LAKE ONTARIO FISH COMMUNITIES AND FISHERIES:

2000 ANNUAL REPORT OF THE LAKE ONTARIO MANAGEMENT UNIT

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Lake Ontario Fish Communities and Fisheries: 2000 Annual Report of the Lake Ontario Management Unit

Introduction

The Lake Ontario Management Unit (LOMU) is part of the Fish & Wildlife Branch, Natural Resource Management Division of the Ontario Ministry of Natural Resources (OMNR). The LOMU is OMNR's lead administrative unit for fisheries management on Lake Ontario and the St. Lawrence River.

The 2000 Annual Report documents results of LOMU programs, completed in 2000, to assess the fish communities and fisheries of Lake Ontario.

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Acknowledgements

The contributions of all Lake Ontario Management Unit staff are gratefully acknowledged. Also, we would like to acknowledge the help and information provided by our many partners and volunteers.

Species Highlights

Alewife

- Moderate decline in numbers; 1998 year class still dominant (Chapter 1)
- Poor body condition (Chapter 1)

Rainbow smelt

- Very low abundance (Chapter 1)
- Poor body condition (Chapter 1)

Chinook salmon

- Catch rates in boat fishery continue to be good (Chapter 8)
- Decline in natural reproduction (Chapter 1)

Eels

- Counts of young eel migrating upstream at the Cornwall eel ladder remain 3 orders of magnitude below peak levels (Chapter 4)
- Commercial harvests remain far below historic levels, with no expectation of recovery in the near future (Chapter 6)

Lake trout

- Continued decline in abundance of mature fish (Chapter 2)
- Some signs suggesting that the decline in early survival is slowing down, and the condition of young fish is improving (Chapter 2)

Lake whitefish

- Continued poor body condition and growth (Chapter 2)
- Delayed age-at-maturity (Chapter 2)
- Poor recruitment (Chapters 2, 12)
- Continued decline in adult abundance (Chapters 2, 12)
- Decline in commercial fishery harvests (Chapter 5)

Rainbow trout

- Catch and harvest rates in boat fishery low, consistent with cool spring (Chapter 1)
- Counts at Ganaraska continue to decline (Chapter 1)
- High level of exploitation of the Ganaraska and Wilmot wild populations (Chapter 10)
- Poor 2000 year class of wild rainbow trout (Chapter 1)

Round goby

- Evidence of dispersal in the Bay of Quinte (Chapter 3)

Smallmouth bass

- Continued improvement in year class strength (Chapter 3)
- Adult abundance remains low (Chapter 3)

Walleye

- Continued decline in population (Chapter 3)
- Continued decline in open-water angling catch, harvest and effort (Chapter 7)
- Decreased harvest in 2000 winter fishery (Chapter 7)
- Decline in aboriginal spear fishing harvests (Chapter 9)
- Decline in commercial harvests in 2000 (Chapter 5)

Yellow perch

- General decrease in abundance and harvest in 2000 follows several years of increase (Chapters 3, 4, 5, 6 and 7)
- Continuing decline of large yellow perch in Lake St. Francis (Chapter 4)

1

Lake Ontario Offshore Pelagic Fish Community

T. Schaner, J. N. Bowlby, M. Daniels, and B. F. Lantry[1]

Introduction

The principal members of the offshore pelagic community in Lake Ontario are alewife and rainbow smelt, and their salmonine predators – chinook, coho and Atlantic salmon, lake trout, rainbow trout, and brown trout. Some of the less abundant species include threespine stickleback, emerald shiner and gizzard shad.

Alewife and rainbow smelt are not native to Lake Ontario, but they have long been well established in the lake. Their numbers, especially those of alewife, have declined recently as a result of several factors. The nutrient loading into the lake decreased due to improved land use and sewage treatment practices in the recent decades. In the early 1990s the lake was colonized by the zebra mussel. These two factors resulted in reduced plankton productivity, and therefore less available forage for alewife and smelt. Meanwhile the alewife and smelt continued to suffer from predation by the piscivores – salmon and trout.

Salmon and trout populations in Lake Ontario are sustained chiefly by stocking. As well, significant natural reproduction occurs in chinook salmon and rainbow trout. Chinook salmon are the principal stocked species, followed by rainbow trout and lake trout, and lesser numbers of coho salmon, brown trout, and Atlantic salmon. In the late 1980s and early 1990s Canadian and U.S. agencies stocked more than 8 million fish into Lake Ontario. With the declining populations of alewife and smelt there were concerns that predator demand would exceed the available prey, and starting in 1993 stocking levels for all species were reduced to levels that would lower prey consumption by approximately one-half. Based on further public consultation stocking was modestly increased in 1997 (Stewart et al. 1999).

This chapter describes our current information on the status of alewife, rainbow smelt, chinook salmon and rainbow trout. Lake trout, which play a significant role in the offshore pelagic community, but are also associated with the benthic community, are discussed in the next section (Chapter 2).

Information sources

Alewife and smelt populations are assessed in hydroacoustic surveys conducted cooperatively in the summer and fall by OMNR and the New York State Department of Environmental Conservation (Schaner and Schneider 1995). In these surveys we collect hydroacoustic data, as well as mid-water trawl samples that are used to interpret the hydroacoustic data. In the summer of 2000 we conducted a full survey consisting of seven transects and covering the entire lake. A similar survey is normally also conducted in the fall, but bad weather conditions only allowed us to complete two transects in the eastern portion of the lake, and the results are not reported here.

We have recently come to suspect that the methodology currently used to estimate alewife and smelt numbers suffers from problems caused by extensive overlap of acoustic target strengths of young-of-the-year (YOY) and yearling-and-older (YAO) alewife, resulting in YAO estimates being contaminated by YOY fish, and influenced by their trends. New information on target strength characteristics (Warner et al. 2001) furthermore

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suggests that alewife produce stronger targets than we assumed based data from older literature (Love 1977), putting in question the target strength level used in separating targets from YAO fish from those caused by smaller fish. We expect that the overall effect of re-examining our past data based on this new information will be to reduce the past population estimates. The revision is not finished. In this report we therefore present only data from the 1998-2000 surveys - the estimates may be biased, but the surveys were processed in a consistent manner, all based on targets greater than –49 dB. The short time series provides a context for the 2000 estimate.

Salmon and trout are assessed in a variety of ways. Chinook salmon growth is monitored during fall in the spawning run at the Credit River at the Reid Milling dam in Streetsville; fish are caught for spawn collection for the Ringwood Fish Culture Station. Spawning rainbow trout growth and population are monitored during spring at the Ganaraska River fishway. Chinook salmon and rainbow trout populations are indexed by angler catch rates from the boat fishery in western Lake Ontario (Chapter 8). Wild juvenile salmon and trout populations are enumerated by electrofishing randomly selected sites in Lake Ontario tributaries

Alewife

The summer 2000 population estimate of YAO alewife, based on acoustic targets greater than –49 dB, was 1.54 billion fish. This is a 15% decrease from the population level estimated in the summer of the previous year (Fig. 1). The population in 2000 was dominated by the 1998 year class, and to a large extent the decrease in numbers from previous summer represents the expected gradual decline of this prominent year class.

Trawl catches of alewife from the summer 2000 survey show that there were three distinct size classes present (Fig. 2). The dominant middle mode around 125 mm was formed by fish of the 1998 year class. A weaker group of fish with mode at 100 mm represents the 1999 year class. The fish above 130 mm are 3-years old and older, and this group is probably still dominated by fish from the 1995 year class.

The body condition of alewife, expressed as predicted weight of 120 mm fish, was poorer in the

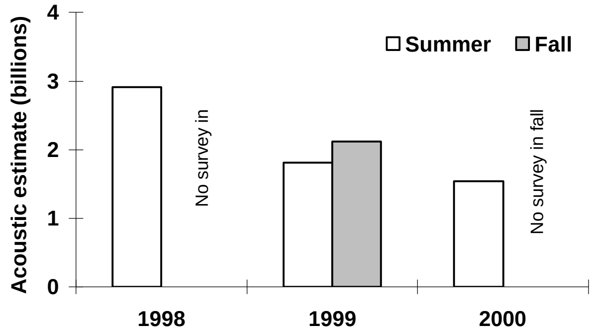

FIG. 1. Acoustic estimates of absolute abundance of alewife in Lake Ontario, 1998 to 2000.

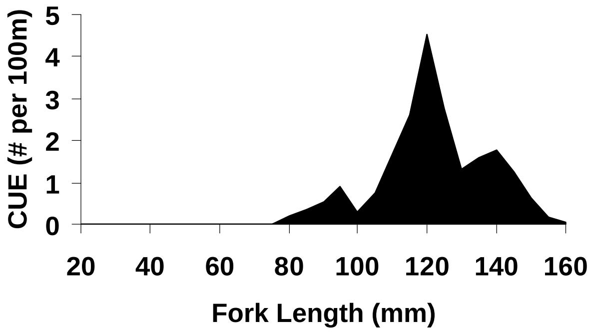

FIG. 2. Length frequency distribution of alewife in mid-water trawls conducted in summer 2000.

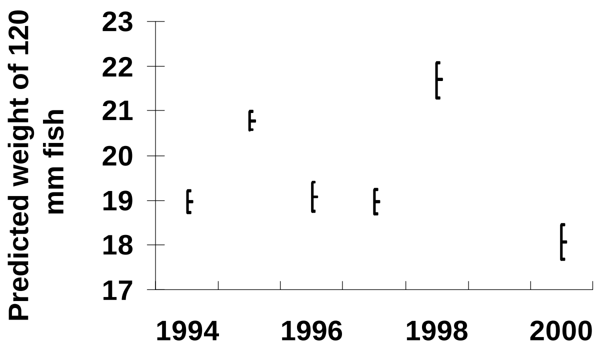

FIG. 3. Predicted weight of 120 mm alewife in summer of 2000. Based on ln(weight)-ln(length) regression of fish above 100 mm.

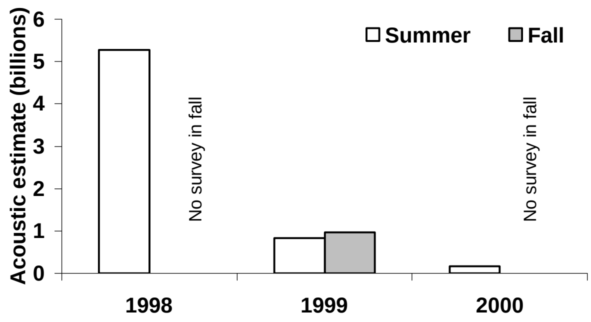

FIG. 4. Acoustic estimates of absolute abundance of rainbow smelt in Lake Ontario, 1998 to 2000.

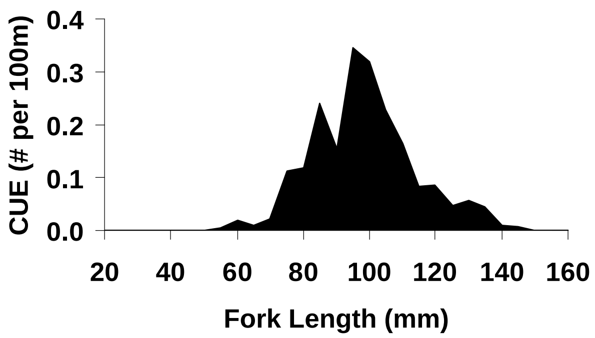

FIG. 5. Length frequency distribution of rainbow smelt in mid-water trawls conducted in summer 2000.

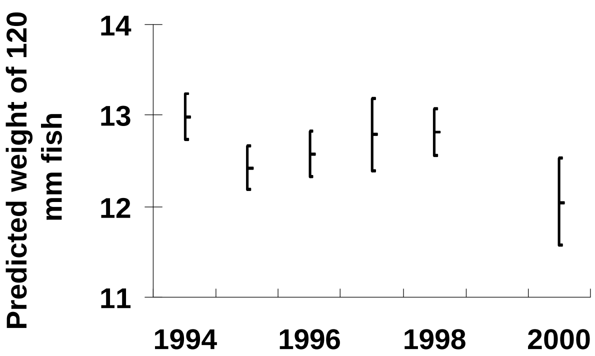

FIG. 6. Predicted weight of 120 mm smelt in summer of 2000. Based on ln(weight)-ln(length) regression of fish above 100 mm.

summer of 2000 than in any other summer since we started collecting body condition data in 1994 (Fig. 3). The condition in the preceding fall (not shown) was also the poorest since 1994. Longer term perspective (data from O'Gorman et al. 2000), however, suggests that the poor body condition in 1999-2000 may be no worse than what was observed in the mid 1980s. It is also interesting to note that the recent decline in body condition of alewife is mirrored by a similar decline in the body condition of smelt (see below), suggesting lack of a common food source.

Rainbow Smelt

The 2000 lake-wide summer estimate of YAO smelt was 163 million fish, a significant decrease from 800 million fish estimated for 1999. The smelt population in Lake Ontario tends to oscilate on a two year cycle, such that populations of YAO smelt peak during odd numbered years due to recruitment of prominent year classes which are produced in even numbered years. The decrease from 1999 to 2000 is therefore not unexpected. The overall population level in the two years, however, is of concern. The 1999 estimate was the lowest of the 'strong year' population estimates, and the 2000 estimate was the lowest of all estimates since the start of the program in 1991.

In spite of low population levels, the smelt show no sign of a density-dependent improvement in growth or body condition. Trawl catches from summer 2000 (Fig. 5) show a modal length of smelt around 100 mm (1998 year class), which is an increase of only approximately 10 mm from previous summer. This amount of growth between second and third summer of life is less than we have seen in odd-even year combinations in the past. The body condition of smelt in the summer of 2000 was also lower than in previous summers since 1994 (Fig. 6), and the condition in the preceding fall was the lower than in previous falls (not shown).

Other pelagic prey species

Threespine sticklebacks which first appeared in significant numbers in 1993 continue to be found in the mid-water trawl catches in steady numbers (Fig. 7). These small fish probably easily escape through the large mesh of the mid-water trawl, and the catches do not properly represent their possibly high population levels.

