FISH-COMMUNITY OBJECTIVES FOR LAKE ONTARIO

Great Lakes Fishery Commission

SPECIAL PUBLICATION 99-1

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August 1999

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Thomas J. Stewart
Lake Ontario Management Unit
Ontario Ministry of Natural Resources, RR #4
Picton, Ontario, CANADA, K0K 2T0

Robert E. Lange
Great Lakes Fishery Section
New York State Department of Environmental Conservation
Bureau of Fisheries, 50 Wolf Road, Room 522
Albany, NY 12233-4753

Sandra D. Orsatti
Lake Ontario Management Unit
Ontario Ministry of Natural Resources, 300 Water Street
Peterborough, Ontario, CANADA, K9J 8M5

Clifford P. Schneider
Lake Ontario Unit
New York State Department of Environmental Conservation
Cape Vincent, NY 13618

Alastair Mathers
Lake Ontario Management Unit
Ontario Ministry of Natural Resources, RR #4
Picton, Ontario, CANADA, K0K 2T0

Marion E. Daniels
Lake Ontario Management Unit
Ontario Ministry of Natural Resources, 300 Water St.
Peterborough, Ontario, CANADA, K9J 8M5

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EXECUTIVE SUMMARY

This document summarizes a scientific consensus on major factors influencing the fish community of Lake Ontario, describes the results of public discussion on possible futures for the fish community, and outlines binational (whole-lake) fish-community objectives. These objectives will be used as a guide by New York and Ontario to carry out their mandates to manage the fish and fisheries of Lake Ontario.

Lake Ontario supports diverse recreational, commercial, and aboriginal fisheries. Total annual expenditures by anglers participating in Lake Ontario recreational fisheries were estimated at $53 million (Canadian) for Ontario waters in 1995 and $71 million (U.S.) for New York waters in 1996. The predominantly Canadian commercial fishery had a landed value in 1996 of $1.5 million (Canadian).

Alewives (see Appendix for scientific names) are the principal prey of most fish predators and are important for maintaining predator growth. Alewives may impede recruitment of native fish by preying on their young and by inducing early mortality syndrome—a fatal disease affecting young fish because of a thiamine deficiency in parental diets.

By 1994, management agencies reduced stocking of salmon and trout to 4.5 million fish—a cut of nearly 50%. Following public consultation in 1997, stocking of salmon and trout was increased moderately to 6.0 million fish. Reproduction and survival of chinook salmon have increased, and abundance of other alewife predators (for example, the walleye and cormorant) is high. Increases in alewife predators have markedly reduced alewife abundance.

Nutrients have declined in Lake Ontario, and the recent invasion of zebra and quagga mussels has caused changes in how nutrients are cycled through food webs. These changes have decreased alewife productivity. Alewife biomass reached a 20-yr low in 1997, and further declines are likely.

Reestablished native forage fish (for example, ciscoes and deepwater sculpins) can provide prey that are alternatives to alewife, rainbow smelt, and slimy sculpin. The feasibility of reestablishing these species by direct transfer from the upper Great Lakes or by culture is difficult to assess without experimentation.

Parallel public consultation processes in Ontario and New York focused on future options for the fish community; means of achieving desired outcomes; and risks, benefits, and uncertainties associated with various management options.

A diversity of stakeholder perspectives was advanced, and some common themes emerged. Stakeholders greatly value the trout and salmon fishery, which requires large-scale stocking and an abundance of alewives. Stakeholders also support ecological principles relating to rehabilitation of native fish, including an increased role for wild fish.

Managing for abundant alewives and viable trout and salmon fisheries is incompatible with managing for native fishes. An incongruity between the fishery that stakeholders want and what a scientific assessment of ecological trends in Lake Ontario indicates is possible presents a fundamental dilemma to the Lake Ontario Committee—the binational body that develops fishery policy for the lake. The Committee concluded that trout and salmon abundance should be maintained to provide quality fishing opportunities without putting excessive predation pressure on alewives.

The Committee believes that the Lake Ontario ecosystem is not yet sufficiently well understood to unequivocally rule out socioeconomically desirable but possibly unsustainable objectives. The Committee's objectives are implicitly experimental and are subject to frequent review and revision as the ecosystem evolves and yields greater insights. In the interim, the Committee endorses the following objectives for the three major components of the lake's fish community.

The ***nearshore fish community*** will be composed of a diversity of self-sustaining native fishes characterized by

- Maintenance of existing walleye populations and expansion of walleye populations into favorable habitats

- Maintenance of existing yellow perch populations and expansion of yellow perch populations into favorable habitats

- Population recovery of lake sturgeon populations sufficient for removal from New York's list of threatened species

- Population levels of smallmouth bass, largemouth bass, and sunfish populations attractive to anglers

- Increasing numbers of American eels consistent with global efforts for their rehabilitation

The ***offshore pelagic fish community*** will be characterized by

- A diversity of salmon and trout

- Chinook salmon as the top predator

- Abundant populations of rainbow trout (steelhead)

- Fishable populations of coho salmon and brown trout

- Populations of stocked Atlantic salmon at levels consistent with investigating the feasibility of restoring self-sustaining populations

- Amounts of naturally produced (wild) salmon and trout (especially rainbow trout) that are consistent with fishery and watershed plans

- A diverse prey-fish community with the alewife as an important species

The ***offshore benthic fish community*** will be composed of self-sustaining native fishes characterized by

- Lake trout as the top predator
- A population expansion of lake whitefish from northeastern waters to other areas of the lake
- Rehabilitated native prey fishes

INTRODUCTION

Responsibility for Lake Ontario fisheries management is shared by the Ontario Ministry of Natural Resources (OMNR) for the Province of Ontario and the New York State Department of Environmental Conservation (NYSDEC) for the state of New York. As described in the Convention on Great Lakes Fisheries between the United States and Canada (Great Lakes Fishery Commission 1956), Lake Ontario includes

- The waters of Lake Ontario proper (including the Bay of Quinte)
- The Niagara River below Niagara Falls
- The St. Lawrence River from Lake Ontario to the 45^{th} parallel of latitude

Also included are smaller tributaries used by fish stocks of common concern.

Fisheries management of shared stocks, as defined by A Joint Strategic Plan for Management of Great Lakes Fisheries (Joint Plan) (Great Lakes Fishery Commission 1997), includes the preparation by each lake committee of fish-community objectives for each of the Great Lakes.

The Lake Ontario Committee (LOC), which includes representatives from the NYSDEC and OMNR, last published fish-community objectives in 1989 (Kerr and LeTendre 1991). Since publication of the 1989 document, the Lake Ontario ecosystem has changed substantially—especially in response to water-quality improvements and the invasion of zebra and quagga mussels. Compared to the early 1980s, the biomass (total weight) of prey fish like the alewife and rainbow smelt has been reduced by one-half. In 1993, after extensive public consultation, the NYSDEC and OMNR reduced salmon and trout stocking levels in an effort to balance the demand these predators placed on prey-fish populations. These reductions were not a direct result of a fish-community-objectives exercise, although the reductions did represent a change in management direction for the offshore zone of the lake.

To be meaningful and useful for fisheries management, fish-community objectives for Lake Ontario must reflect the current and most-complete scientific understanding of the Lake Ontario ecosystem and must also be responsive to the social, economic, and cultural needs and preferences of stakeholders. In preparation for revising the lake's fish-community objectives, the LOC undertook two major initiatives to ensure that these important factors would play a prominent role in the planning process. First, in 1996, a group of scientists from a variety of agencies and academic institutions participated in two workshops funded by the Great Lakes Fishery Commission (GLFC) and Environment Canada (EC). The purpose of these workshops was to evaluate natural and human influences on Lake Ontario fish communities. Second, during the winter of 1996-97, public consultation exercises were conducted by the NYSDEC and OMNR. The information about the status of Lake Ontario reported in this document largely reflects what was available and presented during these consultations.

This document outlines binational, whole-lake fish-community objectives for Lake Ontario, excluding the St. Lawrence River.[1] This document will be used by the NYSDEC and OMNR to guide the delivery of their mandates for managing the fish community and fisheries of Lake Ontario. These objectives are also a starting point for discussions with management agencies, interest groups, and the general public for developing more-specific fisheries, habitat, and watershed-management plans. In addition, the objectives will contribute to other management planning initiatives, for example, Remedial Action Plans (RAPs) and the Lakewide Management Plan (LAMP) for Lake Ontario.

GOAL STATEMENT

In the Joint Plan (Great Lakes Fishery Commission 1997), a common goal statement was developed for all Great Lakes fishery-management agencies

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

[1]A similar planning process for the St. Lawrence River will be undertaken in 1999.

