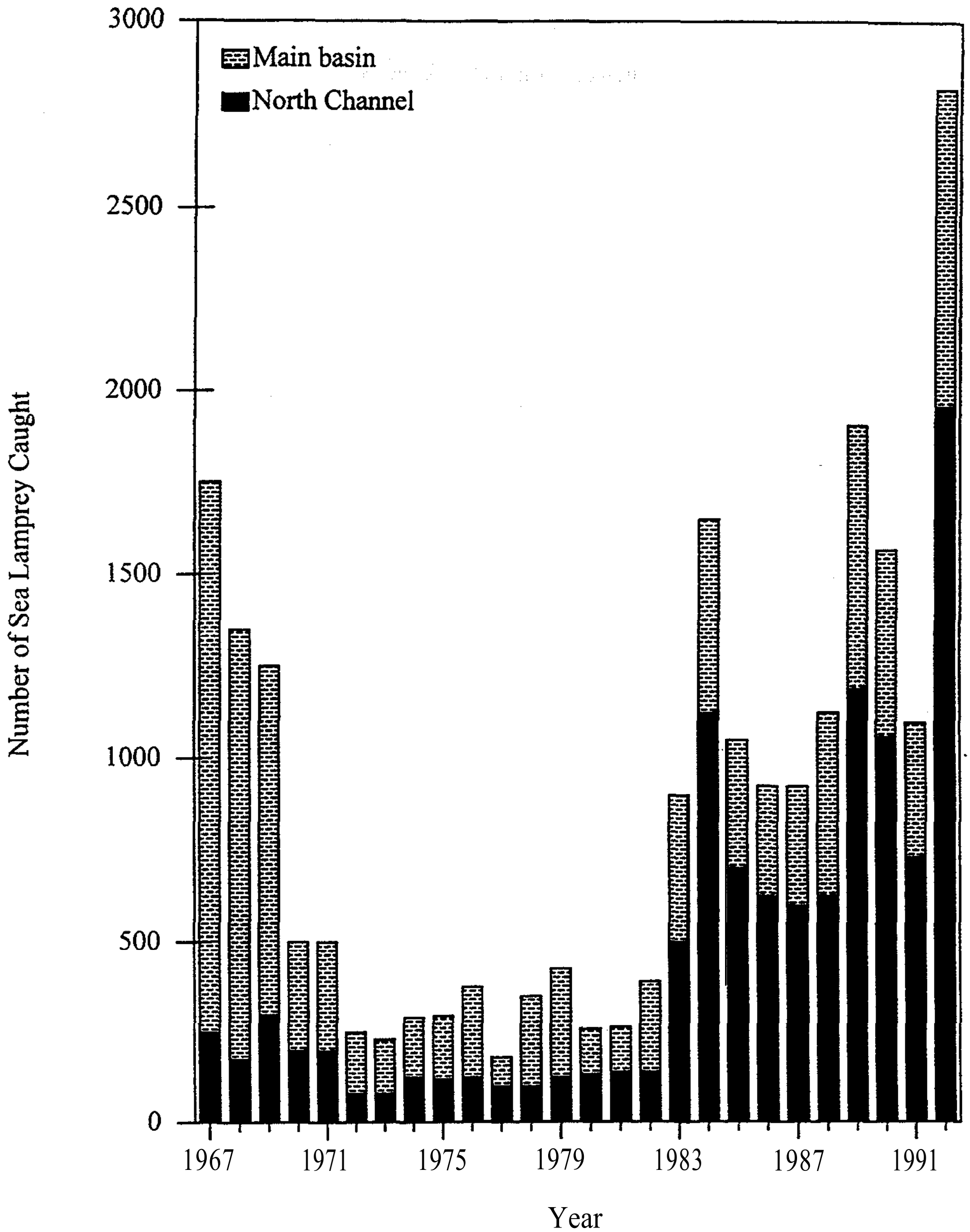

Fig. 22. Number of juvenile sea lampreys caught by Canadian commercial fishermen in the North Channel and northern waters of the main basin of Lake Huron, 1967-92.

Control biologists estimate relative abundance of adult sea lampreys from assessment traps fished on the Ocqueoc, Cheboygan, St. Marys, and Thessalon Rivers (Fig. 23). The majority of spawning sea lampreys are captured on the St. Marys and Cheboygan Rivers. Populations of spawning sea lampreys in the St. Marys and Cheboygan Rivers were estimated as 23,700 (ranging from 16,800 to 35,600) and 35,900 (ranging from 21,400 to 52,400), respectively, in 1978-92. In 1992, almost twice as many spawning sea lampreys were in the Cheboygan River (50,843) as in all United States waters of Lake Superior (28,781).

The abundance of juvenile sea lampreys in Lake Huron has been determined from a mark and recapture program. Heinrich et al. (1985) estimated that approximately 250,000 sea lampreys inhabited northern Lake Huron in 1982. Approximately 248,000 sea lampreys were estimated to be in the Michigan waters of Lake Huron in 1987. The value for the entire lake in that year was 340,000 (J. Heinrich, U.S. Fish and Wildlife Service, Marquette Biological Station, 1924 Industrial Parkway, Marquette, Michigan, 49855, pers. commun.).