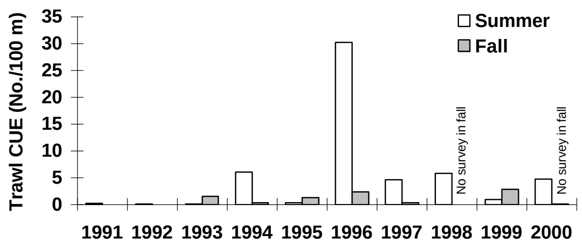

FIG. 7. Catch rates of threespine stickleback in mid-water trawls in Lake Ontario, 1991 to 2000.

Emerald shiners were observed in appreciable numbers in trawl catches in years 1995 through 1997, and practically absent in the periods of 1991-1994 and since 1998. This species has been known to fluctuate between periods of scarcity and great abundance (Scott and Crossman 1973), and our observations suggest that this is the case with the Lake Ontario population.

Stocking Program

In 2000, OMNR stocked about 2.2 million salmon and trout into Lake Ontario (Table 1). Just over 550,000 chinook salmon spring fingerlings were stocked at various locations, mainly in the western end of the lake, to provide put-grow-and-take fishing opportunities. About 175,000 coho salmon fall fingerlings and spring yearlings were stocked into the Credit River, as part of the recently re-instated coho program. We began a wild egg collection for coho salmon in the Credit River in the fall of 2000. In support of an ongoing program to determine the feasibility of restoring self-sustaining populations of Atlantic salmon to the Lake Ontario watershed, about 257,000 Atlantic salmon fry were stocked into various Lake Ontario tributaries by OMNR and it's partners. About 170 pre-spawning Atlantic salmon adults, some with radio tags, were also released into Wilmot Creek and the Humber River to study interactions among various salmon and trout species during the fall spawning period, to monitor spawning behaviour, and determine spawning success. About 444,000 lake trout yearlings were stocked as part of a long-term rehabilitation program. Efforts are focused in eastern Lake Ontario where most of the historic spawning shoals are found. About 150,000 rainbow trout yearlings were stocked by OMNR, and 239,000 fry were reared by local community groups. About 167,000 brown trout yearlings were stocked at various locations to provide shore and boat fishing opportunities.

Detailed information about 2000 OMNR stocking activities is found in Appendix A. The New York Department of Environmental Conservation (NYDEC) also stocked 3.7 million salmon and trout into Lake Ontario in 2000 (Eckert 2001).

TABLE 1. Salmon and trout stocked into Province of Ontario waters of Lake Ontario, 2000, and target for 2001.

Species	Age	Number Stocked 2000	Target 2001
ATLANTIC SALMON	Eyed eggs	13,618	
	Delayed fry	140,313	80,000
	Advanced fry	116,768	80,000
	Adults	172	
		270,871	**160,000**
CHINOOK SALMON	Spring fingerlings	**555,555**	**540,000**
COHO SALMON	Fall fingerlings	53,476	
	Yearlings	122,071	150,000
		175,547	**150,000**
LAKE TROUT	Yearlings	**443,768**	**440,000**
RAINBOW TROUT	Eyed eggs	247,222	
	Fry	239,000	
	Yearlings	150,455	140,000
		636,677	**140,000**
BROWN TROUT	Yearlings	**167,023**	**165,000**
SALMON & TROUT TOTAL		**2,249,441**	**1,595,000**

Chinook Salmon

Abundance

Catch rates from the launch-daily boat fishery in western Lake Ontario (Chapter 8) provide our only index of abundance for chinook salmon. These catch rates have not changed significantly from 1997 to 2000 (Fig. 8). Chinook salmon populations have been steady for the past four years.

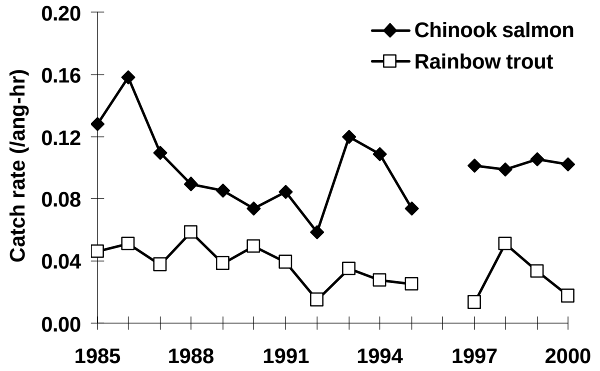

FIG. 8. The catch rate of chinook salmon and rainbow trout in the western Lake Ontario launch daily salmonid boat fishery (Ontario portion) from 1985 to 2000.

Growth

The length of male and female 2-yr-old and 3-yr-old chinook salmon in the Credit River during fall 2000 remained high, as good as the past several years (Fig. 9). Such good growth rates were consistent with the availability of the strong 1998 and 1999 year classes of alewife for food. The pattern of body condition of chinook salmon (Fig. 10) showed no relationship with length-at-age. Rather, condition of chinook salmon was correlated with condition of alewife (Fig. 11). Body condition of chinook salmon reflected recent changes in nutrition of prey. whereas length-at-age integrated growth over the life of the fish.

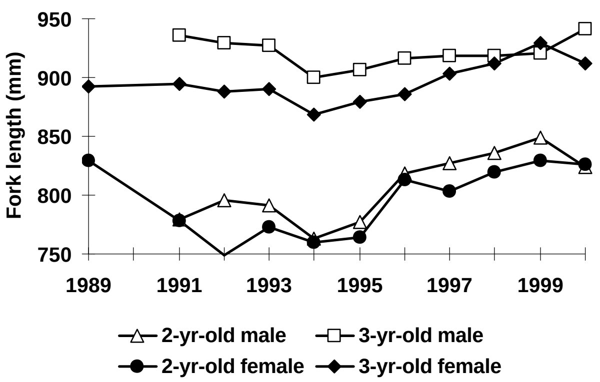

FIG.9. Fork length of chinook salmon in the Credit River during spawning run in September and October.

Year Class Strength of Wild Chinook Salmon

During spring 2000 wild juvenile chinook were enumerated in an electrofishing survey of Wilmot Creek. This survey followed the design of a similar survey in 1997 (Bowlby et al. 1998). However, we determined that chinook salmon did not pass over two beaver dams in 2000, and so 8 of 16 sites were above

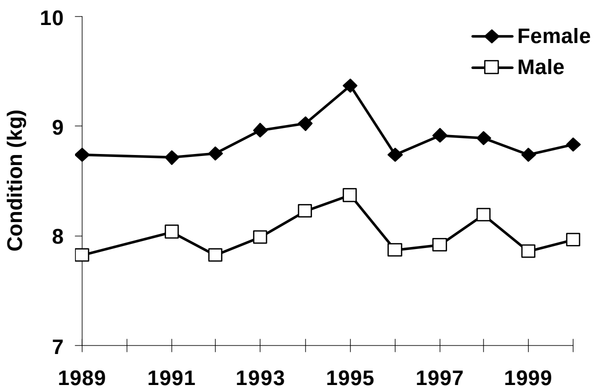

FIG. 10. Condition (mean weight, adjusted for length) of chinook salmon in the Credit River during the spawning run in September and October.

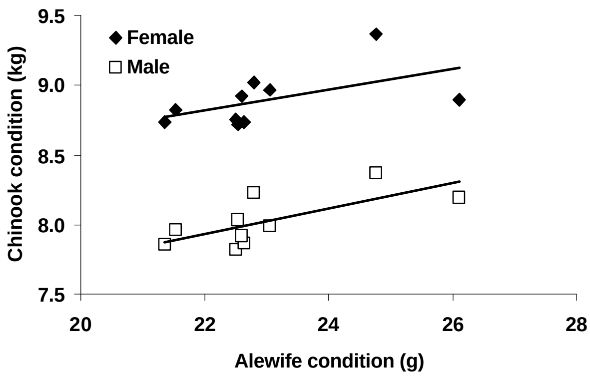

FIG. 11. A plot of condition of chinook salmon in the Credit River during the spawning run in September and October and condition of alewife in Lake Ontario.

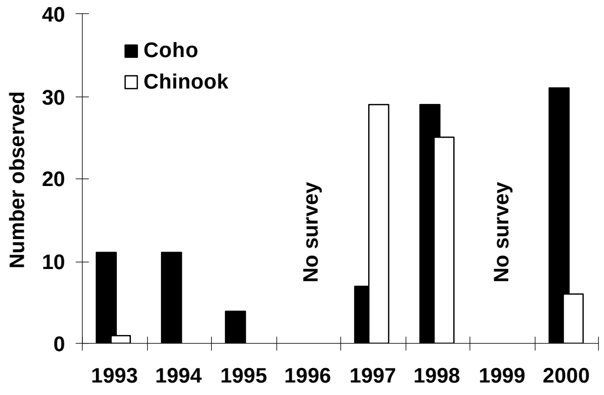

FIG. 12. Number of wild coho and chinook salmon observed during summer surveys of Lake Ontario tributaries in Ontario. No surveys were conducted in 1996 and 1999.

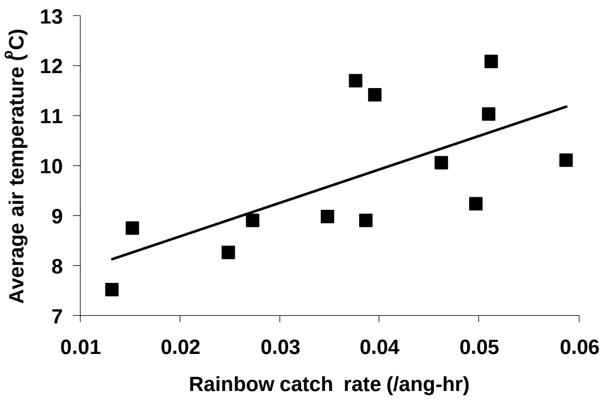

FIG. 13. The catch rate of rainbow trout in the western Lake Ontario launch daily salmonid boat fishery and average air temperature at Trenton and Toronto Island during April and May.

the dams and were either not surveyed or contained no chinook salmon. As well, wild chinook salmon and coho salmon were observed during summer in an electrofishing survey of juvenile rainbow trout (see below).

In 2000 we estimated that Wilmot Creek produced 22,878 wild chinook salmon, compared with a revised estimate of 66,313 in 1997. However, in the 8 sites below the beaver dams we found no significant difference (p=0.29) in density of chinook salmon (2.8/m in 1997, 1.9/m in 2000). Fewer chinook salmon were observed in summer 2000, than in 1997 or 1998 (Figure 12). In some other streams besides Wilmot Creek, a combination of beaver dams and low stream flows in September 1999 may have prevented the adult chinook salmon from reaching spawning areas. In 2000 coho salmon were observed in similar numbers to 1998 (Fig. 12). As well, they were observed at some sites above beaver dams where chinook salmon were absent. Coho salmon spawn later than chinook salmon. Increased stream flows in October may have allowed them past some dams.

Both spring and summer surveys show declines in wild juvenile chinook salmon in Ontario tributaries of Lake Ontario. The inability of adult chinook salmon to pass some beaver dams has reduced juvenile production in several streams. However, natural reproduction of chinook salmon is still substantially greater than even 5 years ago.

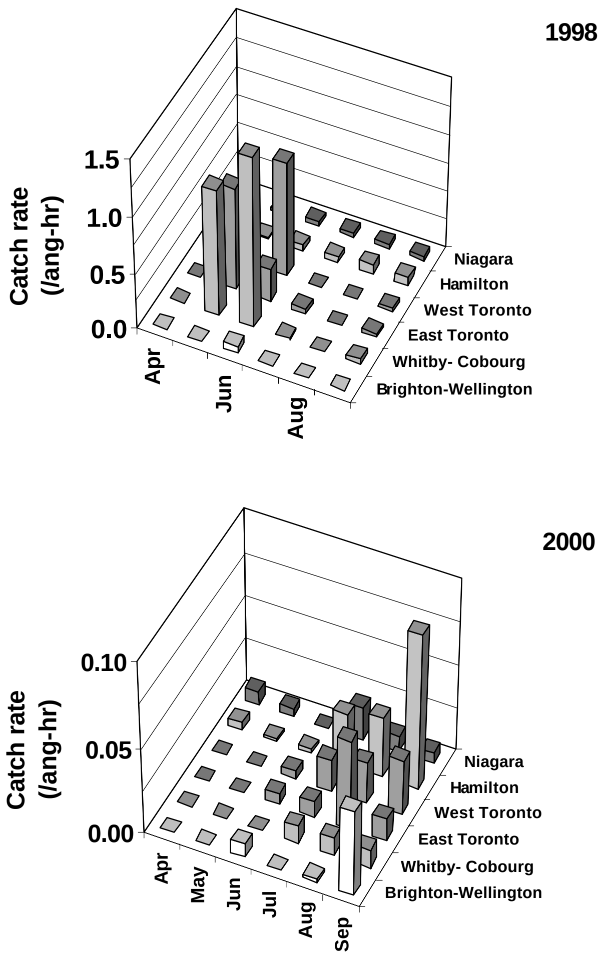

FIG. 14. The seasonal and spatial pattern of catch rates of rainbow trout by launch daily anglers in western Lake Ontario during 1998 and 2000.

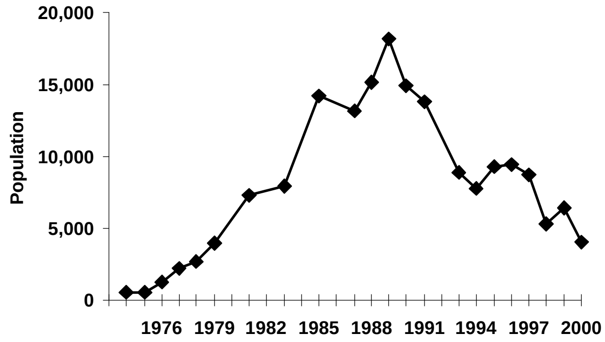

FIG. 15. The estimated upstream count of rainbow trout at the Ganaraska River fishway at Port Hope, Ontario during April and May.