GUIDING PRINCIPLES

The following principles identify resource-management values common to the NYSDEC and OMNR. The principles underpin the implementation of fisheries-management activities that support attainment of Lake Ontario's fish-community objectives.

- The lake must be managed as a whole ecosystem because of the complex interrelationship of all species (including humans) and the environment

- The public has a role to play in ensuring that healthy fish communities and fisheries are passed on to future generations

- Humans are part of the ecosystem—their actions can influence certain aspects of the ecosystem—but their ability to directly set its future course is limited; responsible management, therefore, must continually strive to better understand the structure, function, and limits of the ecosystem

- Stakeholders contribute critical biological, social, economic, and cultural information to fisheries-management agencies in support of fisheries-management decision making—with decision making comes a duty to share accountability and stewardship

- Managing a fish community requires a long-term perspective that recognizes short-term social, cultural, and economic requirements—human use that is not ecologically sustainable cannot yield sustainable economic benefits

- Protection and rehabilitation of fish communities and their habitats are the most-fundamental requirements for productive, long-term fisheries

- The amount of fish that can be produced and harvested from an aquatic ecosystem has ecological limits

- Self-sustaining native and naturalized species support diverse, long-term fish communities that can provide continuing social, cultural, and economic benefits

- Stocked fish can contribute to the ecological function of the fish community, support the rehabilitation of native fish species, and provide put-grow-take fishing opportunities

- Protecting and rehabilitating native and desirable naturalized species, including individual stocks, are important in supporting biodiversity

- Protecting and rehabilitating rare and endangered species are important for maintaining biodiversity

- Protecting and rehabilitating critical fish habitat, including tributary and inshore spawning and nursery areas, are required to sustain productive fisheries over the long term

- Determining how well the ecosystem is managed depends on the availability of timely scientific information provided through broad-based, long-term monitoring and research

DESCRIPTION OF LAKE ONTARIO

Lake Ontario (Fig. 1) ranks as the twelfth-largest lake in the world. Its surface area of 18,960 sq km (7,340 sq mi) makes it the smallest of the Great Lakes. Of the lake's surface area, 52% is within the Province of Ontario and the remainder is in the state of New York. The lake's drainage area of 64,030 sq km (24,720 sq mi) is dominated by forests (49%) and agriculture (39%). A total of 7% of the basin is urbanized.

Major urban industrial centers—Hamilton, Toronto, and Rochester—are located on Lake Ontario's shore. The New York shore is less urbanized and is not intensively farmed, except for a narrow coastal plain. There are approximately 6.6 million people living within the Lake Ontario basin—nearly 69% reside in Ontario. Most of the population is concentrated in the western half of the basin, including the Toronto-Hamilton crescent, which contains more than half of the population of the entire Canadian Great Lakes basin. In New York, population density is highest in the Rochester and Syracuse-Oswego areas.

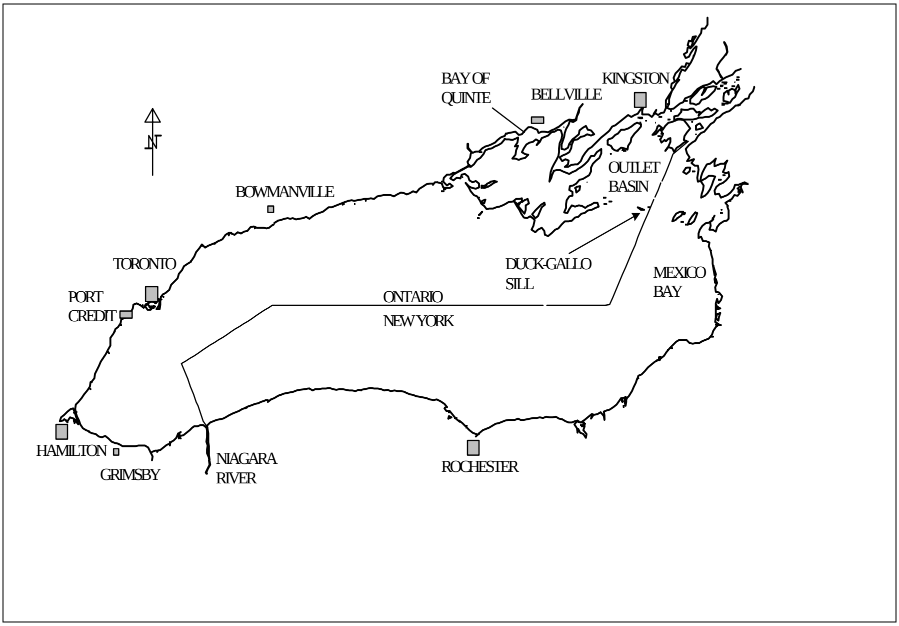

Fig. 1. Map of Lake Ontario.

A total of 85% of the lake perimeter is characterized by regular (nearly straight) shorelines sloping rapidly into deep water. The bottom topography of the lake is relatively smooth with the exception of the Duck-Gallo Sill, which provides a distinct separation between the eastern outlet basin and the remainder of the lake. The main basin reaches a maximum depth of 244 m (802 ft) and is bounded by the Niagara Peninsula to the west and by Mexico Bay to the east. The eastern outlet basin of the lake is much shallower and smaller than the main basin. However, with many embayments and peninsulas, the outlet basin accounts for more than 50% of the lake's shoreline. The only islands are those near the outlet at the eastern end of the lake and Toronto Island to the west.

Lake Ontario's current nutrient levels are characteristic of an oligotrophic (low productivity) system. A total of 86% of inflows comes from the upper Great Lakes and Lake Erie via the Niagara River. Water quality is affected by upstream sources and inputs from local industry, urban development, agriculture, and landfills. Lake water levels are influenced by dams and locks in the St. Lawrence River.

HISTORICAL LAKE ONTARIO FISH COMMUNITY

Early changes to the Lake Ontario fish community are well documented (Smith 1968; Christie 1973; Kerr and LeTendre 1991; Smith 1995). Prior to European colonization, Atlantic salmon, lake trout, and burbot were the most-abundant piscivores (fish-eating predators). Lake whitefish and lake herring were abundant in shallower, offshore waters. Prey fish in deeper, offshore waters included several species of deepwater ciscoes (also called chubs) and deepwater and slimy sculpins. In warmer, nearshore areas, yellow perch, walleye, northern pike, and lake sturgeon were abundant and supported important fisheries. Emerald and spottail shiners were important prey fishes.

A long period of habitat loss and degradation followed European colonization. Water quality deteriorated slowly at first with the effects of forest clearance but accelerated during 1940-70 in response to increasing amounts of urban runoff (Schelske 1991). The non-native alewife, rainbow smelt, and sea lamprey (a parasitic fish) colonized Lake Ontario probably as a result of Erie Canal access (Smith 1995). Commercial fisheries continued throughout the period of degradation, which put additional pressure on native fish stocks. These impacts culminated in the 1960s resulting in

- The virtual elimination of large piscivores
- Severely reduced abundance and extinction of other native fishes
- An overabundance of alewives, rainbow smelt, and sea lampreys

Growing concern over the continuing decline in water quality and enrichment of Lake Ontario prompted international efforts to reduce pollutants and nutrient loading (Stevens and Neilson 1987). The Great Lakes Water Quality Agreement (GLWQA) between the United States and Canada, signed in 1972 and amended in 1978 (International Joint Commission 1994), resulted in improved water quality (Stevens and Neilson 1987; Johengen et al. 1994) and renewed interest in restoring the Lake Ontario ecosystem. Fish stocking and sea lamprey control conducted since the 1970s resulted in an increased abundance and diversity of fish. The fish community today is very different from the one at the time of European settlement.

CURRENT LAKE ONTARIO FISH COMMUNITIES

Habitat Zones and Food Webs

To simplify our presentation, Lake Ontario was partitioned into two major overlapping and interacting habitat zones—a nearshore zone and an offshore zone. Feeding relationships among fish and other organisms within each zone are called food webs. The fish community inhabiting the nearshore zone is considered to be part of one food web, whereas the offshore zone is divided into a benthic (living near the bottom) food web and a pelagic (living in the open water) food web. Benthic and pelagic organisms are also part of the nearshore food web. Most aquatic food webs depend mainly on the production of microscopic plants called algae, which require light and nutrients to thrive. Algae are eaten by tiny animals living in the water column called zooplankton and by certain bottom-dwelling organisms called benthos. Benthos depend mainly on dead material (detritus) that settles to the bottom. Zooplankton and benthos provide the link from algae to fish and cycle material through the food web.

The Nearshore Zone and Food Web

The nearshore zone includes shallow (< 15 m deep)[2] coastal waters and all embayments. In this zone, wind and wave exposures vary from very shallow, protected embayments having little water exchange with the open lake to exposed coastal areas contiguous with the offshore zone.