The St. Marys River Problem

The St. Marys River is the connecting waterway between Lakes Superior and Huron and is the largest tributary (mean annual discharge of 2,140 m/s) to Lake Huron. The sea lamprey was first observed in the river in 1962 when larvae and recently transformed juveniles were captured during dredging operations. Lampreys passed through the system as early as 1939 because the first individual was taken then from Lake Superior. Schleen (1992) implicated the St. Marys River as a major source of juvenile sea lampreys for Lake Huron.

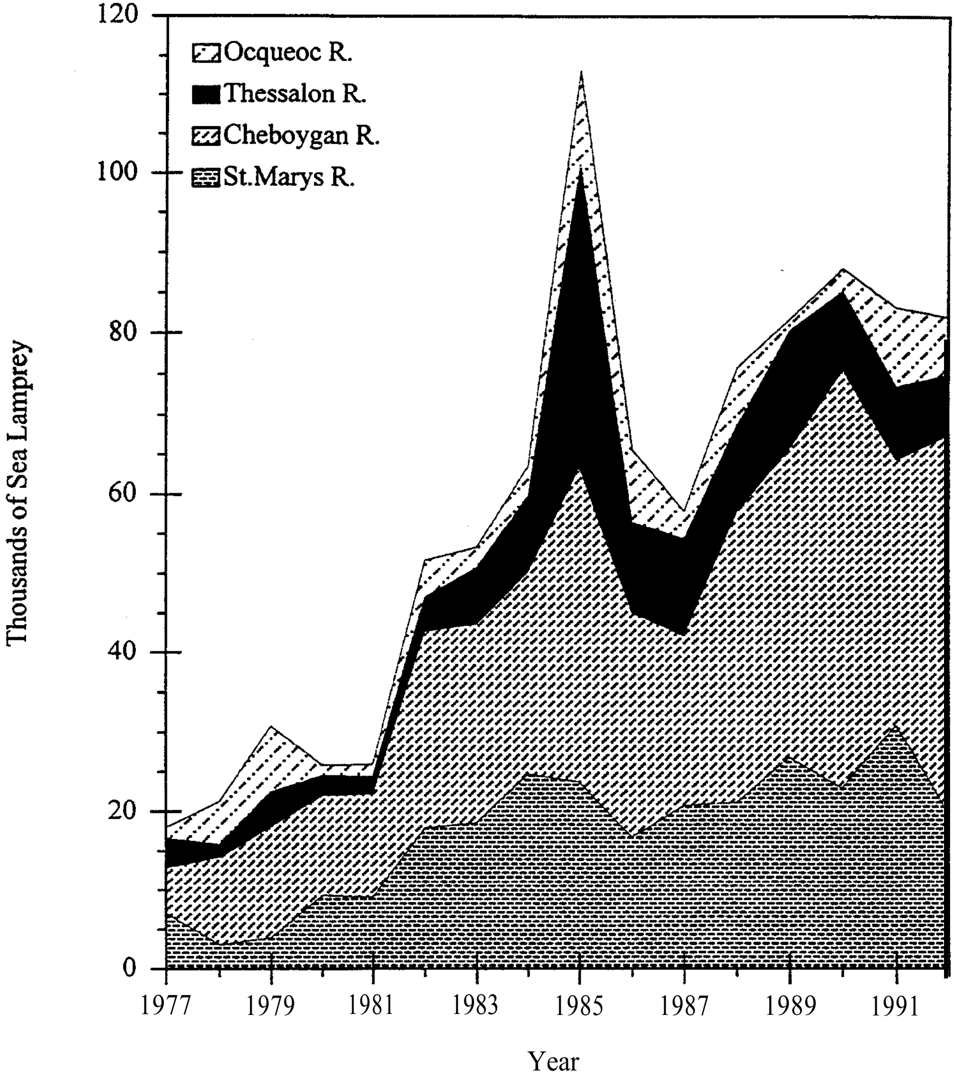

Fig. 23. Estimated number of adult sea lampreys ascending four tributaries of northern Lake Huron, 1977-92.

Annual assessments show that the level of sea lamprey control in tributaries of Lake Huron, excluding the St. Marys River, is comparable to that found in the other Great Lakes. However, there are more juvenile sea lampreys in Lake Huron than in the other four Great Lakes combined (Schleen 1992). An estimated 6.8 million larval lampreys (age 2 and older) were present in the St. Marys River in 1984 (Eshenroder et al. 1987), and the annual rate of transformation of this larval population into parasitic juveniles was estimated at 4% (272,000 animals) in 1988 (Schleen 1992). Sea lampreys are attached to 1 of 5 chinook salmon in Michigan waters of Lake Huron; fewer than 1 of 100 chinook salmon host lampreys in the other Great Lakes (Schleen 1992). In addition to lake trout and chinook salmon, the sea lamprey is also attacking other fish species in Lake Huron (Table 6).

In 1991, GLFC directed its sea lamprey control advisory committee to recommend management actions to address the problem in the St. Marys River. The advisory committee formed a task to recommend a control strategy for 1992 to 1995 and charged the group to:

- identify control options,

- predict the effectiveness and costs of the control options, and

- identify information needs required to assess the options before and after implementation.

In 1992, the task group recommended an integrated control strategy that incorporates short- and long-term actions and uses a progressively increasing combination of techniques. These techniques focus on actions that achieve reduction in the reproductive potential of the sea lamprey. The task group also recommended additional research activities that should allow prediction of the effectiveness and costs of various lampricide-treatment options (Schleen 1992).