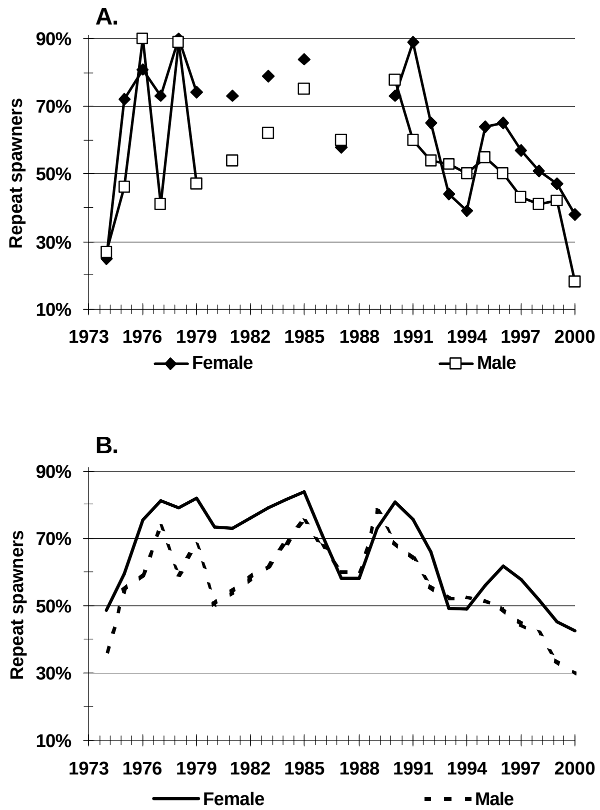

FIG. 16. The repeat spawner rate of rainbow trout in April at the Ganaraska River fishway, in Port Hope, Ontario. A. Yearly values. B. Three-year running averages to reduce the effect of strong and weak year classes.

Rainbow Trout

Lake Ontario

Catch rate of rainbow trout from the launch-daily boat fishery in western Lake Ontario (Chapter 8) is our primary index of rainbow trout abundance for the Ontario portion of Lake Ontario. In 2000 the catch rate declined to the 3rd lowest value recorded since 1985 (Fig. 8). However, catch rates of rainbow trout in Ontario waters of Lake Ontario were positively correlated with spring air temperatures (Fig. 13). The poor catch rates of rainbow trout in 2000 were consistent with one of the colder springs in recent years. During years with warm springs such as 1998, the catch of rainbow trout was higher during spring, especially from Port Credit to Cobourg (Fig. 14). These high catch rates were consistent in timing and location of with the migration of wild post-spawning rainbow trout from north shore streams. In cooler springs, such as 2000 post-spawning rainbow trout did not appear to frequent the north shore of Lake Ontario.

Ganaraska River

The difficulties in sampling rainbow trout in Lake Ontario has led us to use the Ganaraska River population to gain some insights into the status of rainbow trout in Lake Ontario. The spawning migration during spring has been a great opportunity to count mature rainbow trout from lake Ontario. Since 1974, counts of rainbow trout at the Ganaraska River fishway have been used to index rainbow trout abundance. In 2000, the estimated run past the fishway during spring again decreased considerably to 4,050 fish (Fig. 15). This run had been relatively constant from 1993 to 1997 at a level about 50% higher than 1998 and 1999. Previous declines in the run were related to increases in the age of maturity (Bowlby et al. 1998). However, this most recent decline may be related to a high exploitation by shore based fisheries (Chapter 10).

In 2000 the repeat spawner rate of Ganaraska rainbow trout declined again to a combined estimate of 28% for both sexes (Fig. 16). Clarkson and Jones (1997) have shown that the repeat spawner rate is equivalent to the survival rate. This was well below the recommended limit of 50% (Swanson 1985), suggesting overharvest of the population in the previous year. With an assumed natural mortality of about 20-25% (based on repeat spawner rates in the

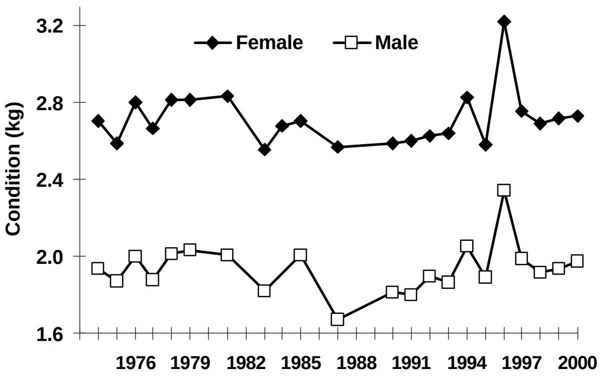

FIG. 17. Condition (mean weight, adjusted for length) of rainbow trout in April at the Ganaraska River fishway, in Port Hope, Ontario.

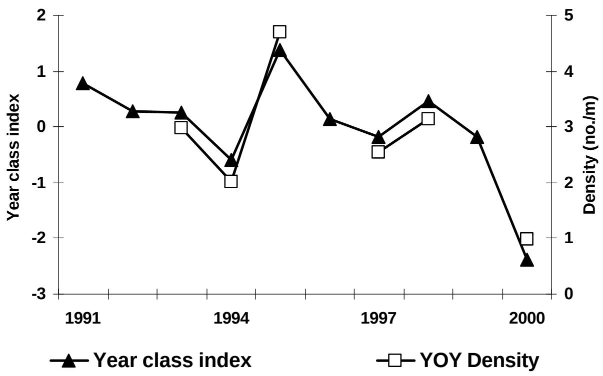

FIG. 18. Density of young-of-the-year (YOY) and year class strength of rainbow trout in Ontario tributaries of Lake Ontario.

1970s), the current repeat spawner estimate provides independent confirmation of the 50% exploitation for the Ganaraska rainbow trout (Chapter 10).

Body condition of adult rainbow trout in the Ganaraska River was determined as the least-square mean weight after adjusting for length using analysis of covariance. Body condition for both female and male rainbow trout has been steady since 1997 (Fig. 17). Body condition of rainbow trout was consistent with past observations by Bowlby et al. (1994) that condition of salmon and trout in Lake Ontario is inversely related to chinook salmon numbers.

Year Class Strength of Wild Rainbow Trout

Wild rainbow trout comprise close to 30% of the Ontario harvest of the boat fishery. To evaluate these populations juvenile rainbow trout were captured by electrofishing at randomly selected sites established in 1993 in north shore Lake Ontario tributaries (Bowlby et al. 1994). Year class strength of wild rainbow trout in Lake Ontario tributaries was calculated as the least-square mean density of juvenile rainbow by year class in Lake Ontario tributaries in Ontario.

Since 1991 rainbow trout year class strength was highest in 1995 and lowest in 2000 (Fig. 18). However, sampling was not done in 1996 and 1999 (Fig. 18), and this has reduced our confidence in the year class strength estimates from these years. The mean density of young-of-the-year rainbow trout in these tributaries was lowest in 2000, and was similar to year class strength (Fig. 18). The low density of young-of the year in 2000 represents the first year class failure we have seen for the period of the survey. These low densities are consistent with reduced number of spawners and low stream flows during spring 2000. The spawning run of rainbow trout in the Ganaraska river was the lowest since 1978, and is consistent with anecdotal information from other streams. As well, our data showed that low flows in 2000 made it difficult for rainbow trout to get past some beaver dams which generally do not present a barrier. However, sites above these dams could not alone account for the low young-of-the-year density in 2000. Low flows also may have flushed less silt from spawning riffles, and potentially lowered survival of eggs in the gravel.

Atlantic Salmon

The review of the first 5-year phase of our Atlantic salmon restoration program is ongoing. We continue to analyse, interpret and report on the research data collected under the plan by OMNR and it's partners. Progress will be measured against the benchmarks set out in the original plan. The results of this program review will be reported in the future.

Management Implications

The abundance of alewife over the past six or seven years appears to fluctuate at a level that is lower than in the early 1990s, but relatively steady. The 1995 and 1998 year classes have provided the boost necessary to maintain the population levels over leaner years. The smelt population appears to be at a very low levels - the estimate for yearling-and-older smelt in 1998 was unusually low for what should have been a peak year (according to alternate year recruitment pattern), and the population in 2000 was at the lowest level since the start of the survey series in 1991. The poor body condition of both alewife and smelt in 1999-2000 suggests that the food resources are limited. It is too early to speculate whether, and by what mechanism, the low numbers of smelt may be related to this potential food limitation. Next year, which according to the observed pattern should be one of increased abundance, will indicate whether the 1999-2000 low abundances of smelt were simply a low point in a cycle, or a more permanent change in abundance.

Chinook salmon and rainbow trout populations in Lake Ontario have stabilized since the mid 1990s, as a result of the stocking reductions in 1993 and 1994. Despite some natural reproduction in both of these species, the stability in salmonid stocking has likely played a major role in stablilizing these populations.

The rainbow trout population in the Ganaraska River is almost entirely dependent on natural reproduction rather than stocking. The declines in the counts at the fishway and in the repeat spawner index, especially in the last 2 years, are consistent with significant exploitation of this population. The spring and fall shore fisheries, the boat fishery, and the stream fishery, all contribute to this exploitation. Across all of these fisheries, total exploitation on the Ganaraska rainbow trout population was approximately 50% (Chapter 10). There is a need to determine an appropriate level of exploitation for rainbow trout, especially in light of the management objective (Stewart et al. 1999) to encourage wild production of rainbow trout in Lake Ontario.

Assessment and Research Needs

The Lake Ontario ecosystem continues to change. This is demonstrated in changing composition and general reduction in prey fish assemblage, natural production of salmonids, and shifts in fish distribution in response to physical parameters. Having accumulated several years of observations of the changing system, it may be time to re-evaluate the food-web models, and update our understanding of the trophic relationships in the lake.

The increasing difficulties in aging chinook salmon by length or scales, has made it difficult to estimate year class strength. The emergence of this problem coincides with the increases in natural reproduction of chinook salmon (Bowlby et al. 1998). We suspect the differing size and age between wild and stocked chinook smolts has obscured the length-frequency distributions that used to clearly separate age groups, and the prevalence of small yearling alewife has given yearling chinook faster growth relative to other age groups. We should obtain ages of chinook salmon from otoliths, which we have been collecting since 1991.

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2

Lake Ontario Offshore Benthic Fish Community

J. A. Hoyle and T. Schaner

Introduction

The most abundant members in the Lake Ontario offshore benthic fish community include one top predator, lake trout, and two benthivores, lake whitefish and slimy sculpin. Much less abundant benthic species include burbot, round whitefish and deepwater sculpin. Other, primarily pelagic species, overlapping in distribution with the benthic community includes alewife, smelt, lake herring and threespine stickleback.

The benthic fish community has undergone tremendous change. Stress brought about by over-exploitation, degraded water quality, the parasitic sea lamprey, and increases in larval fish predators (i.e., alewife and smelt) caused lake trout, four species of deepwater cisco and deepwater sculpin to be extirpated, or nearly so, and lake whitefish and burbot to decline to very low numbers by the 1960s and 1970s.

Harvest control, improvement to water quality, lamprey control, and large-scale stocking of salmon and trout, all initiated in the 1970s, have since led to recovery of some species. Lake trout numbers are maintained largely by stocking but modest levels of natural reproduction have occurred since 1993. Lake whitefish recruitment increased beginning in the late 1970s and populations of two major spawning stocks (i.e., Bay of Quinte and Lake Ontario) recovered over the mid-1980s to early 1990s time-period. Slimy sculpin, which did not experience major negative impacts during the 1960s and 1970s, declined in abundance under intense predation pressure by lake trout through the 1980s and early 1990s—at least in the shallow regions of their distribution. Burbot abundance remained low. Changes in round whitefish abundance, a species confined largely to north central Lake Ontario waters, are not well documented and are not considered further here. Deepwater sculpin, thought to be extirpated from Lake Ontario since the early 1970s, re-appeared in small numbers beginning in 1996. Deepwater cisco remained absent.

Most recently, following the invasion and proliferation of dreissenid mussels in the early 1990s, profound impacts on the benthic fish community are now being played out. Dreissenid mussels have negatively impacted the native benthic invertebrate community. In particular, *Diporeia* (deepwater amphipod), an important diet item for benthic fish (e.g., juvenile lake trout, lake whitefish, slimy sculpin and deepwater sculpin), have declined to negligible levels in the presence of *Dreissenia*. The biggest impacts documented to date have been on lake whitefish and include declines in abundance, recruitment, and body condition.

This chapter updates the status of lake trout, lake whitefish, slimy sculpin, burbot and deepwater sculpin for 2000. For further discussion on lake whitefish population status see Chapter 12.

Information Sources

Information on the benthic fish community is collected in the eastern Lake Ontario fish community index gillnetting and trawling program (Fig. 1, Hoyle 2000a), and also, in the case of lake whitefish, from commercial catch sampling during lake whitefish spawning runs (Hoyle 2000b). For a complete list of species-specific catches in this program, see Appendix B.

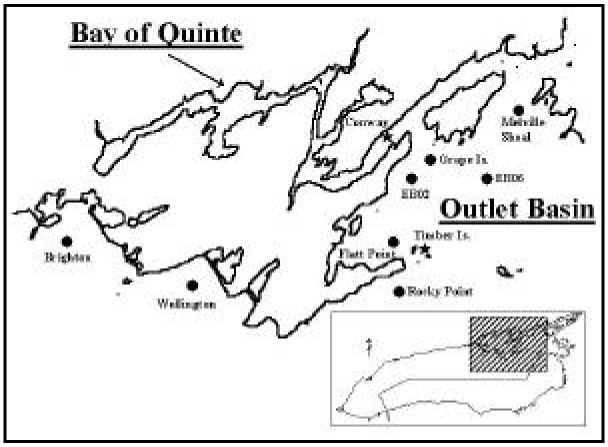

FIG. 1. Map of northeastern Lake Ontario showing fish community index gillnetting (circles) and trawling (stars) locations in the Outlet Basin and the lower Bay of Quinte.