Similarly, the degree of nutrient enrichment and extent of habitat alteration and shoreline development varies widely. The physical structure provided by aquatic plants and by variations in bottom substrate, bottom relief, water flow, light, and temperature is an important feature of the nearshore zone and is required by fish for feeding, avoiding predation, or for spawning or nursery habitat.

The importance of the nearshore zone to Lake Ontario fish communities cannot be overemphasized. With few exceptions, most Lake Ontario fish spend at least part of their life cycle in the nearshore zone. The eggs, larvae, and juveniles of many fish are the most-vulnerable life stages, and they depend on nearshore habitat. The nearshore food web is a complex association of phytoplankton, zooplankton, benthos, and mostly smaller fish. The resident fish community inhabiting the nearshore zone varies with season, the degree of nutrient enrichment, temperature, and available habitat. Dominant fish species that spend most of their life cycle in the nearshore zone include walleye, smallmouth and largemouth bass, northern pike, freshwater drum, yellow perch, white perch, gizzard shad, various minnows, and several sunfishes. The American eel is also an important nearshore fish predator, but it is currently at historically low levels of abundance (Casselman et al. 1997).

[2]The 15-m depth boundary between the nearshore and offshore zones is an over-simplification intended only to illustrate the concept of two zones.

The Offshore Zone and Food Webs

The offshore zone of Lake Ontario can be described as waters beyond the 15-m depth contour, excluding embayments. Absence of a terrestrial interface reduces the habitat diversity of this zone, but temperature is a dominant structural influence on fish distribution. The development and expansion of thermal bars (a band of warm, nearshore water) in spring, establishment of a thermocline in midsummer, and wind-driven mixing and movement of water result in large variations in temperature among depths and regions. Mixing of offshore waters reduces spatial variation in water quality, as compared to the nearshore zone. Many fish species associated with the offshore zone rely on the nearshore zone or tributaries for spawning and nursery habitat.

The Offshore Pelagic Food Web

The offshore pelagic food web consists of small prey fish feeding on zooplankton that in turn are eaten by large predatory fish. The most-common zooplankters eaten are cladocerans and copepods. Other important planktonic species include the opossum shrimp (often better known by its scientific name *Mysis relicta)*, the recently introduced spiny water flea, and veligers (larvae) of the introduced zebra and quagga mussels. Important prey fish are the alewife and rainbow smelt. Chinook salmon, coho salmon, rainbow trout, brown trout, and adult lake trout are pelagic predators whose abundance is maintained by stocking.

The Offshore Benthic Food Web

The offshore benthic food web is composed of several species of deepwater zooplankters, mysids, and amphipods (*Diporeia* spp.). Vertical migrations of mysids, alewives, and rainbow smelt provide an important mechanism for transferring energy between the pelagic and benthic food webs (O'Gorman et al. 1987; Mills et al. 1992; Johannsson 1993). The benthic fish community is dominated by juvenile and adult lake trout and slimy sculpins. Burbots are also present in low numbers, and lake whitefish are abundant in northeastern waters.

LAKE ONTARIO FISHERIES

Lake Ontario supports diverse recreational, commercial, and aboriginal fisheries. The largest fishery consists of boat, shore, and tributary angling for salmon and trout in both New York and Ontario. Yields from the salmon and trout boat fishery peaked at 2,600 metric t (one t = 1,000 kg) in 1987 and declined to 824 t in 1995 (Fig. 2). Although not as well documented, yield for the shore and tributary fishery for salmon and trout is at least as large as the boat fishery (Savoie and Bowlby 1991; Tom Eckert, New York State Department of Environmental Conservation, Cape Vincent, NY 13618, pers. commun.). Yields for other large recreational fisheries between 1985 and 1996 ranged from 213 to 122 t for the Bay of Quinte walleye fishery and from 14 to 30 t for the New York walleye, yellow perch, and bass fishery. Smaller sport fisheries include those in warmwater embayments in New York, which are not monitored, and in the eastern outlet basin, which harvests < 2 t.

Annual participation in the salmon and trout boat fishery remained relatively constant from 1986 to 1991 at approximately 4.0 million angler hours; however, by 1995, it had declined to 2.2 million angler hours. Total annual expenditures by anglers participating in Lake

Ontario's recreational fisheries were estimated at $53 million (Canadian) for Ontario waters in 1995 (Department of Fisheries and Oceans 1997) and $71 million (U.S.) for New York waters in 1996 (Connelly et al. 1997).

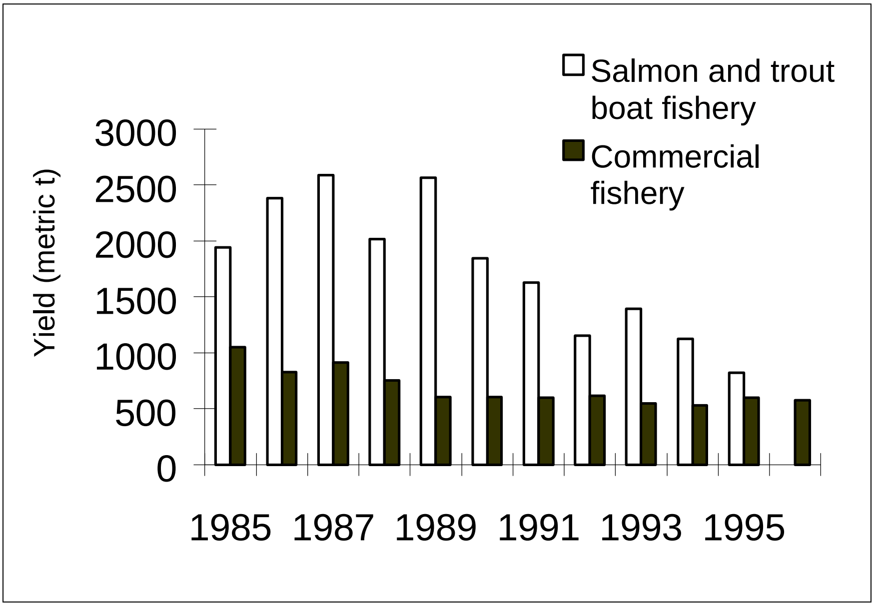

Fig. 2. Lakewide yields from Lake Ontario's New York and Ontario angling boat fishery for salmonids and from Ontario's commercial fishery, 1985-96. The boat-angling harvest was not measured in 1996.

The commercial fishery, largely centered in Ontario's nearshore eastern waters, yielded 1,050 t of fish in 1985. However, by 1996, the yield declined to 574 t (Fig. 2). A total of 17 species of fish were harvested. The most important were the lake whitefish, walleye, yellow perch, and American eel. The landed value in 1996 was estimated at $1.5 million (Canadian). The nearshore aboriginal fishery each spring harvested from 7 to 29 t of walleye from Ontario's rivers from 1994 to 1996.

MAJOR FISH-COMMUNITY INFLUENCES

The complexity of the Lake Ontario ecosystem makes it difficult to determine all the factors that shape the current fish community. Several key factors can be identified, although unpredictable events (for example, weather) can affect reproduction or survival of a species and lead to unanticipated changes. The findings of two scientific workshops (ESSA Technologies 1996) are drawn upon to describe the major trends in Lake Ontario's fish communities and the major factors influencing them. We believe that management taken to achieve fish-community objectives must be based on the best available science, however incomplete, yet adapt to new information and chance events.

Nutrients

Nutrients, particularly phosphorus, exert a major influence on the structure of Lake Ontario's fish community. Lake Erie provides the largest loading of phosphorus to Lake Ontario via the Niagara River. Within-basin loadings include outputs from sewage treatment plants and runoff from urban areas and agricultural lands. These localized sources can cause an excessive buildup of nutrients, bacteria, sediments, and contaminants in nearshore areas and embayments. Excess phosphorus in the 1960s resulted in widespread nuisance levels of filamentous algae that caused beach closings and smothered fish spawning areas. Implementation of the GLWQA reduced phosphorus inputs and relieved many of the associated problems. Phosphorus levels throughout the lake declined in response to reduced nutrient loadings (Fig. 3), but local impacts from past loadings persist.