Table 6. Sea lamprey wounding rates on various fish species caught in northern Michigan (MH-1) waters of Lake Huron, February-December 199 1.

Species	No. of fish	Marks/l 00 fish
Burbot	176	7.4
Bloater	440	0.2
Channel catfish	46	110.9
Chinook salmon	648	22.8
Longnose sucker	1.50	2.7
Lake trout	417	9.1
Northern pike	185	10.3
Pink salmon	69	1.5
Rainbow trout	33	12.1
Walleye	1,362	1.3
Lake whitefish	2,971	1.5
White sucker	1,241	4.3

STATUS OF SPECIES DIVERSITY, GENETIC DIVERSITY, AND HABITAT IN 1992

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Species Diversity

The fishery objectives recognize and protect the array of other indigenous fish species because they contribute to the richness of the fish community. The objectives further state that these fish-cyprinids, rare ciscoes, suckers, burbot, gars, and sculpin-are important because of their:

- ecological significance,
- intrinsic value, and
- social, cultural, and economic benefits.

Little biological information exists on most of these species in Lake Huron because they are not important to commercial or sport fisheries-except possibly for the common carp, white sucker, and longnose sucker.

We chose to discuss burbot and cyprinids in this section instead of the past and present species richness in Lake Huron. Burbot and cyprinids are abundant in Lake Huron and interact with a large proportion of the present Lake Huron fish community. We believe that the burbot may be the most abundant predator in the lake and deserves some attention here.

Burbot

Abundance

The burbot historically was a very important and abundant member of the Lake Huron cold-water fish community, but abundance declined because of sea lamprey predation. Burbot populations have been recovering slowly in both Michigan and Ontario waters during the last 13 yr, but populations appear to have stabilized in 1987-89 (Fig. 24). In Michigan waters, the recovery appears to be most pronounced in south-central (MH-4) and north-central (MH-2) Michigan waters where catch rates have risen to approximately 5 fish/305 m of graded-mesh gillnet. In Ontario waters, trends in burbot abundance have been similar in both Georgian Bay and the main basin. Populations of burbot in both Michigan and Ontario waters of Lake Huron have declined approximately 50% from peak abundance in 1987-89.

Food Habits

Burbot consume a wide variety of prey and, as such, are potential competitors with lake trout and other salmonines. The diet of burbot has been studied in MH-1 and on Six Fathom Bank during 1991 and 1992 to determine its food preferences. Of the 322 fish examined in MH-1, 73% contained food items, compared with approximately 5 0% for lake trout from the same area. Each burbot contained an average of 4 prey fish in its stomach compared with 2 prey fish in the stomach of each lake trout. Numerically, burbot diet was composed of

- 50% rainbow smelt,
- 5% alewives,
- 13% unidentified sculpins
- 3% sticklebacks,
- 2 1% unidentifiable fish remains, and
- 8% other fish or invertebrates.

The burbot collected at Six Fathom Bank in June, 199 I and 1992 consumed mainly alewives and slimy sculpins. Numerically, burbot ate more sculpins-but on a weight basis, alewives made up a larger portion of the diet. The majority of food items in the burbot diet from Six Fathom Bank were <100 mm total length. The rainbow smelt was not found in the diet of burbot, but was found in the diet of lake trout from Six Fathom Bank. Recently stocked lake trout were common in the diet of burbot from Six Fathom Bank in 1991.

Sea Lamprey Wounding

Burbot are subject to attack by sea lampreys in Lake Huron. The average sea lamprey wounding rate on burbot in St. Martin Bay in April and May, 1991-92 was 17 marks/l 00 fish caught in fykenets and trapnets in water 1-2 m deep. Sea lamprey wounding of burbot from St. Martin Bay increased with size of fish:

- 5 marks/100 fish 43-53 cm long,
- 13 marks/100 fish 53-63 cm long,
- 32 marks/l 00 fish 63-73 cm long, and
- 62 marks/100 fish >73 cm.

In comparison, no sea lamprey marks were found on 320 burbot caught with graded-mesh gillnets in waters l-50 m deep in the Drummond Island Refuge in October, 199 1 and 1992.