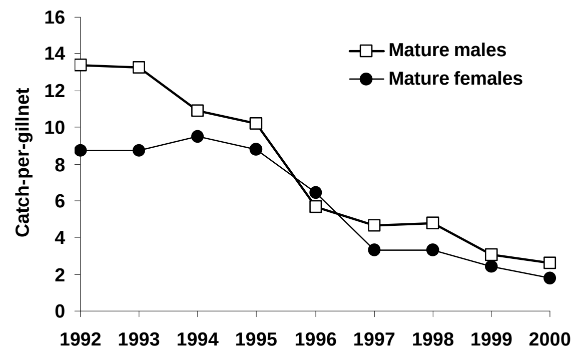

FIG. 2 Catch of mature lake trout per standard gillnet set in the community index gillnetting program. Only catches from July-September made at bottom temperatures less than 12 °C were used.

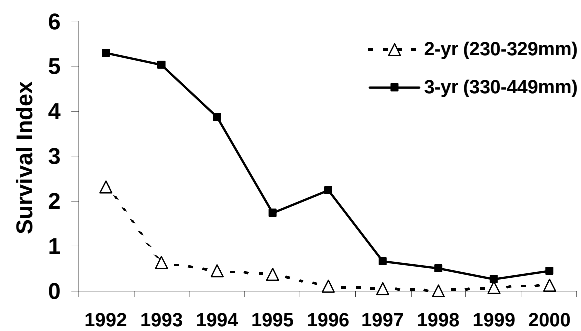

FIG. 3. Survival index of stocked fish to ages 2 and 3. Based on information from the recently discontinued coded wire tags, and from length frequency distributions, fish in the ranges of 230-329 and 220-449 mm were assumed to be 2 yr-old and 3 yr-old respectively. The graph shows the catches per standard set in the community index gillnetting program divided by the number of yearlings (in millions) of the corresponding year class stocked in the Canadian waters east of Brighton.

Lake Trout

Abundance

The decline in abundance of adult lake trout continues (Fig. 2). The decline started in the mid-1990s, and it can partly be attributed to a reduction in stocking in 1993 to approximately half the previous levels. In Canadian waters, however, the reduction was carried out mainly in the western portion of the lake, while in the east, where our data are collected, the stocking continued at only moderately reduced levels. Lake trout tend to remain near their stocking location, and therefore reduced stocking cannot account for the magnitude of the decline in adult fish.

The decline is largely due to low survival of the stocked fish during their first year in the lake. A decrease in early survival has been observed since 1980s, but in the early to mid-1990s it dropped precipitously (Fig. 3). Reduced survival of young fish effectively means reduced recruitment, and a shift in the age structure toward older fish. This is reflected in the mean size of adult fish – in the Canadian waters of Lake Ontario the mean size continues to increase.

Although our ability to assess early survival rates at their current low levels is diminished due to low sample sizes, it appears that the decline has stopped in the past two years (Fig 3). This suggests that in the next three or four years the adult population could stabilize, as the recruitment ceases to decline.

Body condition and growth

The body condition of the lake trout is assessed as the mean weight at a standard length, as predicted from length-weight regressions. The condition of large fish appears to fluctuate without a trend in the 1990s (Fig. 4, 680 mm fish), with higher values in 1995-96 and 1999, which may be attributed to strong 1995 and 1998 year-classes of alewife (see Chapter 1). The condition of juvenile lake trout (Fig. 4, 430 mm fish) appears to have decreased over the mid-1990s. A similar decrease occurred in lake whitefish (see below), and the trend in both species was probably linked to changes in availability of invertebrate prey. Low catches of juvenile lake trout in the monitoring program in recent years limit the statistical significance of our observations, however there is some indication, that since 1998 the condition of juvenile lake trout has improved (Fig. 3, 430 mm; data from smaller fish, not shown).

Lamprey wounding

The frequency of fresh lamprey wounds in lake trout has been demonstrated to be a direct indicator of mortality due to lamprey. Overall, due to successful lamprey control program in the Great Lakes, the lamprey wounding levels remain well below the rates observed during 1970s and early 1980s. Recent data indicate that there was a slight rebound of lamprey in 1995, after very low levels in the early 1990s (Fig. 5).

Natural reproduction

Emergence of naturally produced lake trout fry has been documented in Lake Ontario since the late 1980s, and successful survival beyond larval stage was first demonstrated in 1994, when yearling and 2 yr-old fish began to be caught in bottom trawls. Fish of every year class starting with 1992 have so far been caught, albeit in small numbers. Most of the catches come from the U.S. waters, where there are several extensive bottom trawling programs in which young lake trout are routinely caught. Bottom trawling in Canadian waters is limited, and since 1994 only 15 naturally produced lake trout were caught, and none in 2000. The catches from both Ontario and New York waters indicate prominent 1993 and 1994 year-classes, while fewer fish were caught from the later year-classes.

Lake Whitefish

Abundance

Lake whitefish abundance (1 yr-old and older) is monitored at several gillnetting locations in eastern Lake Ontario (see Fig. 1). Abundance was very low prior to 1980, increased rapidly to a peak in 1993, and declined rapidly through the mid to late-1990s. Abundance remained low in 2000 (Fig. 6).

Recruitment

Lake whitefish recruitment is traditionally measured as young-of-the-year (YOY) catch in mid-summer bottom trawls. Trawl catches of YOY have been low since 1996 (Fig. 7). No YOY fish have been observed for at Timber Island (Lake stock) during the past three years, and only small numbers have been observed for the Bay stock at Conway. The rapidly declining abundance of lake whitefish caught in gillnets (1 yr-old and older) observed after 1993 (Fig.

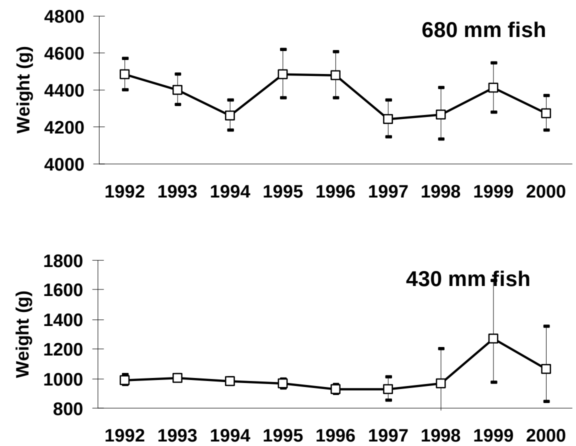

FIG. 4. Lake trout body condition, expressed as predicted weights of 430 and 680 mm fish. The weights were calculated from regression of log transformed round weight on log transformed fork length, and only data from 50 mm brackets around the shown values of fork length were used in the regressions (405-455 mm and 655-705 mm). The error bars represent 95% confidence intervals on the estimated weight.

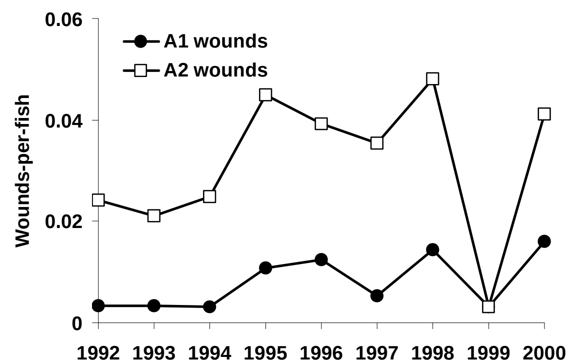

FIG. 5. Number of A1 and A2 (International Joint Commission classification) lamprey wounds per lake trout observed in the index gillnetting program.

6) is contradictory to the large YOY catches in 1994 and 1995 (Fig. 7). A year-class strength index based on gillnet catches of fish aged 1 to 4-yr indicates that the strength of the 1994 and 1995 year-classes did not persist beyond the YOY stage (Fig. 7). Consistent with this observation is that young lake whitefish carcasses were observed in the bottom trawls during 1997 and subsequent years (Hoyle et al. 2001).

Body condition and growth

The body condition of spawning lake whitefish

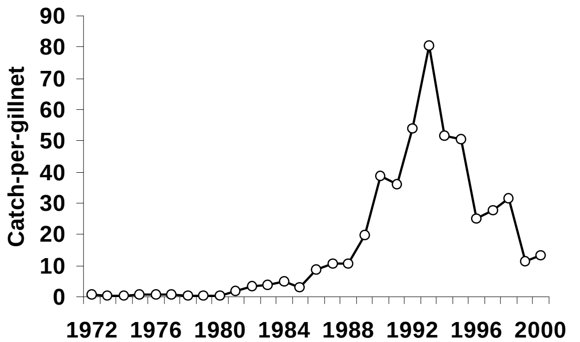

FIG. 6. Lake whitefish catch-per-gillnet (sum of catch adjusted to 100 m of each mesh size, $1^1/_2$ to 6 inch, in the Outlet Basin of Lake Ontario, 1972 to 2000.

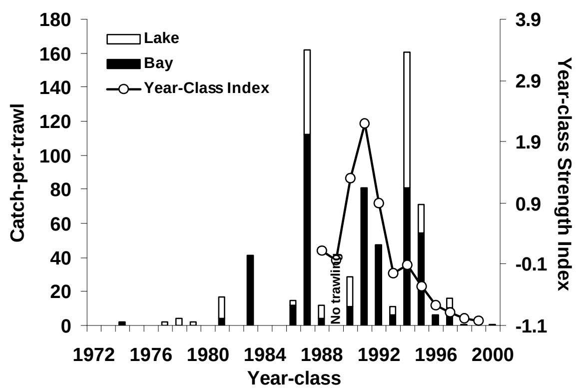

FIG. 7. Young-of-the-year lake whitefish catch-per-trawl (adjusted to 12 min duration) for Lake (Timber Island) and Bay (Conway) stocks (stacked bars), 1972 to 2000 (no trawling in 1989), and an index of year-class strength (normalized values) for fish age-1 to age-4 caught in index gillnets (see Fig. 6 for description of gillnets), in the Outlet Basin of Lake Ontario, 1988 to 1999 (solid line).

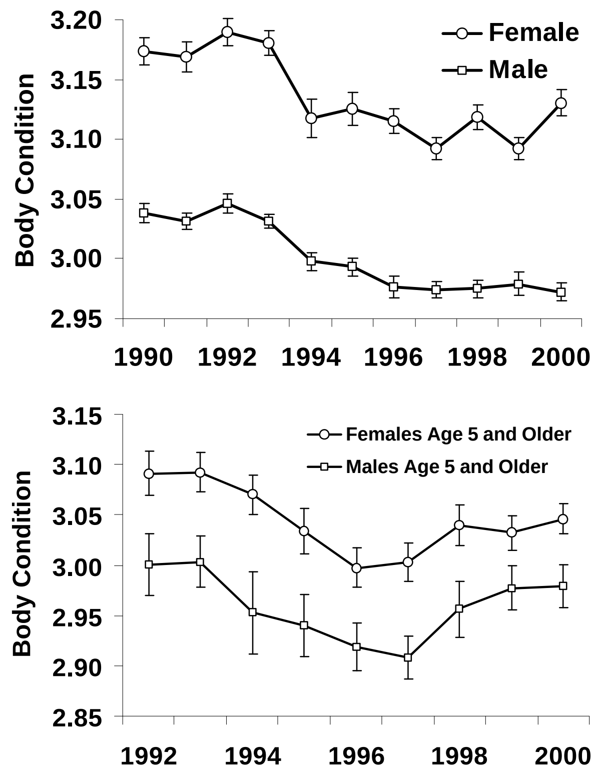

FIG. 8. Lake whitefish body condition (least-squares mean log_{10} round weight adjusted for differences in length among years) in samples collected during: fall spawning runs for Lake Ontario and Bay of Quinte stocks (combined), 1990 to 2000 (upper panel), and mid-summer index gillnetting for mixed stocks in the Outlet Basin, 1992 to 2000 (lower panel).

(both major spawning stocks combined) remained poor in 2000 (Fig. 8). Body condition has been consistently poor since 1994, and has been attributed to the dramatic decline in *Diporeia* (deepwater amphipod) abundance—formerly the most important prey item in the whitefish diet—following dreissenid mussel invasion (Hoyle et al. 2001).

However, body condition for mixed stocks of lake whitefish (5 yrs-old and older) caught in mid-summer index gillnets shows improvement in the last three years (Fig. 8). Body condition trends for young lake whitefish (not shown) also improved. A similar result was observed for juvenile lake trout (see above), and is the first positive sign of improvement in the eastern Lake Ontario offshore benthic food web.

Lake whitefish growth rate (von Bertalanffy growth coefficient K, Fig. 9) was high in the early 1990s, declined from 1994 to 1997 and remained low subsequently. This pattern of decline in growth rate is also apparent in the mean length for age-6 fish (Fig. 9).

Age-at-maturity

Lake whitefish age-at-maturity (females) was 4 to 5-yrs-old in the early 1990s but has gradually increased after 1995 to over age 6 by 2000 (Fig. 10).

Slimy Sculpin

Slimy sculpin abundance remained low in the Outlet Basin of Lake Ontario (Fig. 11), and has now been low since the early 1990s. The decline in

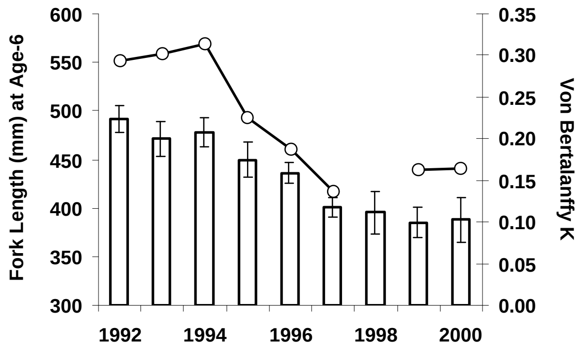

FIG. 9. Mean fork length at age-6 (open bars, +/- 2SE) and von Bertalanffy growth coefficient K (line, ages 1 to 12 yr; no value for 1998), for lake whitefish caught during mid-summer index gillnets in the Outlet Basin, Lake Ontario, 1992 to 2000.