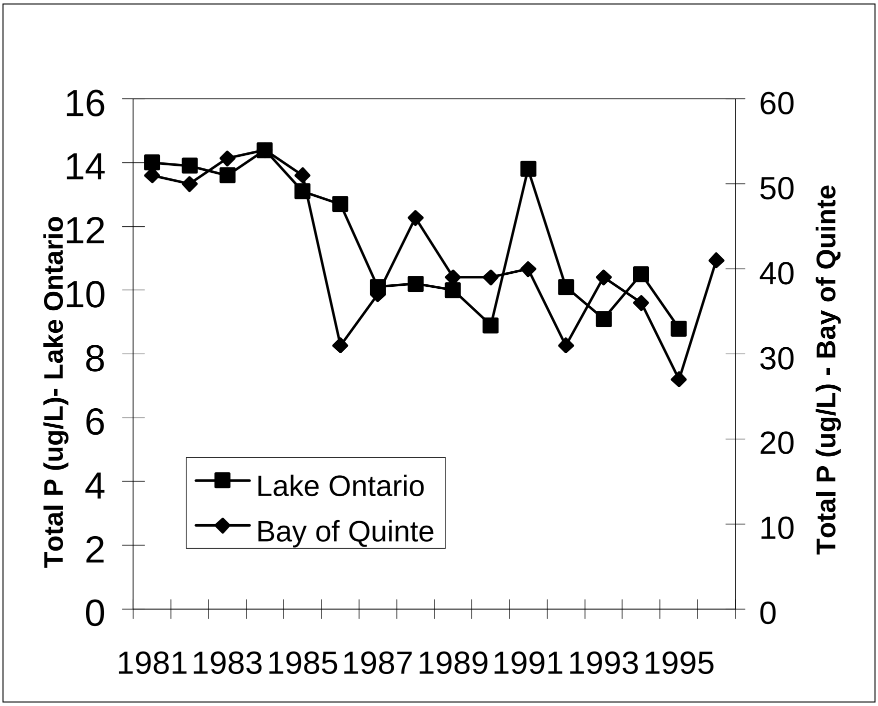

Fig. 3. Total phosphorous concentration in offshore waters of Lake Ontario and the Bay of Quinte, 1981-96 (Nicholls and Heintsch 1997; O.E. Johannsson, Department of Fisheries and Oceans, unpubl. data).

The recent invasion of zebra and quagga mussels has caused changes in how nutrients are cycled through food webs. These mussels had colonized western Lake Ontario and the south shore by 1991-92 and the eastern outlet basin by 1993. The Bay of Quinte was not fully colonized until 1994 (Mills et al. 1993; Schaner and Stewart 1995; Bailey et al., in press). Mussels exaggerate the effects of nutrient abatement by filtering and clarifying the water column. The offshore and nearshore fish communities respond differently to nutrient abatement and mussel invasion.

In the offshore zone, reduced nutrients had similar effects on the pelagic and benthic food webs. Lower zooplankton production resulted in reduced prey- and predator-fish biomass that resulted in lower potential yields from trout and salmon fisheries. The effect of reduced nutrients on the benthic food web is complicated by the continued expansion of zebra and quagga mussels into deep water where they are likely to cause shifts in species composition among invertebrates.

In the nearshore zone, nutrient reductions combined with increases in mussel density have modified fish habitat. Submerged aquatic plants proliferated (Ontario Ministry of Environment and Energy 1995) in response to clearing of the water column and now provide refuge and nursery areas for a variety of fish species. Increased water clarity (Fig. 4) has benefited some species and hindered others. For example, light-sensitive predators like the walleye may move to deeper waters. Northern pike, bass, and sunfish tolerate higher light levels and benefit from increased vegetation (Emery 1973; Scott and Crossman 1973). Nutrient abatement likely improved the quality of nearshore spawning substrate for species like lake trout and whitefish by reducing the amount of filamentous algae and detrital matter on spawning shoals. Nutrient reduction combined with reduced sediment load and proliferation of mussels will likely lead to an increase in fish species diversity in the nearshore zone.

The effect of these changes on the biomass (total weight) of fish in the nearshore zone and yield from nearshore fisheries is not clear. The reductions of algae and zooplankton associated with reduced nutrients will be offset somewhat by improvements in habitat and increased fish diversity—but by how much is unknown. Also, existing fisheries will require time to adapt to changing conditions.

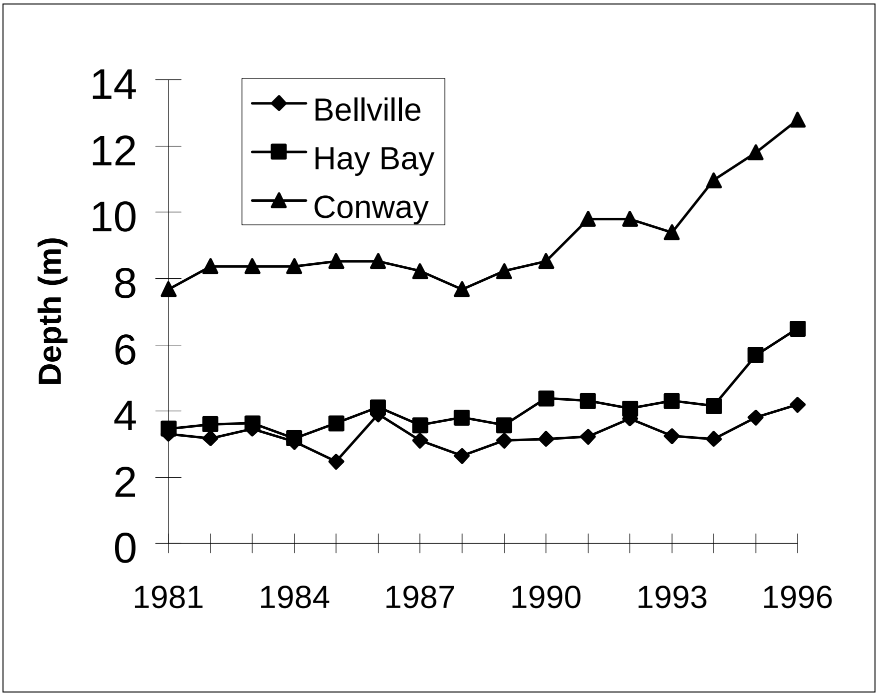

Fig. 4. Mean depth of the euphotic zone (the uppermost portion of the water column that could potentially support aquatic plant growth) in the Bay of Quinte, Lake Ontario, 1981-96 (S. Millard, Department of Fisheries and Oceans, unpubl. data).

Alewife

The alewife exerts the dominant biotic influence on fish communities in Lake Ontario. Alewives are the principal prey of most predatory fish and fish-eating birds (Brandt 1986; Jones et al. 1993; Weseloh and Collier 1993; Rand et al. 1994). Chinook salmon, in particular, rely heavily on alewives in their diet even when alewife numbers are low (Stewart and Ibarra 1991).

Alewives prey on the pelagic larvae of many fish species (Brandt et al. 1987; Eck and Wells 1987; Krueger et al. 1995). As alewife abundance declined in Lake Ontario in recent years (Fig. 5)

- Lake trout began to successfully reproduce
- Threespine stickleback abundance increased
- Lake whitefish populations recovered
- Populations of other native fish species (for example, yellow perch, emerald shiner, and lake herring) improved

More recently, a diet high in alewives was shown to result in early mortality syndrome in the offspring of lake trout—presumably because of thiamine deficiencies (Fisher et al. 1996; McDonald et al. 1998). The alewife is likely a major impediment to establishment of a self-reproducing lake trout population. A reproductive failure of Atlantic salmon in New York's Finger Lakes was also linked to thiamine deficiency and a parental diet high in alewives (Fisher et al. 1996). A high abundance of alewives may impede future attempts to rehabilitate Atlantic salmon in Lake Ontario.

Alewives spend most of their adult life in offshore waters but provide an important seasonal food supply to nearshore predators. In the spring, adults migrate to the nearshore zone to spawn. Some juveniles remain in the nearshore zone until fall, after which they move to deep waters. These migrations result in a transfer of energy from the nearshore to the offshore zone. Alewives thereby provide offshore predators access to nearshore food webs.

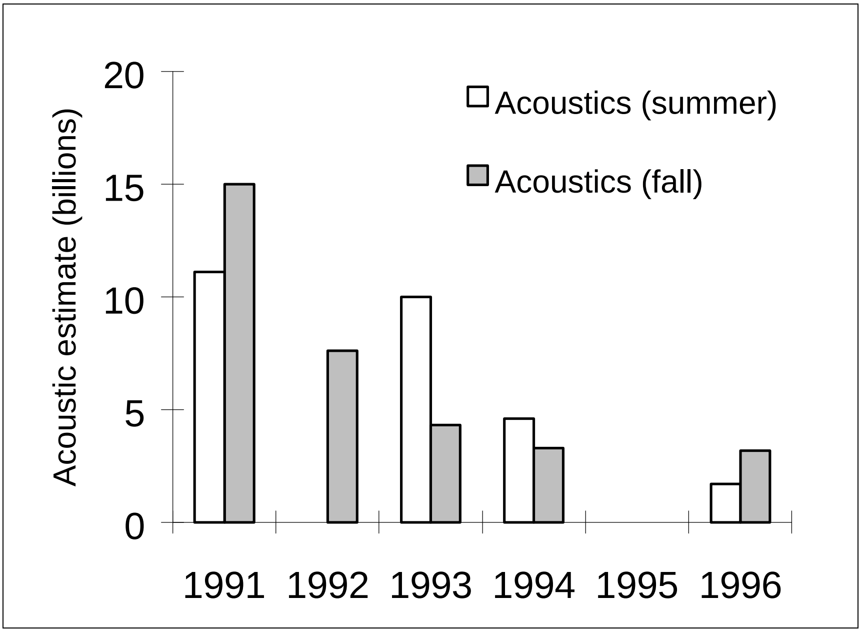

Fig. 5. Acoustic estimates of abundance (number of fish) for alewives in Lake Ontario, 1991-96.