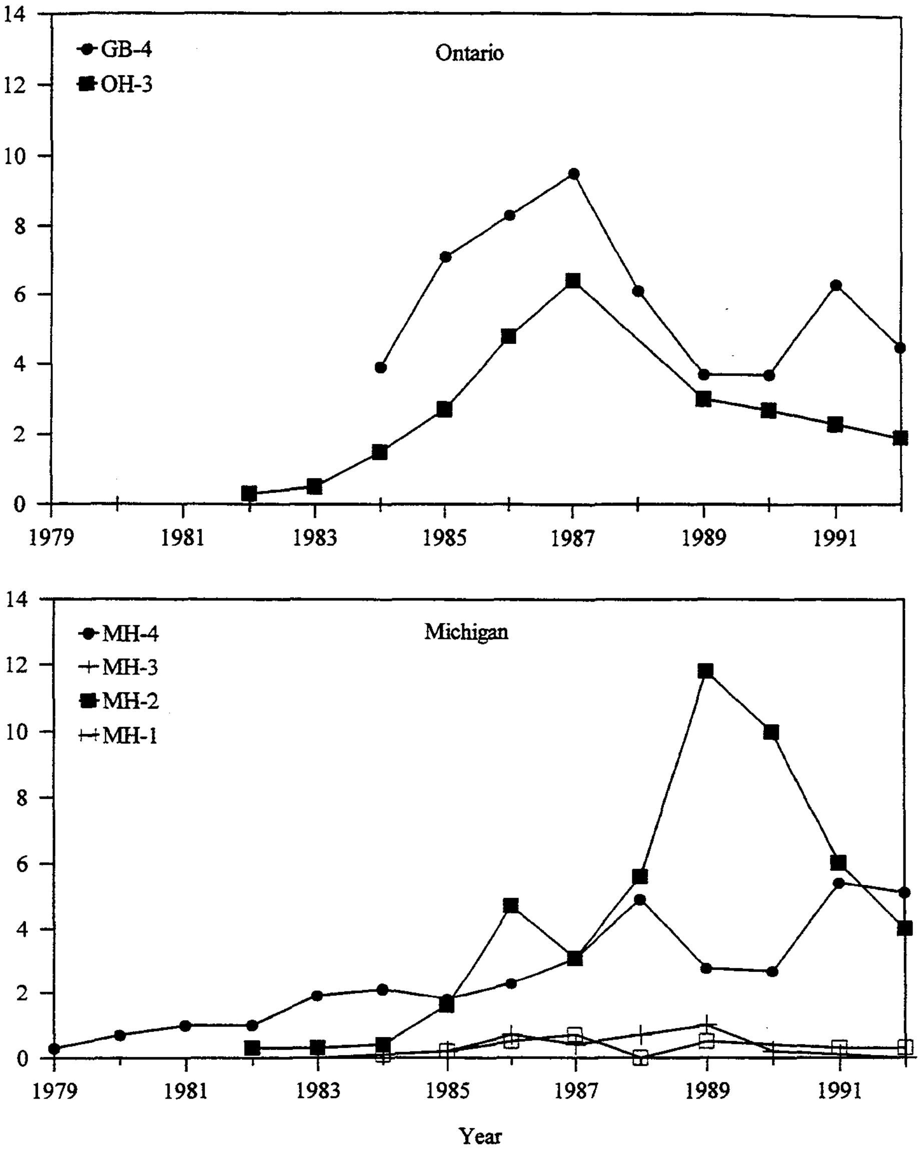

Fig. 24. Relative abundance of burbot caught during index gillnet surveys in some statistical districts of Ontario and Michigan waters in Lake Huron, 1979-92.

Cyprinids

Cyprinids and other small species are very abundant members of the Lake Huron fish community and occupy mainly nearshore waters <3 m deep. The spottail shiner is indigenous to Lake Huron and was the most abundant cyprinid taken at night in seine hauls from St. Martin Bay. The shiner made up 28%, by number, of all fish caught in 199 1 and 1992. Other members of the nearshore fish community caught in the seine hauls included the sand shiner, longnose dace, logperch, and johnny darter. These species provide an important food source for young walleyes and northern pike in St. Martin Bay.

Genetic Diversity

The fishery objectives are to:

- maintain and promote genetic diversity by conserving locally adapted strains, and

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

Fishery managers have a responsibility to include basic genetic management practices in all plans for preserving or enhancing the fish community in waters under their jurisdiction. Populations persist, in part, because they contain the genetic diversity that enables them to survive and adapt to changing environmental conditions. Loss of this genetic variability can significantly hinder the success of any management plan.

The importance of genetics in fishery management has received increasing emphasis during the past 20 yr. Failure of hatchery stocking to produce the desired effects has resulted in the examination of hatchery practices to discover the causes (Allendorf and Phelps 1980; Leary et al. 1985; Allendorf and Ryman 1987). Concerns regarding the potential effects of stocking on the genetic integrity of wild populations is also an issue (Krueger and Menzel 1979; Seelbach 1986). These analyses have led to an increased awareness of the potential effects of ignoring genetic implications when developing fishery-management plans.

Genetic variation is lost when a population is reduced to low numbers. Inbreeding that occurs in depleted stocks tends to exacerbate the diminished genetic fitness of the population and can actually accelerate the extinction of the population. Restoration of severely depleted stocks generally includes hatchery supplementation as a major component. When establishing a founder stock for a hatchery program, it is important that the source be genetically suited to accomplish the goals of the management program (Allendorf and Ryman 1987).

Several genotypes are being tested for lake trout rehabilitation in Lake Huron by the USFWS and the OMNR (Table 7). In most cases, the origin and performance of the strain (in terms of preferred habitat, population stability, and genetic fitness) and the region of Lake Huron that the strain was to be stocked in were the principal criteria used to determine suitability. Lake trout strains are being evaluated on both offshore and nearshore reefs in hopes of finding specific genotypes most likely to produce self-sustaining populations. Stocking the Lake Manitou strain of lake trout appears to have been responsible for partial recovery of the South Bay population that is now successfully reproducing (Fig. 1).

The MDNR has been stocking and evaluating various strains of brown trout in Thunder Bay. Management plans call for the development of a lacustrine strain of brown trout with strong piscivorous traits to meet sport-fishing and ecological criteria within the bay. When a strong candidate has been identified, genetic management will seek to protect and enhance the fitness of the hatchery product.

Another management initiative receiving increasing scrutiny is walleye restoration in Saginaw Bay. The management strategy for restoration of walleyes in Saginaw Bay has evolved from one of stocking "any available walleye" to an approach involving two or possibly three strains (Table 7).