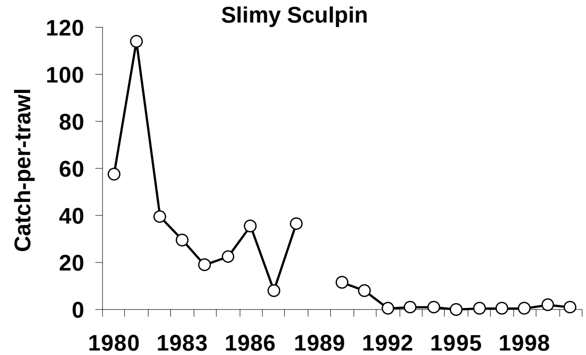

FIG. 11. Slimy sculpin abundance (catch-per-trawl at EB02 and EB06) in the Outlet Basin, Lake Ontario, 1980 to 2000 (no trawling in 1989).

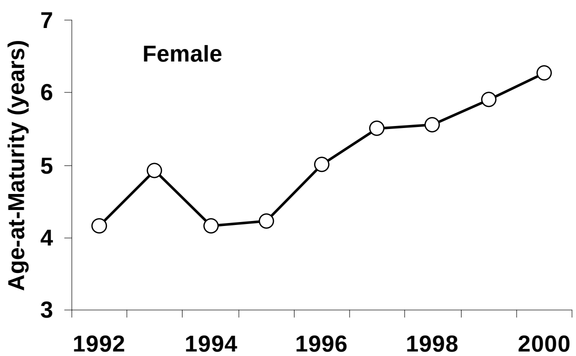

FIG. 10. Mean age-at-maturity (Lysak's method) for lake whitefish caught during mid-summer index gillnets in the Outlet Basin, Lake Ontario, 1992 to 2000.

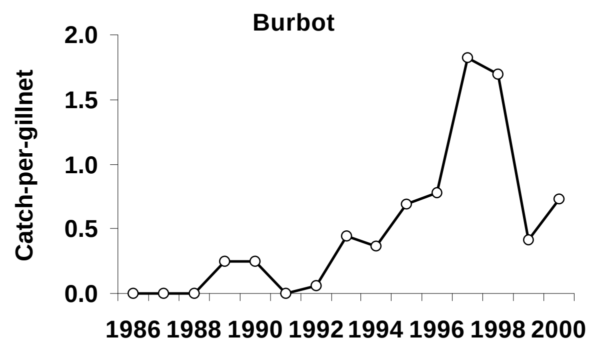

FIG. 12. Burbot abundance (catch-per-gillnet) in the Outlet Basin, Lake Ontario, 1986 to 2000.

abundance was likely related to intense predation pressure by stocked lake trout. Most recently, low abundance levels are also likely being maintained by the same factors that are limiting lake whitefish, changes in the benthic food web due to dreissenid mussel impacts.

Burbot

Burbot catches in the Outlet Basin of Lake Ontario, although modest, increased steadily through the late-1980s and 1990s time-period. Catches have been somewhat lower for the last two years (Fig. 12).

Deepwater sculpin

As in 1999, no deepwater sculpin were caught in 2000, although only a small amount of bottom trawling was conducted in areas suitable for this species. A single deepwater sculpin was captured in U.S. programs on Lake Ontario during 2000 (compared with three in 1999) north of Sodus Bay New York, near the Canadian border (Randy Owens, U. S. Geological Survey, Great Lakes Science Center, Lake Ontario Biological Station, Oswego, New York, personal communication).

Management Implications

The lake trout in Lake Ontario are currently maintained through stocking. The goal of the stocking program is to re-establish a self-sustaining population. The numbers and population characteristics that were deemed to be necessary for natural reproduction to occur have been in place since the 1980s, but it wasn't until the early 1990s that we observed the first naturally produced fish. The adult population at this time still consists almost entirely of stocked fish, and, due to the history of survival of young fish, the numbers of adults will likely continue to decline over the next few years. At this time, when there are promising signs of success, it is important to maintain the stocking program to maintain a sound base of adult fish. The chances of success of the rehabilitation program will become clearer in the next few years, as the wild fish observed in the 1990s are becoming mature, and the second generation of wild fish starts emerging .

The future outlook for lake whitefish is extremely uncertain. Although the density of whitefish has declined significantly for several years, body condition (as measured for spawning fish) and growth remain poor, indicating that food resources are still limiting. Lake whitefish are now maturing two years later than they did less than a decade ago. There are some early indications that the density of lake whitefish will soon reach a point that is compatible with the current carrying capacity of eastern Lake Ontario. This would be confirmed by further improvements in body condition, and a new growth regime of smaller, slower growing, later maturing fish. In fact body condition has improved for lake whitefish caught during mid-summer index gillnets in the last three years. But ultimate abundance levels cannot be predicted; especially given that several consecutive poor year-classes have now occurred. A further decline in lake whitefish abundance is expected.

These results make it difficult to determine a safe level of harvest. Harvest levels during the mid-1990s of the recently recovered whitefish stocks matched historical long-term average harvest. However, current harvest levels cannot be sustained.

Fish community objectives for Lake Ontario's offshore benthic fish community (Stewart et al. 1999) suggested that ecological conditions of the early 1990s were favorable for rehabilitation of the offshore benthic food web. Negative impacts observed on this food web following dreissenid mussel invasion in the late 1990s, such as those now documented for lake whitefish, will make achievement of management objectives for the offshore benthic food web much more difficult.

Assessment and Research Needs

The information used to assess lake trout comes from the community index gillnetting survey in eastern Lake Ontario. In the late 1990s the catches of lake trout fell below levels needed to accurately monitor the population status in Canadian waters. In 2000, the gillnetting program was expanded in order to obtain a larger sample of lake trout, and further expansion may be necessary if the catches continue to decline.

The monitoring of naturally produced lake trout is also inadequate. Currently the levels of natural reproduction are low, and only point to the feasibility of rehabilitation. In the future when natural reproduction of lake trout increases, we will need to monitor its levels, and thus we will need an ability to routinely identify naturally produced fish. New methodology utilizing radioisotopes in otoliths is emerging, promising to be capable of distinguishing stocked and wild fish at any age. It is currently being tested on Lake Ontario chinook salmon, and its applicability to lake trout needs to be investigated without delay.

For the past decade lake whitefish stock status has been assessed with detailed information on abundance, recruitment and biological attributes. Commercial harvest allocation has been conservative with increases in quota being made in conjunction with abundance increases. A more precise approach, for example a statistically based catch-age stock assessment, would provide both a more objective method to determine appropriate harvest levels and better predictive capabilities. The recent decline in lake whitefish abundance warrants a more rigorous determination and application of a total allowable catch (TAC). This approach would fit an age-structured population model to the mix of fishery and survey data currently available. The first steps toward a biologically based TAC are presented in Chapter 12.

The cause of low YOY lake whitefish catches in mid-summer assessment bottom trawls is not known. Poor egg and larval fish survival may be related to the very poor body condition of adult fish in the spawning stocks. Also, in the case of the Bay of Quinte stock, predation by yellow perch may also be a factor. Yellow perch, a known larval lake whitefish predator, has increased dramatically in abundance. Other possibilities include: increased water clarity may have affected vulnerability of fish to the sampling gear, and the distribution of the larval fish may have changed. A study to determine the critical life stage (larval to mid-summer YOY) being impacted is warranted. Documented impacts on lake whitefish following dreissenid mussel invasion suggest that other benthivores may also have been impacted. A review of slimy sculpin biological attribute data (e.g., body condition) would broaden our understanding of impacts on the benthic food web.

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3

Lake Ontario Nearshore Fish Community

J. A. Hoyle, J. N. Bowlby and T. Schaner

Introduction

The Lake Ontario nearshore fish community is highly diverse. There are six common top predators: longnose gar, bowfin, northern pike, smallmouth bass, largemouth bass, and walleye. Other common species include gizzard shad, various species of minnows, white sucker, brown bullhead, American eel, trout-perch, white perch, several sunfishes (e.g., rock bass, pumpkinseed, bluegill, black crappie), yellow perch, and freshwater drum. The lake sturgeon—which inhabits a wide-range of water depths—is a formerly common species showing increased abundance in the past few years. The alewife, primarily an offshore pelagic species, utilizes the nearshore as a spawning and nursery area and can be seasonally very abundant in nearshore areas.

The fish community in the coastal nearshore areas surrounding the main body of Lake Ontario is relatively sparse. Therefore, much of the nearshore fish community production comes from major embayments such as the Bay of Quinte, and Lake Ontario's relatively shallow Outlet Basin. Here, several species of particular management interest have shown dramatic changes in abundance in the past decade. The Bay of Quinte and eastern Lake Ontario ecosystems have undergone tremendous change, both gradually since water quality clean-up efforts initiated in the late 1970s, and rapidly following the invasion and proliferation of dreissenid mussels in the early to mid-1990s. The ecosystem change has included increased water clarity, increased levels of aquatic vegetation, and a modified fish community. Smallmouth bass, abundant throughout the 1980s, declined dramatically in the Outlet Basin of Lake Ontario after 1992. The decline appears to be largely due to unfavorable summer water temperatures during the exceptionally cool years of the early 1990s (Hoyle et al. 1999) but has also been attributed to predation by the avian predator, the cormorant, in the New York waters of eastern Lake Ontario (Schneider et al. 1999). Yellow perch have increased dramatically in very recent years in the Bay of Quinte and to a lesser degree in eastern Lake Ontario. This species appears to be capitalizing on changes in habitat and declines in competitors (e.g., alewife) and predators (alewife and walleye). Walleye, having recovered to very high levels of abundance through the early 1980s and early 1990s, have declined dramatically in recent years.

This chapter focuses on the nearshore areas of northeastern Lake Ontario and the Bay of Quinte, and in particular on three species of particular management interest, smallmouth bass, yellow perch, and walleye.

Also included are an update on lake sturgeon status in 2000, and a report on round goby observations in the Bay of Quinte.

Information Sources

Information on the nearshore fish community is collected annually during the eastern Lake Ontario and Bay of Quinte fish community index gillnetting and trawling program (Hoyle 2000). For a complete list of species-specific catches in this program, see Appendix B.

Walleye population size in eastern Lake Ontario and the Bay of Quinte was estimated using the Peterson mark-recapture method. Walleye were marked in fall 1998 and 1999 and recaptured in fall 1999 and 2000. This was a cooperative program between the OMNR and the Ontario Fish Producers Association; walleye were captured in trapnets operated by OMNR staff and commercial fishermen. OMNR staff conducted all walleye marking and observations for recapture fish. Trapnets were located throughout the Bay of Quinte and east and west of Prince Edward County. CAGEAN population estimates were presented previously by Stewart et al. (2000).

Information on round goby was obtained from an angler awareness program that was initiated following the first reported sighting of round goby during the summer of 1999.

Smallmouth bass

Abundance

Smallmouth bass abundance in eastern Lake Ontario (Fig. 1) was high in the late 1970s, declined through the early and mid-1980s, then remained steady or increased slightly to the early 1990s. After 1992, abundance declined rapidly to 1996, showed a moderate increase over the next two years to 1998, and then again declined over the next two years (Fig. 2). Trends in abundance were age-specific. Young bass (i.e., 2 to 5 yrs-old) showed a cyclical pattern of abundance with peaks during the years 1980, 1983 to 1985, 1991 to 1993, 1998 and 1999, and low points during 1981, 1986 to 1990, and 1994 to 1997 (Fig. 3). Older bass (>5 yrs-old) showed a marked decrease throughout the past 20 years.

Year-class Strength

Trends in year-class strength revealed that the eastern Lake Ontario smallmouth bass population is characterized by periodic strong year-classes, and intervening years of weak year-classes (Fig. 4).

Cumulative gillnet catch-per-unit-effort for ages 2 to 4 yrs showed strong year-classes in 1980, 1983, 1987, 1988 and 1995. Only extremely weak year-classes were produced through the 6-yr period from 1989 to 1994. The strongest year-class during this period, 1991, was only of moderate strength. Direct and complete estimates of year-class strength were not possible beyond 1996. However, smallmouth bass year-class strength in eastern Lake Ontario is positively correlated with July/August water temperatures during the first year of life (Hoyle et al. 1999). This allows prediction of smallmouth bass year-class strength, based on mid-summer water temperature for the years 1997 to 2000 (1995 and 1996 predicted year-class strength also shown for comparison (Fig. 4). The 1998 and 1999 year-classes were predicted to be high and above average. Year-classes from 1996 and 1997 were relatively weak but, with the exception of 1991, stronger than during the period of very weak year-classes from 1989 to 1994 (Fig. 4). These results suggest that smallmouth bass abundance should increase in eastern Lake Ontario over the next several years.

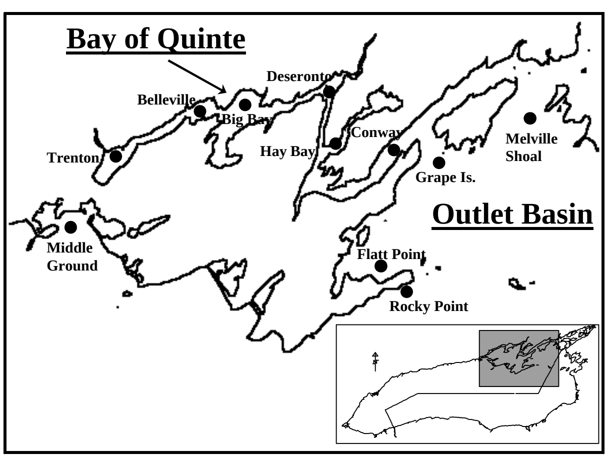

FIG. 1. Map of northeastern Lake Ontario showing fish community index gillnetting and trawling locations in the Outlet Basin and the Bay of Quinte.

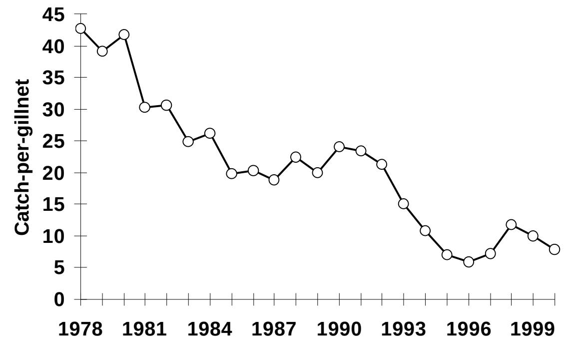

FIG. 2. Smallmouth bass abundance (3-yr running average) in eastern Lake Ontario index gillnets during mid-summer, 1978 to 1999. One site (Simcoe Island) was sampled for the years 1978 to 1985, while three sites (Melville Shoal, Grape Island, and Rocky Point, Fig. 1) were sampled from 1986 to 2000.