Consumption of alewives by predatory trout and salmon in 1992 was estimated to exceed supply. If stocking of trout and salmon was maintained, alewife numbers would not quickly rebound from a moderately severe overwinter mortality (Anonymous 1992). To reduce the risk of an alewife collapse and the associated adverse impacts on the chinook salmon recreational fishery, fishery-management agencies in 1994 reduced stocking of salmon and trout to 4.5 million fish—almost a 50% cut. Follow-up studies (Rudstam 1996) and observations of declines in growth and condition of chinook salmon in 1994 confirmed that chinook salmon were likely prey limited during the early 1990s. Alewife recruitment has been generally very poor since 1992 with the exception of the stronger 1995 year-class. In 1997, following public consultation, stocking of salmon and trout was moderately increased to 6.0 million fish.

In the same year, production of wild chinook salmon in tributaries increased, and alewife biomass reached a 20-yr low. Collectively, these changes increase the risk of an alewife population collapse.

Rainbow Smelt and Native Prey Species

The offshore prey-fish community is less diverse now than it was historically. The historic prey-fish community was composed of four species of ciscoes and deepwater, slimy, and spoonhead sculpins (Smith 1968; Christie 1973; Smith 1995). Only one species of cisco (the lake herring) remains. It persists as a small population in eastern Lake Ontario and produced several stronger year-classes in the 1990s. Three other ciscoes inhabited deep water and are likely extinct in Lake Ontario. Two of these species, however, still exist in the other Great Lakes. The deepwater sculpin was also thought to have been eliminated from Lake Ontario, but three specimens were found in 1996 (Hoyle 1997).

The ecology of rainbow smelt, an introduced species, has been less studied than that of the alewife. In the last two decades, rainbow smelt and alewife populations have declined in parallel. The interaction between the rainbow smelt and alewife is complex—each can prey on the other's young and compete with the other for food (Smith 1970; Christie 1973; O'Gorman 1974). Many of the food-web interactions identified for the alewife (for example, predation on fish larvae, competition with other planktivores, and importance as a diet item for trout and salmon) also apply to rainbow smelt (Brooks 1968; Christie 1973; Nepszy 1977; Brandt 1986; Loftus and Hulsman 1986). Rainbow smelt inhabit deeper, colder water than alewives and, therefore, are more likely to interact with lake trout and whitefish than with Pacific salmon.

The slimy sculpin is the next most-abundant prey fish. It is the only significant prey fish on the lake bottom in offshore waters (O'Gorman et al. 1987, Owens and Bergstedt 1994) and is an important link in the offshore benthic food web. Slimy sculpins feed on mysids and amphipods (Owens and Weber 1995) and, in turn, are fed upon by juvenile lake trout (Elrod and O'Gorman 1991; Owens and Bergstedt 1994).

Populations of emerald shiner and threespine stickleback, both native species, have recently increased in surface waters in both the nearshore and offshore zones. Despite these recent changes, the prey-fish community and the offshore food web remain largely dependent on alewives, rainbow smelt, and slimy sculpins.

Reestablishment of native prey-fish species (for example, ciscoes and deepwater sculpins) would likely have two effects on the fish community. First, offshore predators feeding on alewives, rainbow smelt, and slimy sculpins would have alternative prey—both pelagic and benthic food webs would benefit. Juvenile ciscoes are pelagic and would provide food for pelagic predators like salmon. Adult ciscoes and deepwater sculpins are benthic and would provide food for lake trout. Second, ciscoes may compete with alewives for food. Maintaining moderate-to-high densities of alewife and the food web it supports may conflict with the reestablishment of native prey species. The feasibility of reestablishing deepwater ciscoes and sculpins by direct transfer from the upper Great Lakes or by culture needs to be researched.

Predators

The second major biotic influence on the Lake Ontario fish community is the overall abundance of fish-eating predators. Predator levels in Lake Ontario increased in the 1980s as a result of increased stocking of salmon and trout (Fig. 6), suppression of sea lampreys (Fig. 7), recovery of walleyes (Fig. 8), and increases in cormorant populations. The numbers of wild Pacific salmon are also increasing. A high abundance of predators in both the offshore and nearshore zones has reduced alewife populations and affected fish communities because the alewife is a key species in the food webs. Cuts in stocking made by the NYSDEC and OMNR in the 1990s were an attempt to lessen predatory pressure on declining alewife populations.

Excessively high predator levels could reduce alewife numbers to a point where nutrition limits the growth and survival of Pacific salmon. In 1994, the growth and condition of chinook salmon declined but has since recovered coincident with stocking cuts and a strong 1995 year-class of alewives. If nutritional limitation is severe, susceptibility to disease and increased mortality may occur. At the same time, further reductions in alewife abundance may benefit native prey fishes and native predators (for example, lake trout).

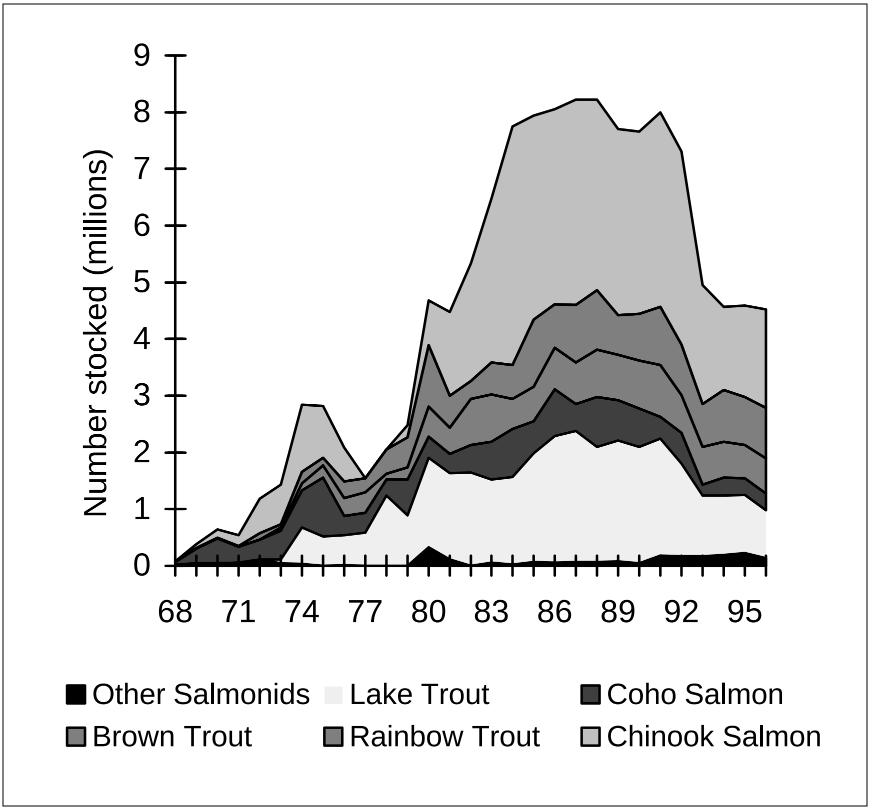

Fig. 6. Numbers of salmonids stocked in Lake Ontario, 1968-96 (excludes fish released at a weight < 1 g).