- The Muskegon River genotype was stocked for the first 6 yr of the restoration strategy.

- A Lake Erie reef-spawning strain was then stocked for 3 yr.

- The strategy then calls for development of a feral Saginaw River strain for the continuation of restoration.

All genotypes have been genetically identified to facilitate long-term evaluation of the various strains.

Lack of genetic variability in hatchery stocks can result in problems (such as increased susceptibility to disease) both in the hatchery and the wild (Allendorf and Phelps 1980). For example, a study done by using starch-gel electrophoresis found that the Jenny Lake strain of lake trout possesses a relatively high frequency of null alleles (enzymatically inactive) predisposing it to developmental problems and making it a poor candidate for use in rehabilitation (Leary et al. 1983). Consequently, this genotype has been replaced by the more genetically variable Lewis Lake strain.

Genetic variation may be the most important biological resource in the artificial propagation of any species (Leary et al. 1985). Often, intentional or inadvertent selection for genetic traits occurs within the hatchery or by management biologists. Practices, such as selection for improved hatchery performance, should be avoided for stocking programs requiring long-term survival in the wild (Allendorf and Ryman 1987). Deliberate selection for desirable traits from a given population generally results in diminished genetic variability and, while possibly beneficial for management of a sport fishery, may have adverse effects on the success of stocking. Some counterproductive desirable traits might be early or late maturation, rapid growth, or aesthetically desirable phenotypic characteristics.

Table 7. Genotypes of lake trout, brown trout, and walleyes stocked in Lake Huron for restoration or fishery development.

Species and genotype	Agency	Yr	Location	Comments
Lake trout:				
Backcross	OMNR	1972-92	Georgian Bay, South Bay	Lake Manitou x splake-being phased out
Lake Manitou	*OMNR*	*1977-92*	South Bay	Lake Superior-not suitable lakewide
Parry Sound	OMNR	1979-80s	Parry Sound	Native to Lake Huron-developing brood stock
Iroquois Bay	OMNR	up to 1989	Iroquois Bay	Native to Lake Huron-developing brood stock
Slate Island	OMNR			Lake Superior-experimental Strain
Michipicoten Island	OMNR			Lake Superior - experimental strain
Marquette	USFWS	1972-92	Lakewide	Lake Superior--questionable future
Seneca Lake	USFWS	1985-92	Six Fathom Bank/Refuge	Finger Lakes, NY-lamprey resistant
Lake Ontario	USFWS	1990-92	Six Fathom Bank/Refuge	Lake Ontario feral-replaced Senecas
Jenny Lake	USFWS	1985-91	Six Fathom Bank/lakewide	Jenny Lake, WY - genetically unfit
Lewis Lake	USFWS	1992	Six Fathom Bank/lakewide	Lewis Lake, WY-replace Jenny Lake

Continued on next page

Table 7, *continued*

Species and genotype	Agency	Yr	Location	Comments
Brown trout:				
Plymouth Rock	MDNR	1990-92	Thunder Bay	Unknown-discontinued
Wild Rose	MDNR	1992	Thunder Bay	Wild Rose, WI-good performance
Seeforellen	MDNR	1992	Thunder Bay	Germany-excellent performance
Ganaraska	MDNR	1992	Ontario waters	Introduced in 1913-naturalized
Walleye:				
Mixed	MDNR	1972-84	Saginaw Bay	Stocked as available
Muskegon River	MDNR	1985-90	Saginaw Bay	Muskegon River, MI
Lake Erie	MDNR	1991-92	Saginaw Bay	Reef spawner from Lake Erie
Mixed	OMNR	-	Georgian Bay	Stream spawners from the Moon, Spanish, and Magnetawa Rivers

Genetic diversity of endemic fish species in Lake Huron must be preserved. Supplementing these stocks with hatchery fish has the potential for degrading the genetic diversity that allowed for their evolution. Remnant stocks can be adversely affected or, in some cases, eliminated if they are continually faced with high mortality resulting from the need to compete in a population enhanced by fish from non-indigenous stocks (Reisenbichler 1984). Efforts should be made to preserve and protect the Iroquois Bay and Parry Sound stocks of lake trout, which are the only known remnants of indigenous Lake Huron lake trout populations. The genetic composition of these two stocks can never be duplicated and can be extinguished rapidly by outbreeding that results from stocking non-indigenous fish. Concerns about negative effects on existing steelhead populations were the primary reason the MDNR discontinued the Skamania-stocking program in Lake Huron in 1991.

When possible, gametes for a hatchery program should be taken from indigenous populations or supplemented with gametes from those populations. If indigenous stocks are unavailable, or in such low numbers that adequate gametes are not available, access to geographically proximate populations inhabiting similar habitats should be pursued as a fast alternative. The OMNR is employing this strategy with its walleye stocking. Rather than selecting a specific stock for its phenotypic qualities or general availability, brood populations from nearby spawning populations are used.

Habitat

The fish-community objectives are to:

- protect and enhance fish habitat and rehabilitate degraded habitats,
- achieve no net loss of the productive capacity of habitat supporting Lake Huron fish communities,
- restore damaged habitats, and
- support the reduction or elimination of contaminants.