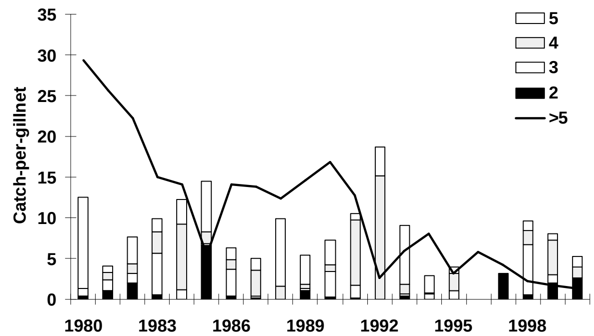

FIG. 3. Smallmouth bass age-specific abundance trends for ages 2, 3, 4, 5 (stacked bars) and >5 yrs-old (solid line) in eastern Lake Ontario index gillnets during mid-summer, 1980 to 2000.

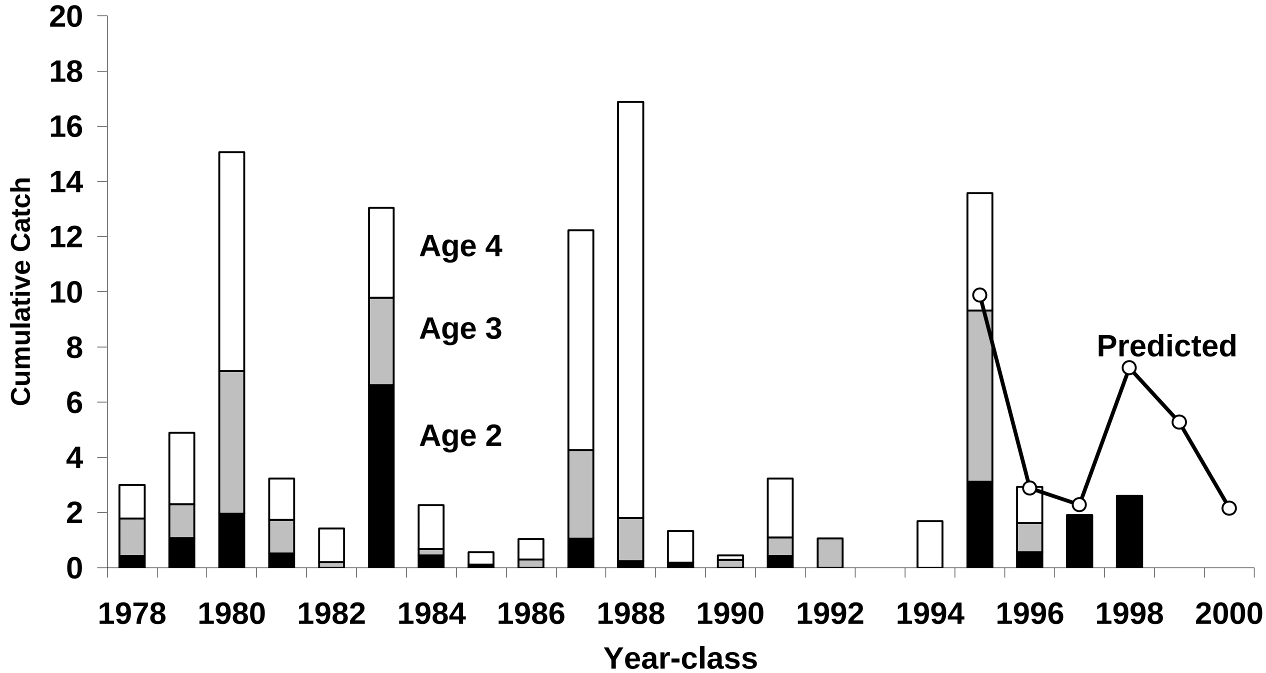

FIG. 4. Smallmouth bass year-class strength measured as the cumulative catch-per-gillnet of ages 2 to 4 yrs-old for the 1978 to 1996 year-classes (ages 2 to 3 yrs-old for 1997, and age 2 yrs-old for 1998 are also shown; stacked bars). Year-class strength for the 1995 to 2000 year-classes was also estimated (solid line) based on the following water temperature vs. year-class strength relationship: Log10(CUE) = 0.329(Water Temperature) - 6.241, r = .74, p = .003, N = 14).*

Bay of Quinte

Smallmouth bass abundance in the Bay of Quinte (Big Bay, Fig. 5) was high in the late 1970s and early 1980s. Abundance declined dramatically through the mid-1980s, and very few smallmouth bass were caught during the late 1980s and early 1990s. Despite the decline in 1999 and 2000, Bay of Quinte smallmouth bass have been more abundant during the past 5 yrs than at any time since the early to mid-1980s (Fig. 5). The year-class composition of the increased catches in recent years (1996 to 2000) was comprised of young fish; all fish were from the 1994 to 1999 year-classes, and 50% originating from the 1995 year-class.

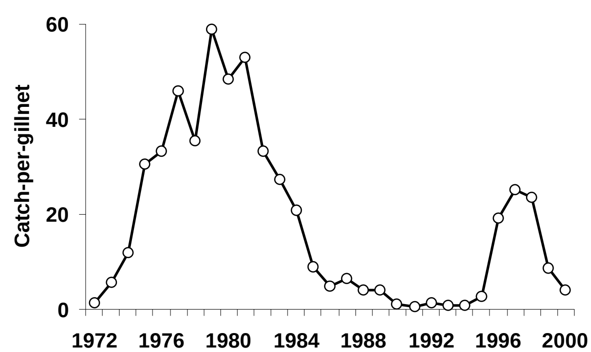

FIG. 5. Smallmouth bass abundance (3-yr running average) in Bay of Quinte index gillnets (Big Bay site) during mid-summer, 1972 to 2000.

Yellow Perch

Yellow perch are the most common species caught in our index netting surveys. Their distribution is wide ranging throughout northeastern Lake Ontario and the Bay of Quinte. Here, several abundance indices are presented corresponding to areas of major commercial harvest interests.

Bay of Quinte

In the Bay of Quinte, yellow perch have increased dramatically in the 1990s but abundance has declined somewhat recently (Big Bay, Fig. 6). The age distribution indicates that the fish are young (mean age = 2.2 yrs-old, Fig. 7). The original increase in abundance was due to increased year-class strength beginning as early as 1993 but especially by 1995 (Fig. 8). The lack of 5 yr-old fish from the 1995 year-class in the Big Bay sample in summer 2000 is puzzling. As 3 yr-olds in 1998, this year-class dominated the catch, and was still prominent as 4 yr-olds in the spring catches of 1999 but was of low abundance by summer 1999 (unpublished data). Thus, the continued preponderance of very small yellow perch in the Bay of Quinte remains puzzling. Poor growth rates does not appear to account for this observation, as growth at Big Bay is similar to growth in other areas of eastern Lake Ontario (Fig. 9). This leaves high mortality rates or migration to other areas, such as the lower Bay of Quinte, as possible alternative explanations.

Yellow perch catches in the Outlet Basin (Melville Shoal and Flatt Point, Fig. 6) remained relatively

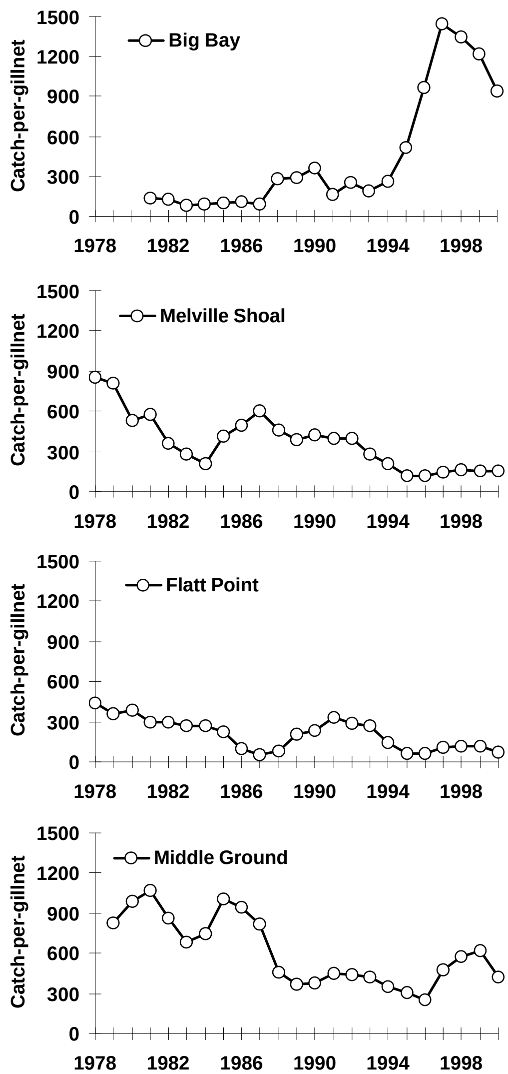

FIG. 6. Yellow perch abundance (catch-per-gillnet, 3-yr running average) in the Bay of Quinte (Big Bay, 1981 to 2000) and eastern Lake Ontario (Melville Shoal, 1978 to 2000; Flatt Point, 1978 to 2000), and Middle Ground (1979 to 2000).

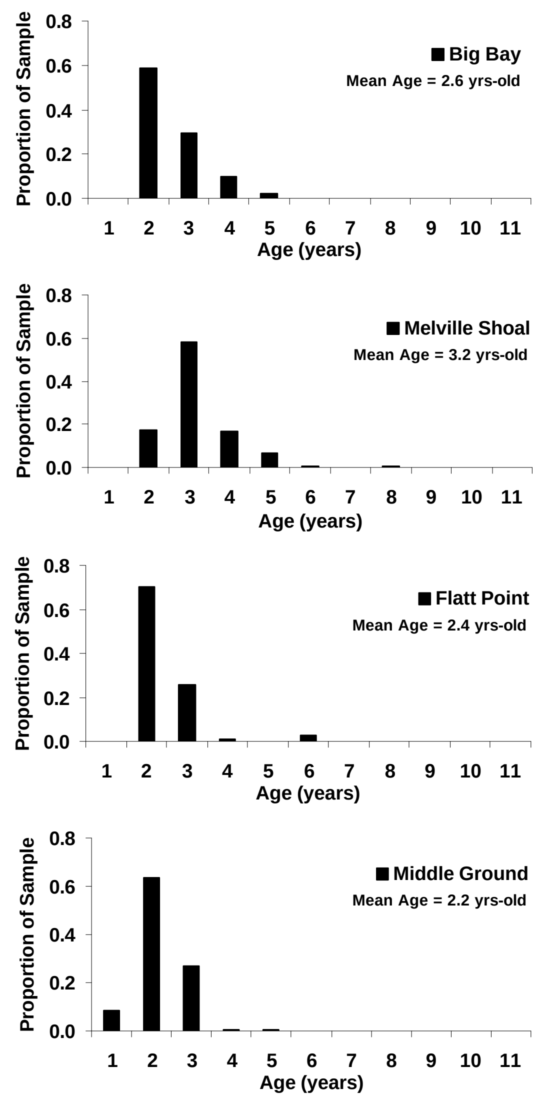

FIG. 7. Yellow perch age distribution in gillnet catches in the Bay of Quinte (Big Bay) and eastern Lake Ontario (Melville Shoal, Flatt Point, and Middle Ground), summer 2000.

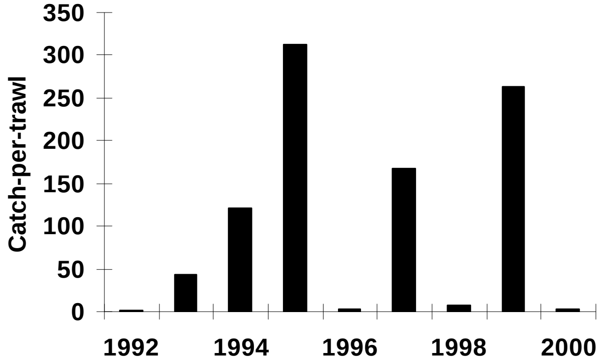

FIG. 8. Yellow perch year-class strength in the Bay of Quinte as represented by YOY catch-per-trawl (6 min duration; six sites: Trenton, Belleville, Big Bay, Deseronto, Hay Bay and Conway), 1992 to 2000.

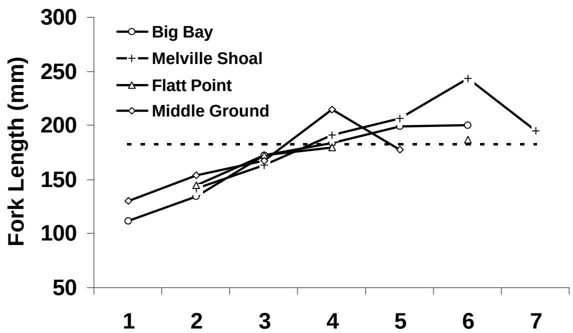

FIG. 9. Yellow perch length-at-age for fish sampled from index gillnets for Bay of Quinte (Big Bay) and eastern Lake Ontario (Melville Shoal, Flatt Point, and Middle Ground), summer 2000. The dashed line shows and approximation of the minimum legal-size (7 1/2 in total length).

steady and at somewhat higher levels in 2000 compared with a the low point in 1995. The mean ages of the 2000 catches were 3.2 and 2.4 yrs-old at Melville Shoal and Flatt Point, respectively (Fig. 7). Yellow perch catches at Middle Ground declined in 2000 for the first time since 1996 (Fig. 6). The mean age of the 2000 catch was 2.2 yrs-old (Fig. 7).

There are very few yellow perch 5 yrs-old and older in the index gillnets.