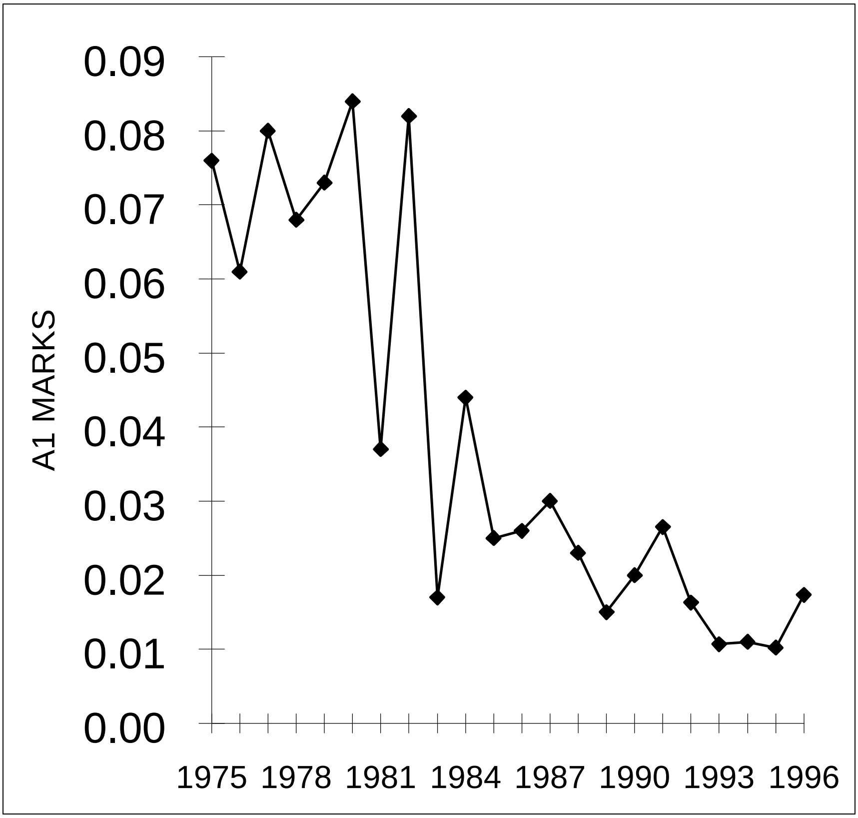

Fig. 7. Sea lamprey marking rates (A1 wounds only) on Lake Ontario lake trout > 431 mm (total length), 1975-96.

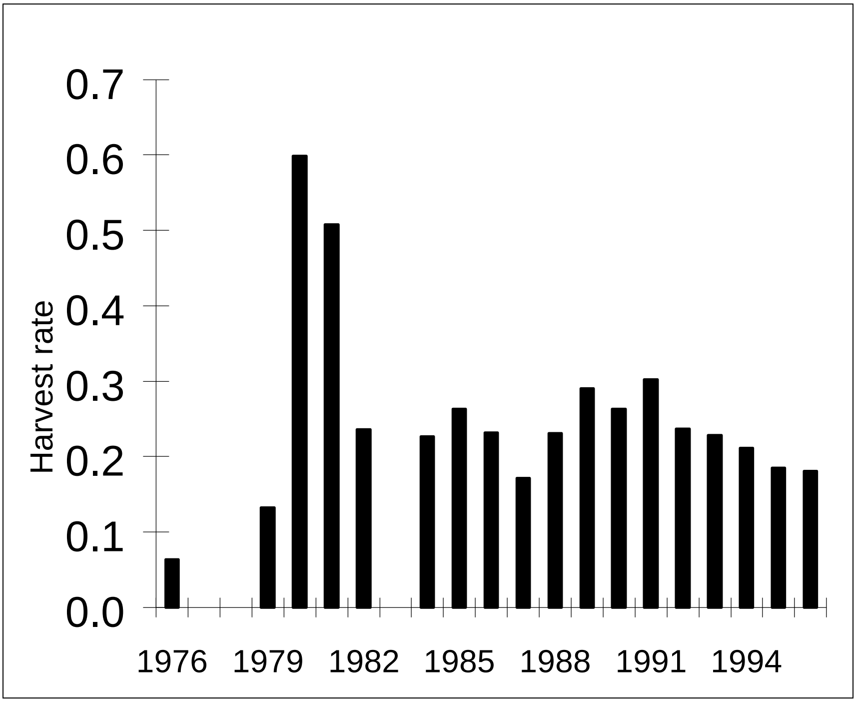

Fig. 8. Harvest rate (number of fish per angler hour) of walleyes for the summer angling fishery in the Bay of Quinte, 1976-96.

Other Factors

Adequate, diverse habitat is the basic building block of a healthy aquatic ecosystem. As described above, changes in nutrient levels and water clarity greatly affect fish habitat. Seven RAPS continue to address water-quality and physical-habitat problems in areas of severe degradation.

Lake Ontario's wetlands have suffered severe losses over the last two centuries because of agricultural drainage and urban encroachment. A total of 68 species of fish use the remaining wetlands either as permanent residents, only for spawning, or as nursery areas for juveniles (Stephenson

1990; Jude and Papas 1992). The value of wetlands is difficult to quantify. Rehabilitation of wetlands provides more and better habitat for fish and wildlife. Water-level regulation is a major stress on the lake's remaining wetlands. Wetland plant diversity and fish diversity are dependent on variations in water levels that mimic natural cycles. Replanting aquatic vegetation, creating channels in cattail marshes, and restoration of natural water-level fluctuations in diked areas can be used to rehabilitate wetlands.

The spawning and nursery habitats for approximately one-third of the fish species in the Great Lakes are located within tributaries. Although chinook salmon and rainbow trout spawn in Lake Ontario tributaries, numerous factors (including barriers, poor water and habitat quality, and unsuitable flow regimes) constrain reproduction. Habitat rehabilitation, improved fish passage, and better storm-water management can improve spawning and nursery habitat for cold-water fish leading to an increase in natural production. The eel ladder at Moses-Saunders Dam, Cornwall, Ontario, allows juvenile eels access to Lake Ontario and its watershed. An eel counter on the ladder provides an index of abundance for this globally significant population.

While levels of contaminants (for example, PCBs, mirex, dioxin, and mercury) have generally declined throughout the 1980s, contaminant levels still warrant fish-consumption advisories for some species and sizes of fish. A high occurrence of cancerous tumors has been reported for benthic-feeding fish in grossly contaminated areas (Baumann et al. 1996). Current levels of contaminants may or may not be limiting populations of fish and wildlife in Lake Ontario (Zint et al. 1995; Weseloh and Collier 1993). However, reducing levels of contaminants will improve environmental quality, reduce risks to human health, and may increase the reproductive potential of fish and wildlife.

STAKEHOLDER CONSULTATION PROCESS

The challenge in developing fish-community objectives is to consider the divergent interests of stakeholders, the limits imposed by the ecosystem, and the mandates of the OMNR and NYSDEC. First, the process adopted by New York and Ontario entailed a scientific consensus on major factors influencing the fish-community structure of the lake (ESSA Technologies 1996). Next, discussions were initiated with stakeholders on possible futures for the fish communities; on means of achieving desired outcomes; and on the risks, benefits, and uncertainties associated with various management options.

Parallel public consultation processes were held in Ontario and New York during the winter of 1996-97. Both jurisdictions assembled small groups of individuals (30 in Ontario and 47 in New York) to participate in weekend workshops. Participants were selected based on their interests and commitment to Lake Ontario fish and fisheries. They included anglers; charterboat operators; commercial fishermen; outdoor writers; and representatives from small businesses, local governments, and environmental groups. Workshop presentations included

- Information about the history of the fish community
- Major factors influencing the fish community
- Ecological theory and principles
- The risks and benefits associated with various management approaches

Each jurisdiction developed a questionnaire and obtained responses from all workshop participants.

In New York, the consultation process was completed by a follow-up meeting of workshop participants. The meeting agenda included a summary of the previous workshop, presentations on Ontario stakeholder views, and a summary of participant recommendations.

Following the Ontario workshops, open public meetings were held in Kingston, Bellville, Bowmanville, Port Credit, and Grimsby. Condensed versions of workshop presentations and recommendations from workshop participants were presented at each open meeting. Attendees of open public meetings were asked to provide comments on workshop recommendations and to complete a questionnaire. An additional 150 questionnaires were submitted after the public hearing. Many facets of the Lake Ontario fish communities and fisheries were discussed during the stakeholder consultations. A diversity of perspectives was evident. Some common topics and preferences emerged from both the New York and Ontario participants.

- A diversity of various offshore-, nearshore-, and stream-fishing opportunities was needed

- An increased risk of further prey-fish reductions caused by more stocking of trout and salmon on top of a decline was foreseen

- More trout and salmon were wanted notwithstanding the increased risk to prey-fish populations—Ontario stakeholders supported moderate increases in stocking and risk, but New York stakeholders were willing to accept substantial increases in stocking and risk

- The existing mix of salmon and trout predators (chinook salmon, coho salmon, lake trout, Atlantic salmon, rainbow trout, and brown trout) in the offshore zone was preferred

- Chinook salmon were the preferred offshore zone top predator

- Coho salmon stocking should be reinstated in Ontario waters

- Increasing the natural reproductive potential of rainbow trout was supported

- Support for Atlantic salmon rehabilitation in New York was mixed, and support in Ontario was conditional on a feasibility study

- Walleye was the preferred Bay of Quinte top predator, and an expansion of its range was supported

- Lake trout rehabilitation was supported

Communication with stakeholders by the NYSDEC and OMNR will be an integral part of the process to update perspectives and, when necessary, to revise the fish-community objectives.