The Lake Huron basin had the following habitat features before degradation in the 1800s and 1900s (Francis et al. 1979):

> *little accumulation of organic sediments except in marshes, and bays; sufficient oxygen concentrations for aquatic life; large areas of clay turbidity from bluff erosion; midsummer stream flows were abundant and cool; extensive wetlands, marshes and aquatic macrophytes; inshore areas were cooler than now-at least near cities and farms.*

Most of the loss of fish habitat has occurred in Saginaw Bay where the largest human population in the Lake Huron basin is found. More than 75% of the historic lakewide yields of walleyes, yellow perch, lake herring, and channel cattish were derived from Saginaw Bay before pollution dramatically reduced productivity of the bay in the mid-1900s. On a positive note, TDS loading into Lake Huron has been minimal during the last few decades in comparison with Lakes Michigan, Ontario, and Erie (Francis et al. 1979). Current TDS loadings into Lake Huron may be less than observed two decades ago because of pollution controls currently in effect.

Protect, Enhance, and Rehabilitate

An aquatic habitat classification system (AHC) applicable to the Great Lakes has been developed to assist fish managers in construction of lake management plans that incorporate habitat protection and enhancement measures useful in estimating fish yields and sustaining fisheries (Sly and Busch 1992). In the future, we hope to monitor progress in protecting and enhancing fish habitat in Lake Huron within the five principal habitat types identified in the AHC:

1) open lake,

2) near-shore waters,

3) adjacent wetlands,

4) connecting channels, and

5) tributaries.

Johnson et al. (1987) described macroinvertebrate associations in unpolluted open-lake and nearshore areas of Georgian Bay to assist in evaluating polluted areas of Lake Huron. This research could be used to evaluate habitat in other areas of Lake Huron.

The open-water habitat of Lake Huron remains relatively unchanged from historic times. The habitat should provide high-quality habitat for fish species such as the lake trout, Pacific salmon, whitefish, deepwater ciscoes, slimy sculpin and deepwater sculpin. Edsall et al. (1992) surveyed the historic open-water lake trout spawning grounds on the Six Fathom Bank-Yankee Reef complex (Fig. 1) and found the lake bottom there contained substantial areas suitable for spawning and fry production.

The nearshore area of Lake Huron is different (Sly and Busch 1992) from the open waters in that it:

- has groundwater intrusion,
- is affected by lake levels and the shoreline,
- receives stresses that do not affect the open water, and
- is where vegetation grows.

This area is important to the reproductive success of many species-particularly lake whitefish and lake trout. The present success of lake whitefish stocks in Lake Huron indicates that much of the nearshore area has not been degraded.

Nester and Poe (1987) visually inspected 12 historical nearshore spawning reefs used by lake trout in Lake Huron to determine current suitability of each area for lake trout reproduction. They based suitability of each spawning ground for successful lake trout reproduction on the:

- structure of the rock,
- depth of interstitial spaces in the rock,
- infiltration of sediments onto spawning grounds, and
- amount of plant growth on the spawning grounds.

Based on their criteria, nine spawning grounds north of Saginaw Bay were classified as suitable for lake trout and three spawning grounds off Port Austin, Michigan, near Saginaw Bay, (Fig. 1) were much less suitable for successful reproduction.

Measures for protection and enhancement of nearshore Lake Huron habitat have already begun. Enhancement of the near-shore area for fish reproduction was initiated by the construction of an artificial reef off Tawas, Michigan in 1987 by a sport-fishing organization and the MDNR. The artificial reef was created to stimulate walleye reproduction; but, as early as 1988, lake trout and lake whitefish were spawning there (Foster and Kennedy, in press). Additional protection to important whitefish and lake trout spawning grounds will be provided by a marine sanctuary that is being proposed for the Thunder Bay area (Fig. 1).

A positive step toward protecting and rehabilitating fish habitat in tributaries to Lake Huron has been taken through the Federal Energy Regulatory Commission (FERC) relicensing of existing hydroelectric facilities in Michigan. The MDNR and Consumers Power Company reached a negotiated settlement over relicensing of a hydroelectric facility on the Au Sable River (Fig. 1). As part of that agreement, Consumers Power agreed to spend a specified amount of money to rehabilitate degraded habitat and provide fish passage. There is also a FERC relicensing agreement on the Thunder Bay River at Alpena, Michigan. The major issues at the Au Sable and Thunder Bay hydroelectric facilities are:

- passage of fish upstream and downstream around the dams,

- maintenance of stable river flows,

- establishment of erosion control, and

- increasing natural reproduction and recruitment of anadromous Great Lakes fish below the dams.

The OMNR has initiated a management plan to regulate shoreline-related activities in the Sault Ste. Marie District (Ontario Ministry of Natural Resources 1991) for protection of near-shore habitat. The Sault Ste. Marie District Shoreline Management Plan encompasses the St. Marys River system southeast through the North Channel into northwestern Georgian Bay. The plan addresses:

- environmental conservation,

- prevention of habitat loss,

- protection of specific vulnerable areas,

- emergency responses to ensure adequate planning in places with flooding and erosion,

- public information for disseminating shoreline management awareness, and

- monitoring and development control.

The Sault Ste. Marie district shoreline protection strategy is being expanded by the OMNR to include the entire Canadian coastline of Lake Huron. The expanded strategy will classify the entire shoreline into sensitivity classes and provide for the protection of the most ecologically sensitive areas.