Walleye

Walleye is the target species of the recreational fishery in the Bay of Quinte (see Chapter 7 in this report). Walleye also are allocated to the Lake Ontario commercial fishery which is largely otherwise supported by lake whitefish, yellow perch and eel (see Chapter 5 in this report), and provide a spring

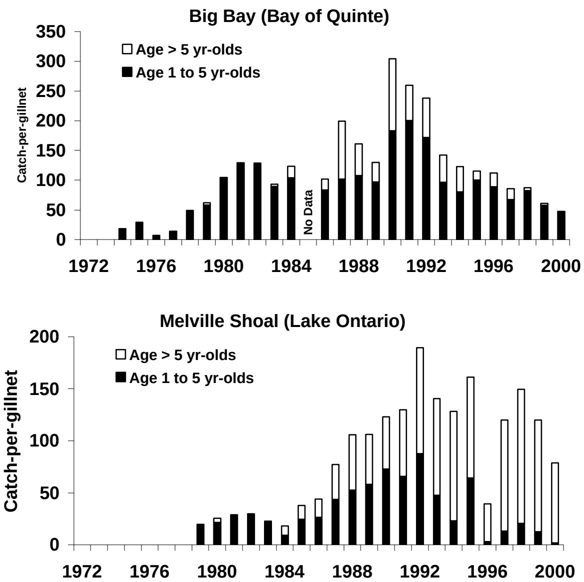

FIG. 10. Walleye catch-per-gillnet, for 1 to 5 yr-olds and >5 yr-olds, in the Bay of Quinte (Big Bay, 1972 to 2000, upper panel) and the Outlet Basin (Melville Shoal, 1977 to 2000, lower panel) in mid-summer.

aboriginal spear fishery in the rivers of the Bay of Quinte (see Chapter 9 in this report). Adult walleye migrate to Lake Ontario immediately following spawning in the Bay of Quinte, and then move back into the bay in the fall to over-winter.

Abundance Trends

Walleye abundance was monitored at Big Bay (Bay of Quinte) and Melville Shoal (Outlet Basin of Lake Ontario, Fig. 1). Walleye age-class composition at the two sites reflected the age-specific distribution pattern of walleye during mid-summer; young fish at Big Bay (e.g., mainly 1 to 5 yrs-old but also some older fish) and older fish at Melville Shoal (e.g., mainly greater than 5 yrs-old but also some younger fish). Walleye abundance increased, beginning in the early 1980s at Big Bay and in the mid-to latter 1980s at Melville Shoal, following production of the 1978 year-class (Fig. 10). Walleye abundance peaked in the early 1990s (Big Bay 1990, Melville Shoal 1992) and then declined markedly in Big Bay but only slightly at Melville Shoal. The 2000 catch at Big Bay was the lowest since 1977, the year prior to walleye resurgence in the Bay of Quinte. Young fish (1 to 5 yrs-old) declined at both sites while older fish (>5 yrs-old) declined at Big Bay but, until 2000, increased or remained steady at Melville Shoal (Fig. 10).

However, catches of walleye greater than 5 yrs-old declined 30% at Melville Shoal in 2000, perhaps signaling the anticipated decline of large walleye due to low recruitment levels in recent years.

Year-class Strength

Walleye year-class was measured two ways (Fig. 11). Young-of-the-year walleye were measured in August bottom trawls at three Bay of Quinte sites, Big Bay, Hay Bay and Conway. In addition, a measure of year-class strength was determined by tracking year-class specific gillnet catches over time for ages 2 to 5 yrs-old (i.e., cumulative catch-per-gillnet) at Big Bay and Melville Shoal.

Catches of YOY walleye indicated virtually no reproduction of walleye prior to 1978, a large 1978 year-class, a general pattern of increasing catches from 1981 to 1990, and finally a decline—with the exception of 1994—to a very low level in 1998. A modest increase occurred in 1999, with catches of YOY fish similar to those of 1995 to 1997 but the 2000 year-class was poor.

Tracking year-class over time for walleye aged 2 to 5 yrs showed the very large 1978 year-class, a steady increase in year-class strength from 1979 to 1988, and then a general decline.

Population Estimates

The population estimates of 3 yr-old and older walleye mirror the abundance trends in index nets. The population increased in the 1980s, peaked in the early 1990s, and subsequently declined (Fig. 12). The greatest decline in population was from 1998 to 1999 (Table 1). Age-specific population estimates indicated that older walleye made up the largest part of the 1998 to 1999 decline (Table 2). The low number of 1 yr-olds in 1999 (Table 2; also low as YOY in 1998, Fig. 11) will translate to almost complete recruitment failure when they become 3 yr-olds in 2001. However, relatively large numbers of 1 yr-old walleye were observed during the 2000 mark-recapture program. This is consistent with a modest sized 1999 year-class, as observed as YOY in 1999 (Fig. 11), and suggests that this year-class that will provide better recruitment in 2002 than the 1998 year-class will in 2001.

Lake sturgeon

Eastern Lake Ontario commercial fishermen have reported moderate numbers of small lake sturgeon

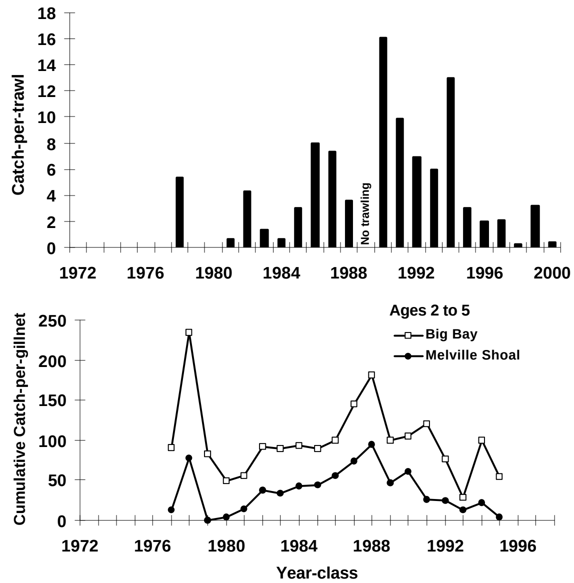

FIG. 11. Walleye year-class strength; measured as young-of-the-year (YOY) catch-per-trawl in the Bay of Quinte (6 min duration),1972 to 2000 (no trawling in 1989), and as cumulative catch-per-gillnet of each year-class measured at ages 2 to 5 yrs-old for the 1977 to 1995 year-classes in the Bay of Quinte (Big Bay) and the Outlet Basin of Lake Ontario (Melville Shoal).

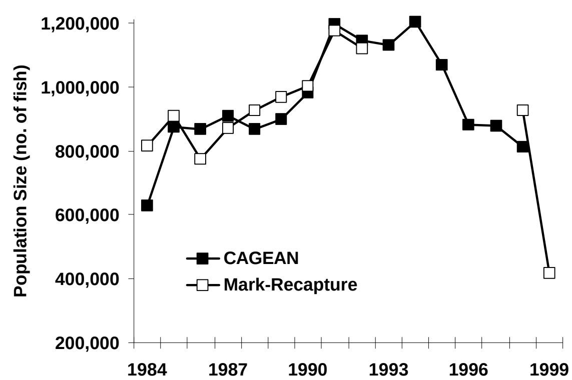

FIG. 12. Population of 3 yr-old and older walleye during fall in eastern Lake Ontario and the Bay of Quinte as determined by CAGEAN and mark-recapture.

annually since 1996 (e.g., 49 fish in 1998, 35 1999, and 24 in 2000). These fish are primarily caught incidentally in gillnets set for yellow perch. Small numbers of sturgeon have also been caught in the eastern Lake Ontario index netting program annually since 1997, but in 2000 no lake sturgeon were caught.

TABLE 1. Population estimates and confidence intervals (C. I.) for 3 yr-old and older walleye in eastern Lake Ontario and the Bay of Quinte for 1998 and 1999.

			95% C. I.	
Mark year	Recapture Year	Population	Lower	Upper
1998	1999	807,837	558,869	1,168,014
1998	2000	1,045,541	751,336	1,455,202
1998	Mean (1999-2000)	926,689	693,744	1,159,634
1999	2000	417,052	325,925	533,693

TABLE 2. Walleye population size (no. of fish) and annual survival in eastern Lake Ontario and the Bay of Quinte for 1998 and 1999.

	Age						
Year	1	2	3	4	5	6 and older	Total
1998	182,589	153,693	188,224	177,699	71,746	489,020	1,262,971
1999	10,552	123,586	83,415	72,965	69,714	190,958	551,191
Annual survival	-	68%	54%	39%	39%	34%	43%

Round Goby

Round goby, an exotic fish from the Ponto-Caspian region, was accidentally introduced into the Great Lakes around 1990, and has since then spread throughout lakes Erie and St. Clair. In 1998 gobies were detected in western Lake Ontario near St. Catherines, and a number of sightings in the following summer suggests that gobies are becoming established in the Niagara-Hamilton area. In 1999, round gobies were also first seen in the Bay of Quinte area in eastern Lake Ontario. Their sudden appearance in Bay of Quinte, despite apparent absence in the intermediate waters of central Lake Ontario, and the fact that they were first detected near docks used by large shipping vessels, suggests that they were introduced through ballast water.

All our information about the spread of the round gobies in the Bay of Quinte comes from anglers' voluntary reports. The sightings in the first year (1999) occurred in Picton Bay and off Amherst Island (Fig. 13). A number of sightings in 2000 suggest that the gobies became established throughout the lower Bay of Quinte (Fig. 12). No reports were received so far from the upper-most reaches of the bay, or from the vicinity of the 1999 sighting off Amherst Island.

Management Implications

Summer water temperature determines eastern Lake Ontario smallmouth bass year-class strength. As a result, smallmouth bass population abundance is highly influenced by the recent annual pattern of summer water temperatures. Smallmouth bass abundance in assessment gillnets was low following poor year-class production during the 1989 to 1994 time period. A strong year-class in 1995 caused smallmouth bass abundance to increase somewhat after 1996. Exceptionally warm water temperatures in 1998 and 1999 will likely result in good year-class production that will, in turn, cause smallmouth bass catches to increase further beginning in 2001. This prediction is significant because of pressures to manage double-crested cormorant populations (an avian piscivore) in eastern Lake Ontario with the expectation of increasing smallmouth bass abundance.

Yellow perch are a valuable commercial species (Chapter 5) that have increased in abundance in the 1990s. However, index gillnet catches and commercial harvest levels in 2000 generally remained steady or declined somewhat (Chapters 4, 5 and 6). Pressures to maximize harvest, and thereby commercial benefits, are high but significant increases in harvest can not likely be supported.

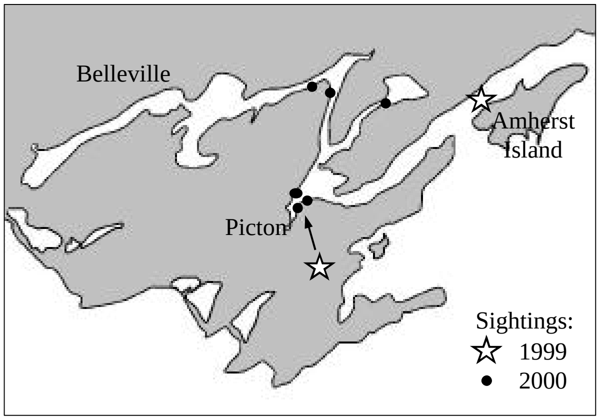

FIG. 13. Sightings of round gobies in eastern Lake Ontario in 1999 and 2000.

The Bay of Quinte walleye and the open-water walleye recreational fishery (see Chapter 7) have declined in recent years. Future trends in walleye and walleye fisheries are of particular management interest. An increase in the catch of YOY walleye in 1999 bottom trawls was encouraging after a very poor 1998 year-class. The 1999 walleye year-class strength is still low relative to year-classes produced in the late 1980s and early 1990s, but may be a signal of what a good year-class will look like in a changed Bay of Quinte ecosystem. The 2000 year-class was poor.

The abundance of large, old walleye will decline over the next several years because small, young walleye are not abundant enough to replace the current numbers of older fish. This was evident in Lake Ontario index gillnets in 2000. The declining trend of large walleye will impact walleye fisheries that exploit large fish: the ice-angling fishery, the commercial fishery, and the aboriginal fisheries.

Assessment and Research Needs

Smallmouth bass support a modest-sized recreational fishery in the Ontario waters of eastern Lake Ontario. Information from routinely conducted surveys would better support the management of this fishery. In the Bay of Quinte, smallmouth bass abundance is expected to increase due to the ecosystem/fish community changes currently unfolding. The species has the potential to generate considerable interest in the Bay of Quinte recreational fishery. Bay of Quinte recreational fishing surveys indicate that largemouth bass abundance is increasing dramatically, although targeted fishing effort remains low. Largemouth bass are not vulnerable to index netting gear currently used in the Bay of Quinte. An index fishing program to target largemouth bass specifically and the nearshore fish community generally is urgently needed.

Yellow perch populations appear to have peaked or declined somewhat after several years of observed increases. The lack of large fish (e.g., >3 yrs-old) in the Bay of Quinte is problematic. So too is the lack of significant increase in the abundance of perch in Outlet Basin assessment gillnets despite increased commercial harvest in this area in recent years; but commercial harvest was lower in 2000 (Chapter 5). These observations require further study.

As for smallmouth bass, yellow perch could potentially provide additional recreational fishing opportunities in the Bay of Quinte. However, the average size of fish caught will likely have to increase before they become attractive to anglers.

Rigorous management of Bay of Quinte walleye, due to wide-ranging interests, necessitates detailed and precise population assessment information. All current assessment programs are important to maintain and to be continually evaluated. In addition, programs to determine the factors currently limiting the production of young walleye would provide better predictive capabilities.

Small lake sturgeon have now been caught in index gillnets and trawls for three consecutive years. Commercial fishermen have reported incidental capture of these small fish for the past four years. The size distribution of the fish suggests that only one or two year-classes were involved. Also, the origin of these fish is not known. Efforts to determine the age structure and origin (e.g., spawning areas) of these lake sturgeon would help management efforts to rehabilitate this species.

Consideration should be given to round goby assessment, since this species will likely proliferate in the habitat offered by the Bay of Quinte. This species is not vulnerable to the fish community index netting methodology currently employed in the bay but may reasonably be tracked in the Bay of Quinte recreational angling survey—with the help of an angler awareness campaign—since gobies are very vulnerable to angling.