THE DILEMMA OF DEVELOPING FISH-COMMUNITY OBJECTIVES

As stated in the introduction, to be truly meaningful and useful for fisheries managers, fish-community objectives must

- Reflect the most-current and complete scientific understanding of the Lake Ontario ecosystem

- Be responsive to the social, economic, and cultural needs of fishery stakeholders

Public consultation indicated very clearly that stakeholders greatly value the trout and salmon fishery of Lake Ontario, which is characterized by diverse angling opportunities for abundant and trophy-sized fish. Although preferences vary among individual anglers, chinook salmon are widely regarded as being the most desirable and highly prized because of their fighting quality and size. In addition to the strong interest in maintenance of the salmon and trout fishery, most stakeholders supported the principles of native-species rehabilitation, including expansion of their ranges, and of achieving an increased role for wild fish.

Alewives are required in sufficient abundance to provide food for salmon and trout, especially chinook salmon. Abundant alewife populations, however, suppress the reproduction of native fish. Managing for abundant alewives and highly productive trout and salmon fisheries is difficult because abundant predators can suppress alewives. Dense alewife populations are also incompatible with native-species restoration.

A majority of stakeholders desire a return to the salmon and trout fisheries of the 1980s and believe that a return can be achieved through increased stocking. However, fundamental changes in the Lake Ontario ecosystem—most notably phosphorus reduction and the invasion of zebra and quagga mussels—have reduced the capacity of the system to produce alewives and support historical (mid-1980s) levels of salmon and trout fishing.

Current stocking levels are an attempt to strike a balance between trout and salmon populations sufficiently abundant to provide quality fishing opportunities and an acceptable risk to the alewife population from the predatory demand associated with the numbers and size of trout and salmon desired by anglers. Stocking levels that minimize the risk to the alewife population are likely below the threshold of what may be perceived by some stakeholders to be minimally necessary for a quality fishery.

The incongruity between the fish community that stakeholders want and what the scientific assessment of ecological trends in Lake Ontario indicates is possible presents a fundamental dilemma to the LOC.

- Should these fish-community objectives anticipate changes in the fish community that are likely to occur within the next decade—even though these likelihoods are inconsistent with the needs and desires of most stakeholders?

- Should the Committee formulate objectives that reflect those needs and desires—despite scientific evidence that maintenance of the preferred fish community would be risky and may not be sustainable in the long term?

The essence of this dilemma and the fundamental realities for Lake Ontario fisheries resources are that we cannot have it all, we cannot have as much as we would like, and choices may be more limited in the future as ecological changes continue. Given the social and economic importance of the fishery, the LOC concluded that trout and salmon abundance should be maintained to provide quality fishing opportunities without putting excessive predatory pressure on alewives. This objective implies that characteristics of the trout and salmon fishery will be preserved and alewife abundance maintained—even though this decision may impede progress towards objectives to rehabilitate native species. To deliberately harm the highly valued trout and salmon fishery would be irresponsible given the clear preferences of the majority of stakeholders.

The LOC acknowledges the uncertainty, high risk, and trade-offs associated with the objective to maintain the characteristics of the existing trout and salmon fishery. The Committee also acknowledges the apparent contradiction of "we cannot have it all" while adopting some objectives that are not complementary and, perhaps, even incompatible. The Committee believes that the Lake Ontario ecosystem is not yet sufficiently understood to unequivocally rule out socioecomically desirable but possibly unsustainable objectives. These objectives are implicitly experimental and will be subject to frequent review and change as the ecosystem evolves and yields greater insights.

FISH-COMMUNITY OBJECTIVES

A general goal for Great Lakes fisheries management is to provide for fish communities based on enduring populations of naturally reproducing fish and on the wise use of stocked fish. In addition, these fish communities are intended to offer the best available social, cultural, and economic benefits and contribute to a healthy environment. The following objectives will shape fish-community management in Lake Ontario. Objectives are described separately for the nearshore food web and for the offshore pelagic and benthic food webs. Where available, relevant benefits, risks, and indicators are identified. Management actions intended to improve aquatic ecosystem function are identified.

Our objectives and indicators are intended to provide general direction for binational management of the lake's fish community and fisheries. More-specific species-management plans are available for Atlantic salmon (Ontario Ministry of Natural Resources 1995), lake trout (Schneider et al. 1998), and American eel (Stewart et al. 1997). Other species-specific and regional plans, consistent with these objectives, will be developed over time.

Nearshore Fish Community Objectives, Benefit, Risks, and Indicators

Objectives

The nearshore fish community will be composed of a diversity of self-sustaining native-fish species characterized by

- Maintenance of existing walleye populations and expansion of walleye populations into favorable habitats
- Maintenance of existing yellow perch populations and expansion of yellow perch populations into favorable habitats
- A population recovery of the lake sturgeon sufficient for its removal from New York's list of threatened species
- Population levels of smallmouth bass, largemouth bass, and sunfishes attractive to anglers
- Increasing numbers of American eels consistent with global efforts for their rehabilitation

Benefit

The benefit of making objectives for the nearshore zone is a diversity of fishes to support recreational, commercial, and aboriginal fisheries at a variety of locations.

Risks

The composition, structure, and function of the nearshore zone food web will largely be governed by

- The status of alewives
- Continued changes in water quality and fish habitat
- The abundance of zebra and quagga mussels

If alewives decline, some species (for example, the emerald shiner and yellow perch) may benefit from reduced predation and competition. Alternatively, lower alewife numbers will increase the level of predation on other species. The benefit could be a more-diverse fish community that is less dependent on alewives. The risk is that alternative prey may not develop quickly enough, and predators like walleye or cormorants could start feeding on the young of valued species like the smallmouth bass or yellow perch. Also, the movement of alewives between the nearshore and offshore zones throughout their life cycle provides an important energy link between the two zones. A major uncertainty is whether other species can provide the same degree of linkage.

Reductions in nutrients and sediment load and proliferation of mussels are modifying nearshore fish habitat and will likely lead to an increase in species diversity. Light-sensitive predator species like the walleye may move to deeper waters. Northern pike, bass, and sunfish—light-tolerant fish adapted to weedy habitats—may increase in number.

The net effect of all these changes on nearshore fisheries is not certain. Walleye populations may decline in some regions and expand in others. New fisheries targeted at bass, pike, and perch may develop.

Indicators

Indicators that nearshore objectives are being met are

- Continued expansion of walleye ranges

- Maintenance in Canada of early-1990s catch rates for walleyes in assessments and in recreational, commercial, and aboriginal fisheries

- Maintenance of late-1980s catch rates for smallmouth bass in assessments and in recreational fisheries

- Increased catches of yellow perch in assessments and in recreational and commercial fisheries

- Increased sightings of lake sturgeon

- A return to the 1980s count of eels ascending the Moses-Saunders Dam

Offshore Pelagic Fish Community Objectives, Benefits, Risks, and Indicators

Objectives

The offshore pelagic fish community will be characterized by

- A diversity of salmon and trout

- Chinook salmon as the top predator

- Abundant populations of rainbow trout (steelhead)

- Fishable populations of coho salmon and brown trout

- Populations of stocked Atlantic salmon at levels consistent with investigating the feasibility of restoring self-sustaining populations

- Amounts of naturally produced (wild) salmon and trout, especially rainbow trout, that are consistent with fishery and watershed plans

- A diverse prey-fish community with the alewife as an important species

Benefits

Benefits from meeting offshore pelagic indicators are

- A diverse sport fishery based on a variety of salmon and trout

- A diversity of sport-fishing opportunities in the nearshore and offshore zones and in tributaries

Risks

The uncertainty and risk associated with achieving these fishery objectives are both high. Reduction in nutrients and increased predation by trout and salmon have resulted in lower levels of prey. Stocking decisions in the 1990s reflected management efforts to recognize the value of the sport fishery and to try to maintain a balance between the numbers of predator fish stocked and prey-fish abundance. The recent increase in stocking of salmon and trout, an apparent increase in wild chinook salmon abundance, and low alewife abundance increase the risk of a food-web collapse. If, on the other hand, the higher levels of stocking can be supported, fishery yields may improve.