Achieve No Net Loss

Wetlands, connecting channels, and tributaries have taken the brunt of habitat destruction in the Lake Huron basin and can be used as the best indicators of ecosystem health. The best gauge for measuring progress toward the habitat objective will be through monitoring population characteristics of yellow perch, walleyes, northern pike, smallmouth bass, catfish centrarchids, and lake sturgeon because these species depend upon wetlands, connecting channels, and tributaries for reproduction and rearing of young.

The International Joint Commission (IJC) identified five Areas of Concern (AOCs) on Lake Huron where habitat, use by fish and wildlife, or use of the area by humans has been impaired because of pollution. The five AOCs are:

1) the St. Marys River,

2) Spanish Harbor,

3) Collingwood Harbor,

4) Severn Sound, and

5) the Saginaw River/Saginaw Bay.

Remedial-action plans are being developed to protect and restore productivity in these areas. Impaired resources in the 5 AOCs are:

- contaminated sediments and fish,
- habitat loss for fish reproduction and rearing,
- reduced species diversity,
- low DO,
- frequent chemical spills,
- massive fish kills,
- rivers fouled with bark and fiber,
- exotic aquatic plants,
- poor water quality from phosphorus loading and erosion, and
- an unstable fish community because of declines in predator populations and shoreline destruction.

An important step toward improving Saginaw Bay water quality and productivity has been the creation of the Saginaw Bay Watershed Initiative. The Saginaw Bay watershed was chosen as the first watershed to be designated under the National Watershed Initiative Program of the U.S. Environmental Protection Agency. This program is a process for determining environmental protection and natural resource management priorities by having local, state, and federal agencies, special interest groups, and citizens work together to identify short- and long-term goals for the area. The initiative encompasses 22 counties in central and eastern Michigan. It hopes to provide funding and resources to implement pollution control and projects within the watershed to:

1) Identify the causes of environmental problems by collecting and analyzing data.

2) Assess trends in water quality, natural resources, and land uses in the watershed.

Winter navigation on the Great Lakes through the St. Marys River system is an important issue related to habitat protection in Lake Huron's largest tributary, which is a connecting channel to Lake Superior. Historically, the St. Marys River provided an important habitat for the reproduction and rearing of fishes that inhabited Lakes Huron and Superior. Construction of the Sault Ste. Marie locks, diversion of water for power generation, and habitat loss related to shoreline construction have led to dramatic reductions in the productivity of the St. Marys River (Edsall and Gannon 1993). In the 1960s, the Great Lakes commercial shipping industry and the U.S. Army Corps of Engineers proposed extending the commercial shipping season to include the winter months. Environmental changes resulting from winter-navigation activities are of major concern in the narrow connecting channels like the St. Mary's River (Liston and McNabb 1984).

In response to the winter-navigation issue, several major studies have been initiated to evaluate its effect on the St. Marys River system (Liston and McNabb 1984; Munawar and Edsall 199 1; Savino et al. 1994). Savino et al. (1994) found no effects on the early life stages of lake herring as a result of sedimentation in the laboratory or the St. Marys River that may be due to winter navigation. However, these authors recommended detailing the spawning site of lake herring and normal survival to hatching in the river before making predictions about the effects of winter navigation. The MDNR is also doing studies related to the effects of winter navigation on lake herring and whitefish populations in the river system. Improving the St. Marys River system for fish production will greatly assist in achieving the fishery objectives for Lake Huron.

Reduce and Eliminate Contaminants

Contaminant levels in Lake Huron fish are generally below guidelines established to protect consumers of fish, but insufficient data are available to evaluate whether those levels are low enough to protect fish. Contaminant monitoring programs on Lake Huron are being conducted by the MDNR COTFMA, OMNR and IJC. The MDNR has a native fish contaminant-trend monitoring program in Saginaw Bay and Thunder Bay. The IJC has a lakewide program.

Levels of contaminants in fish flesh that warrant health-consumption advisories usually occur in specific locations, not throughout the lake. Mean concentrations of PCBs and DDT in lake trout from Ontario waters of Lake Huron in 1978-88 were less than the fish-consumption advisory trigger level of 2 ppm for PCBs and 5 ppm for DDT (Environment Canada 1991). Concentrations of chlordane, PCBs, and DDT all declined in lake trout from southern Ontario waters of the main basin in 1976-90:

- Chlordane concentrations in lake trout declined from 193 ppb in 1979 to 13 ppb in 1990.

- PCB levels declined from 2,598 ppb in 1976 to 521 ppb in 1990.

- DDT levels declined from 1,238 ppb in 1976 to 200 ppb in 1990.

Mean concentrations of mercury in walleyes from the St. Marys River were above the advisory levels of 0.5 ppm. Mercury in walleyes >55 cm standard length was 0.2 to 0.6 ppm higher than levels from other locations in Ontario. Mean concentrations of mercury in walleye fillets from St. Martin Bay, however, were lower than advisory levels (Gwen 1992). Levels of PCBs in lake trout from the main basin in Ontario were much higher than in Georgian Bay or the North Channel (Fig. 25). Locations where fish contaminant levels in whole-fish samples exceeded fish-consumption advisory triggers of the Michigan Department of Public Health (Michigan Department of Natural Resources 1992) in 1990-9 1 were:

- St. Marys River-walleye (total chlordane, mercury)

- Saginaw Bay-carp and channel catfish (PCBs)

- Port Austin-lake trout (total chlordane, PCBs).