If the alewife population continues to decline, chinook salmon populations are also likely to decline because this fish prefers to feed on alewives even when alewives are not abundant. This interaction may result in reduced growth of salmon, as observed in 1994, or may lead to disease outbreaks and increased mortality. If alewives decline markedly, fish with more-general diet preferences (for example, rainbow trout and lake trout) will likely fare better, and reproduction of native species (for example, lake trout and Atlantic salmon) may improve. Reestablishment of a diverse native prey-fish community is a critical uncertainty. The existing native prey may not be able to support the offshore food web in the absence of alewives.

Production of wild rainbow trout will largely be determined by the quality of spawning and nursery habitat in tributaries and by improvements in fish passage. Successful rehabilitation of Atlantic salmon may be negatively affected by an alewife diet, low availability of suitable stream habitat, and competition with other juvenile salmonines in tributaries.

Indicators

Indicators that offshore pelagic indicators are being met are

- Persistence of the current mix of salmon and trout

- Salmon and trout catch rates in recreational fisheries continuing at early-1990s levels

- Increased catches of wild rainbow trout and coho and chinook salmon in assessment and recreational fisheries

- Alewife populations above levels observed in 1994

- Continued population increases of emerald shiners, sticklebacks, and other native prey fish

- Achievement of growth and survival benchmarks (Ontario Ministry of Natural Resources 1995) for juvenile Atlantic salmon in tributaries and increased catches of Atlantic salmon in assessment and recreational fisheries

Offshore Benthic Fish Community
Objectives, Benefits, Risks, and Indicators

Objectives

The offshore benthic fish community will be composed of self-sustaining native fishes characterized by

- Lake trout as the top predator
- A population expansion of lake whitefish from northeastern waters to other areas of the lake
- Rehabilitated native prey fishes

Benefits

Benefits of meeting the offshore benthic objectives are

- A diversity of fish available for commercial and sport fisheries
- A diverse sport fishery based on a variety of trout and salmon including lake trout

Risks

Recent ecological changes indicate more-favorable conditions for the rehabilitation of the offshore benthic food web. These changes include improved natural reproduction of lake trout and increased whitefish abundance. Also, the lake herring, primarily a pelagic species that also contributes to the benthic food web, produced several good year-classes in the 1990s.

Rainbow smelt and alewives are important in the benthic food web, but their populations may decline to critically low levels. The lack of a thriving native prey-fish community may provide an opportunity for the establishment of a new, undesirable exotic species. Reestablishment of a diverse native prey-fish community would benefit the benthic food web. The feasibility of reestablishing other deepwater native fish (for example, deepwater ciscoes) is not known.

Even though conditions may be more favorable for the offshore benthic food web, the combined effect of lower phosphorus levels offshore and the effects of zebra and quagga mussels on phytoplankton, zooplankton, and other invertebrates make sustainability uncertain. For example, the condition (robustness) of lake whitefish in eastern Lake Ontario has declined, perhaps indicating a decline in the quality or quantity of their invertebrate prey. The loss of *Diporeia* from large areas of Lake Ontario and the observation of emaciated whitefish are good illustrations of the uncertainty associated with exotic mussels. This recent discovery makes less certain the apparent improvement in benthic habitat and associated fish communities.

Indicators

Indicators that benthic objectives are being met are

- Achievement of rehabilitation measures for lake trout (Schneider et al. 1998)
- An expanded range for whitefish
- Maintenance of lake whitefish catches at early-1990s levels
- Increased catches of burbot
- Increased sightings of rare native ciscoes and sculpins

Management Actions to Support Healthy Fish Communities Actions, Benefits, Risks, and Indicators

Actions

Management actions that support healthy fish communities will include

- Protecting biodiversity
  - Protecting the genetic diversity of native fishes
  - Protecting and rehabilitating native fishes
  - Protecting and enhancing populations of rare and endangered fishes
  - Controlling new introductions of aquatic species

- Maintaining or improving ecosystem function

  – Maintaining sea lamprey marking rates < 0.02 marks per fish for lake trout

  – Maintaining the integrity of existing food webs

  – Maintaining offshore phosphorus levels consistent with GLWQA targets

  – Achieving nearshore water-quality targets

  – Protecting and rehabilitating critical fish habitat, including tributary and nearshore spawning and nursery areas

- Reducing contaminant levels

  – Reducing contaminant concentrations in fish to levels that result in no sport-fish consumption advisories and that cause no impairment of fish and wildlife reproduction

Benefits

Benefits from protecting biodiversity, maintaining or improving structure, and reducing contaminants are

- Self-sustaining populations supporting enhanced fisheries

- Increases in fish diversity, improved habitat, and better water quality

- A more esthetically pleasing environment

Risks

The major threat to biodiversity is the unintentional introduction of new species via stocking programs, aquaculture, water diversions, navigation channels, and shipping. Species already introduced into the Great Lakes (for example, ruffe) have not yet established themselves in Lake Ontario. Other species (for example, zebra mussels and quagga mussels) continue to increase in abundance. Further declines in rainbow smelt and alewife populations may provide opportunities for new exotics to colonize and expand. Sea lamprey control is currently funded by both the United States and Canadian federal governments and delivered by the GLFC. Maintaining the < 0.02 A-1 sea lamprey marks per fish target for lake trout will protect stocks of salmon and trout, lake whitefish, and walleyes.

Alewives are an important diet item for every fish predator in Lake Ontario. A significant loss of alewives resulting from inflated predator levels risks a collapse of the existing salmon and trout fishery and a loss of structure.

Future reevaluation of water-quality targets, or LAMPs, will need to consider a broad spectrum of needs and benefits—including fisheries values. Both stakeholder and government commitments to nearshore habitat and water-quality cleanup are required to reach targets in the nearshore. The same commitments are needed to protect and rehabilitate tributary habitats. Government, industry, and society must remain committed to contaminant controls and cleanups. The LAMP and RAPs emphasize these commitments.

Indicators

Indicators of needed management actions are

- Increased catches of native and wild fish in assessments and fisheries
- Increased sightings of rare and endangered fish species
- No new introductions of exotic species
- Suppression of sea lamprey populations to early-1990s levels
- Maintenance of offshore phosphorus concentrations at early-1990s levels
- Increasing availability of high-quality spawning and nursery habitats
- Less-severe consumption advisories for fish

CONCLUSION

As the Lake Ontario system continues to evolve, further changes in the fish community and fisheries of Lake Ontario can be expected. Nutrient levels affect the fish community and the latitude for fisheries management. Stocking, harvest controls, habitat protection and rehabilitation, and sea lamprey control are tools that fisheries managers can use to achieve the objectives outlined in this document.

Fish-community and fisheries monitoring programs provide information to track change and to predict the future. Information-based decision making is important in a rapidly changing system where uncertainty and risk are high.

The LOC will strive to achieve the fish-community objectives described in this document. These objectives offer a blueprint for providing sustainable benefits and for improving ecosystem health.

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APPENDIX
Common and Scientific Names of Fish and Invertebrates

alewife	*Alosa pseudoharengus*
American eel	*Anguilla rostrata*
Atlantic salmon	*Salmo salar*
amphipods	*Diporeia* spp., *Gammarus* spp.
brown trout	*Salmo trutta*
burbot	*Lota lota*
cladocerans	*Daphinia* and others
coho salmon	*Oncorhynchus kisutch*
copepods	*Calanus, Cyclops, Diaptomus*
chinook salmon	*Onchorynchus tshawaytscha*
deepwater ciscoes	*Coregonus kiyi, C. hoyi, C. reighardi*
deepwater sculpin	*Myoxocephalus thompsoni*
emerald shiner	*Notropis atheinoides*
freshwater drum	*Aplodinotus grunniens*
gizzard shad	*Dorosoma cepedianum*
lake herring	*Coregonus artedi*
lake sturgeon	*Acipenser fulvescens*
lake trout	*Salvelinus namaycusch*
lake whitefish	*Coregonus clupeaformis*
largemouth bass	*Micropterus salmoides*
minnows	Cyprinidae
northern pike	*Esox lucius*
opossum shrimp	*Mysis relicta*
Pacific salmon	*Oncorhynchus* spp.
pumpkinseed sunfish	*Lepomis gibbosus*
quagga mussel	*Dreissena bugensis*
rainbow smelt	*Osmerus mordax*
rainbow trout	*Onchorynchus mykiss*
ruffe	*Gymnocephalus cernuus*
sea lamprey	*Petromyzon marinus*
slimy sculpin	*Cottus cognatus*

smallmouth bass	*Micropterus dolomieu*
spiny water flea	*Bythotrephes cederstromi*
spoonhead sculpin	*Cottus ricei*
spottail shiners	*Notropis hudsonius*
sunfish	Centrarchidae
threespine stickleback	*Gasterosteus aculeatus*
walleye	*Stizostedion vitreum*
white perch	*Morone americana*
yellow perch	*Perca flavescens*
zebra mussel	*Dreissena polymorpha*