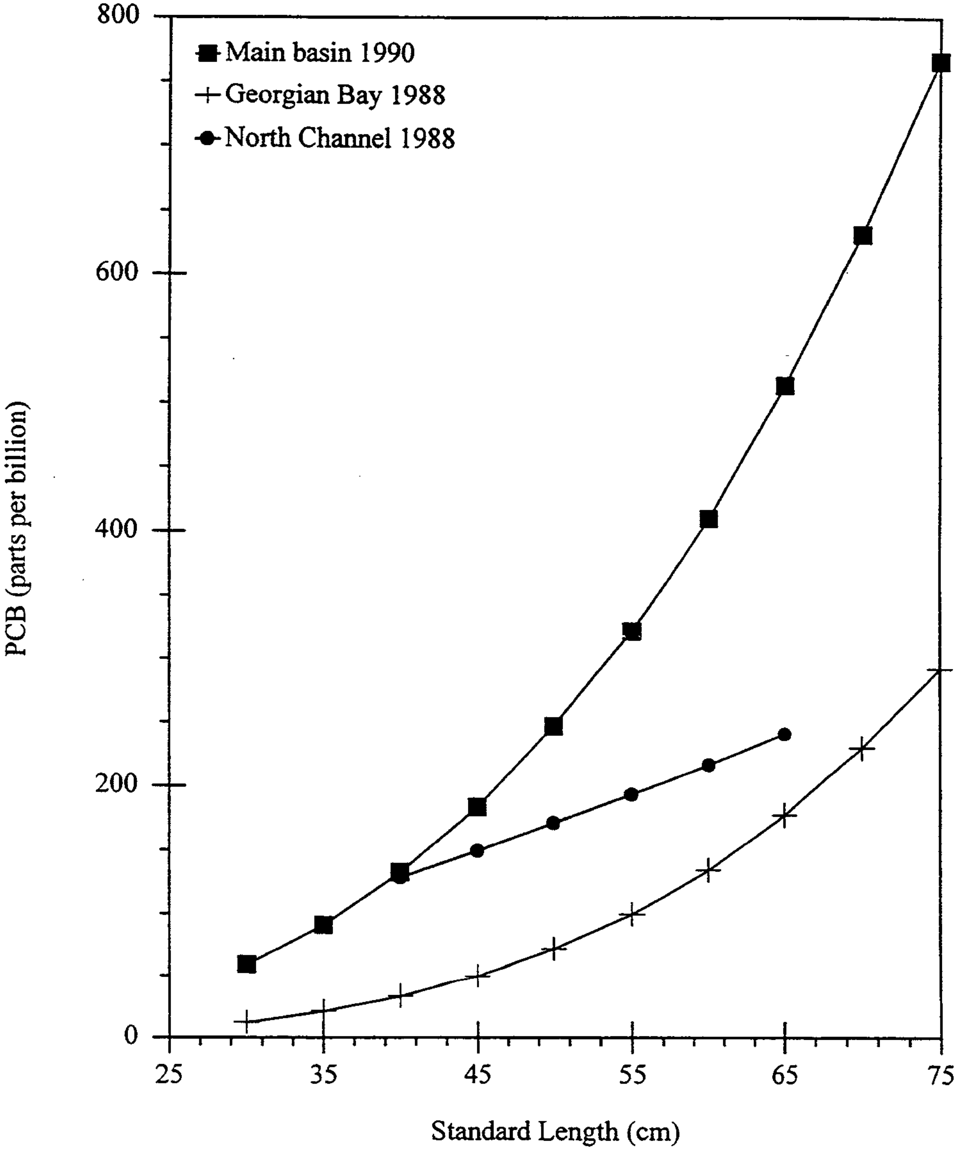

Fig. 25. Concentrations of PCBs in fillets of lake trout 30-75 cm, standard length, from various basins in Ontario waters of Lake Huron, 1988-90.

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APPENDIX
Predatory Fish Stocked in Lake Huron
1968-92*

Yr	Chinook salmon	Coho salmon	Brown trout	Rainbow trout	Lake trout	Back-cross	Walleye	Splake
1968	265	402	0	0	0	0	0	0
1969	250	667	0	0	0	0	0	31
1970	643	571	82	472	0	0	0	248
1971	894	975	159	396	0	0	0	359
1972	515	249	160	379	0	0	0	270
1973	967	100	497	837	629	486	0	289
1974	767	500	420	323	250	250	0	216
1975	655	627	155	484	1,052	0	0	635
1976	830	691	447	399	1,024	0	0	655
1977	733	416	210	286	1,033	0	0	486
1978	1,418	84	258	473	1,217	152	25	0
1979	1,325	1,082	90	447	1,338	603	334	153
1980	1,878	375	90	623	1,381	751	10	0
1981	1,523	135	45	293	1,388	623	294	0
1982	2,001	453	250	444	1,360	926	270	0
1983	2,696	425	667	474	1,099	818	869	0
1984	3,127	470	586	626	841	1,070	1,150	0
1985	3,118	672	623	1,163	2,008	994	1,465	0
1986	3,557	675	767	2,231	1,799	818	1,397	0
1987	3,809	582	582	1,984	1,096	925	1,035	197
1988	4,165	702	637	1,830	1,878	733	678	0
1989	5,018	350	485	1,472	1,998	865	1,073	0
1990	4,768	0	899	1,036	870	531	11	0
1991	3,897	0	846	1,336	1,824	724	951	0
1992	3,966	0	472	2,160	2,928	319	1,273	25

*Values expressed as thousands

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