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4

St. Lawrence River Fish Community

A. Mathers and T.J. Stewart

Overview

The St. Lawrence River fish community is comprised of a rich assemblage of predominantly native warm-water species; 76 fish species have been reported. Smallmouth bass and northern pike are the most abundant top predators, while other important members of the fish community include yellow perch, rock bass, brown bullhead, and pumpkinseed. Other less abundant, but important, fish species inhabiting the St. Lawrence River include walleye, sturgeon and muskellunge.

Yellow perch, smallmouth bass, and northern pike, and more recently walleye, support important recreational fisheries. In addition, the yellow perch and eel support commercial fisheries (Chapter 6).

The waters of the St. Lawrence River, and the Great Lakes in general, have undergone dramatic changes over the past two decades. Nutrient levels have declined, zebra mussels have invaded, and water clarity has increased. Fish populations of the St. Lawrence River have also undergone changes. The overall abundance of fish has declined. In Lake St. Francis, yellow perch populations continue to decline despite implementation of a reduced season and bag-limit in 1997. Smallmouth catches declined while northern catches remained relatively stable. Catches of small pike remained low. Walleye continued to be caught in very low numbers.

American eel spawn in the Sargasso Sea and a portion of the juvenile population migrates up the St. Lawrence River into Lake Ontario. The eels reside in Lake Ontario for several years before migrating back to sea. While in Lake Ontario the eels have provided for a highly valued commercial fishery (Stewart et al. 1997). Eel populations show evidence of decline in many areas of eastern Canada and particularly in Lake Ontario and the upper St. Lawrence River (Ritter et al. 1997, ICES 2001). Declines have been attributed to habitat loss and deterioration (e.g. dams), over-fishing, and environmental change in the northern Atlantic Ocean.

This chapter summarizes index-gillnetting catches in Lake St. Francis for all species in 2000 and updates trends in yellow perch, smallmouth bass, northern pike, and walleye.

Information Sources

The St. Lawrence River fisheries assessment program includes standardized fall gillnetting programs, and monitoring the eels migrating over the fish-way at the R.H. Saunders Hydroelectric Dam in Cornwall. The fall gillnetting program in the St. Lawrence River is designed to detect long-term changes in the fish communities, and has been established in four distinct sections of the river; Lake St. Francis, Middle Corridor, Lake St. Lawrence, and the Thousand Islands. These programs have been coordinated with the New York State Department of Environmental Conservation (NYSDEC) assessment programs to provide 'river-wide' coverage of fisheries resources. Between 1986 and 1995 gillnet assessment programs on the Ontario portion of the River were conducted in each section every second year. The 2000 netting in Lake St. Francis (conducted using methods as described by Bendig 1995) added to the database established in 1984 and represented the eighth netting program in this section of the St. Lawrence River.

An eel ladder was installed at the R.H. Saunders Hydroelectric Dam in Cornwall in 1974 to assist with the migration of the eel upstream of the dam. Annual counts and a new index of recruitment, based on mean daily counts, was reported for the years 1974 to 1995 (Casselman et al. 1997a). In this report, we provide estimates for the total number of eels ascending the ladder and update the recruitment index for 2000.

Species Population Trends

This chapter provides updated trends in abundance for five fish species of local management interest. Yellow perch, walleye, smallmouth bass, and northern pike provide an important recreational fishery in the Lake St. Francis area (Bendig 1995). In addition, the yellow perch and American eel support an important commercial fishery (Chapter 6). The overall catch during 36 gillnet sets in the 2000 Lake St. Francis project included 492 fish of 13 species (a complete summary of standardized gillnet catch-per-unit-effort is listed in Appendix C). The average number of fish captured per net during 2000 (13.7 fish per net) was the lowest observed in the program. There has been a gradual decline in the number of fish caught per net from the start of the program in 1984 (Fig. 1).

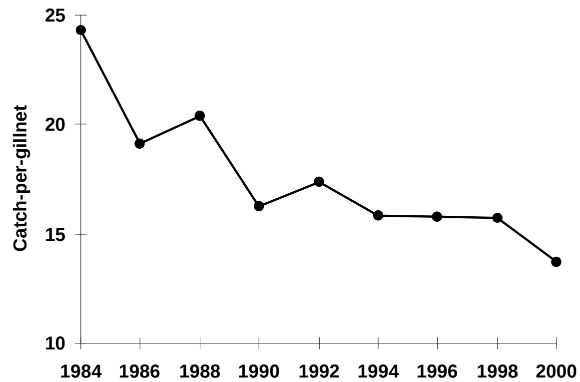

FIG. 1. Catch of all species of fish in standard gillnets set in the Lake St. Francis area 1984 to 2000).

Yellow Perch

Yellow perch continued to be the most abundant fish captured in the Lake St. Francis gillnet program making up 43% of the total catch of all species. The catches of yellow perch during 2000 showed a continuation of the trend of declining catch that started in 1990 (Fig. 2). Yellow perch catches in Lake St. Lawrence have also declined through the 1990s (Klindt and Lantry 2001). Catches of yellow perch in the Thousand Islands area (McCullough 2001, Mathers et al. 2000) and eastern Lake Ontario (Chapter 3) declined during 2000, after several years of improvement. The catch rate of large yellow perch (greater than 220 mm total length) in Lake St. Francis declined in 2000 to the lowest level observed since the program was initiated (Fig. 2).

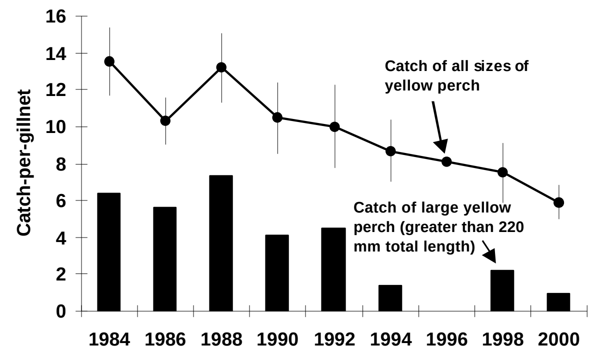

FIG. 2. Catches of large yellow perch (bars) and all sizes of yellow perch (line) in standard gillnets set in the Lake St. Francis area 1984 to 2000.

Smallmouth Bass

Smallmouth bass abundance in gillnets set in Lake St. Francis during 2000 declined from those observed in 1998 but are similar to the catches observed during the 1980s and early 1990s (Fig. 3). Catches in Lake St. Lawrence (Klindt and Lantry 2001) are very similar to those observed in Lake St. Francis. Smallmouth bass catches have declined during the 1990s in the Thousand Islands (McCullough 2001) and in the Eastern Basin of Lake Ontario (Chapter 3).

Northern Pike

Northern pike catches have remained relatively stable throughout the time-period surveyed, although catches of small pike have been relatively low during recent surveys (Fig. 4). Pike catches in Lake St. Lawrence are generally lower than those observed in Lake St. Francis (Klindt and Lantry 2001). A decline in northern pike catches has been reported over the same time period in the Thousand Islands area (McCullough 2001, Mathers et al. 2000).

Walleye

Walleye catches in Lake St. Francis have remained relatively low and stable in recent years (Fig. 5). Relatively high walleye catches have been reported in Lake St. Lawrence recently (Klindt and Lantry 2001).

Other Species

Pumpkinseed, brown bullhead and rock bass are also monitored by this program and are commercially harvested in Lake St. Francis. Catches of pumpkinseed and rock bass appear to have been relatively stable over the last ten years, while catches of brown bullhead have increased recently (Appendix C).

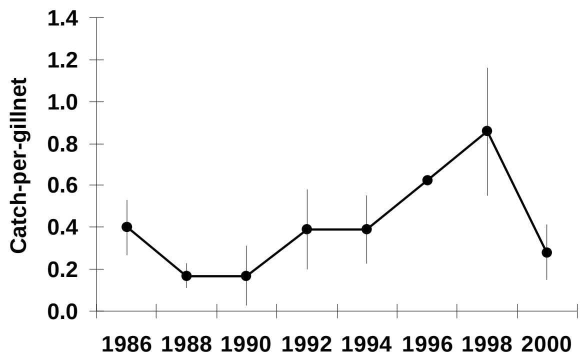

FIG. 3. Smallmouth bass catch in standard gillnets set in the Lake St. Francis, 1984 to 2000.

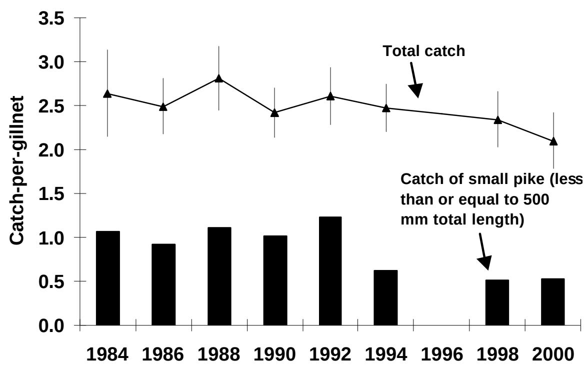

FIG. 4. Catch of small northern pike (bars) and catch of all pike in standard gillnets set in the Lake St. Francis, 1984 to 2000.

American Eel

The eel ladder was opened on June 6 and closed on October 24 (140 days). This year counts were made manually every week by installing the counting net at the top of the ladder and returning to count the number of eel captured the following day. The estimated total number of eels migrating upstream (2,919 eels) was similar to the number observed in 1999, which had the lowest number since the installation of the ladder. The recruitment index (Casselman et al. 1997a) was calculated to be 53.8 eels/day, based on the 31-day peak migration period occurring from July 18 to August 17. This value was higher than observed during 1999 but is 3-orders of magnitude lower than the recruitment indices observed during the early 1980s (Fig. 6). The recruitment index was correlated with commercial catches of eels eight years later in Lake Ontario (Casselman et al. 1997b). Therefore,

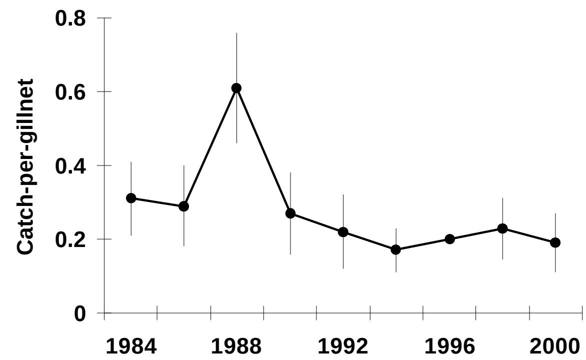

FIG. 5. Upper panel shows walleye catch in standard gillnets set in the Lake St. Francis area , St. Lawrence River, 1984 to 2000.

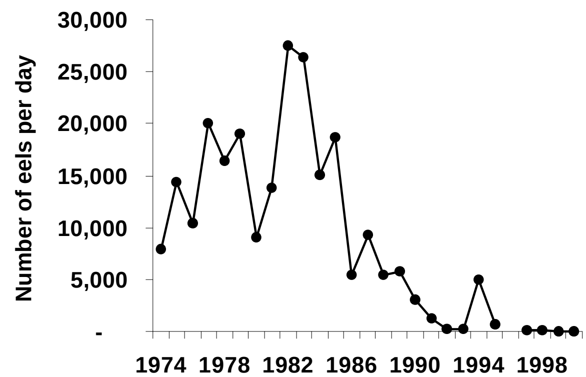

FIG. 6. Mean number of eels ascending the eel ladder per day at the R. H Saunders Hydroelectric Dam, Cornwall, Ontario during a 31-day peak migration period for 1974 to 2000. No counts were available for 1996 (Data from 1974 to 1995 re-drawn from data provide in Table 1, Casselman et al. 1997a).

low indices of recruitment for the last decade (Fig. 6) portend a continued decline in the commercial eel fishery in Lake Ontario.

Management Implications

The outlook for the yellow perch angling and commercial fisheries in Lake St. Francis is not promising for the near future. The continued decline of yellow perch catches in the index gillnets suggests that the management actions implemented to reduced fishing mortality in 1997 have not been successful in increasing the abundance of large yellow perch. If mortality rates prove to be high additional management actions to reduce yellow perch mortality rates should be considered.

The low numbers of new eel recruits passing the eel ladder at the Cornwall dam accounts for the low harvest levels above the dam (Chapter 6), and the continued low harvest in Lake Ontario (Chapter 5). Harvest below the dam (Chapter 6), prior to the eels ascending the ladder, now represents the majority of the harvest from the upper St. Lawrence River and Lake Ontario. Establishment of an eel ladder at the Beauharnois Dam, downstream of the Moses-Sanders Dam, has been proposed for 2001. This should eventually lead to somewhat higher eel abundance in the upper St. Lawrence River and Lake Ontario.

A review of available data by the International Council for Exploration of the Sea (ICES 2001) confirmed either declining or neutral abundance of American eel in Canada and USA. In particular, eels in the St. Lawrence River/Lake Ontario system showed large declines in both recruitment of young eels and escapement of large fecund female silver eel. ICES advised that eel management agencies in the St. Lawrence River/Lake Ontario system should cooperate in meeting the management objectives for the stock. Further, ICES found evidence that reductions in human-induced mortality (which includes both fisheries and hydro dam turbine mortalities) of yellow and silver eels may be required for this area. However, the data to develop escapement biomass limits are not currently available but need to be developed and implemented as soon as possible.

The decline in harvests of yellow perch in all quota zones of the upper St. Lawrence River is consistent with the observed decline in Lake St. Francis yellow perch index gillnetting catches during 2000. In addition, yellow perch abundance in index netting surveys in eastern Lake Ontario and the Bay of Quinte (Chapter 3) also appear to have declined during 2000.

Assessment and Research Needs

Estimates of angler harvest in Lake St. Francis and the rest of the upper St. Lawrence River are needed. Additional analysis to determine the mortality rates of yellow perch in Lake St. Francis during recent years should be conducted. Estimation of the exploitation rate of yellow eel in the upper St. Lawrence River and Lake Ontario would greatly enhance our ability to effectively manage eels.

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5

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J. A. Hoyle, R. Harvey, and S. Orsatti

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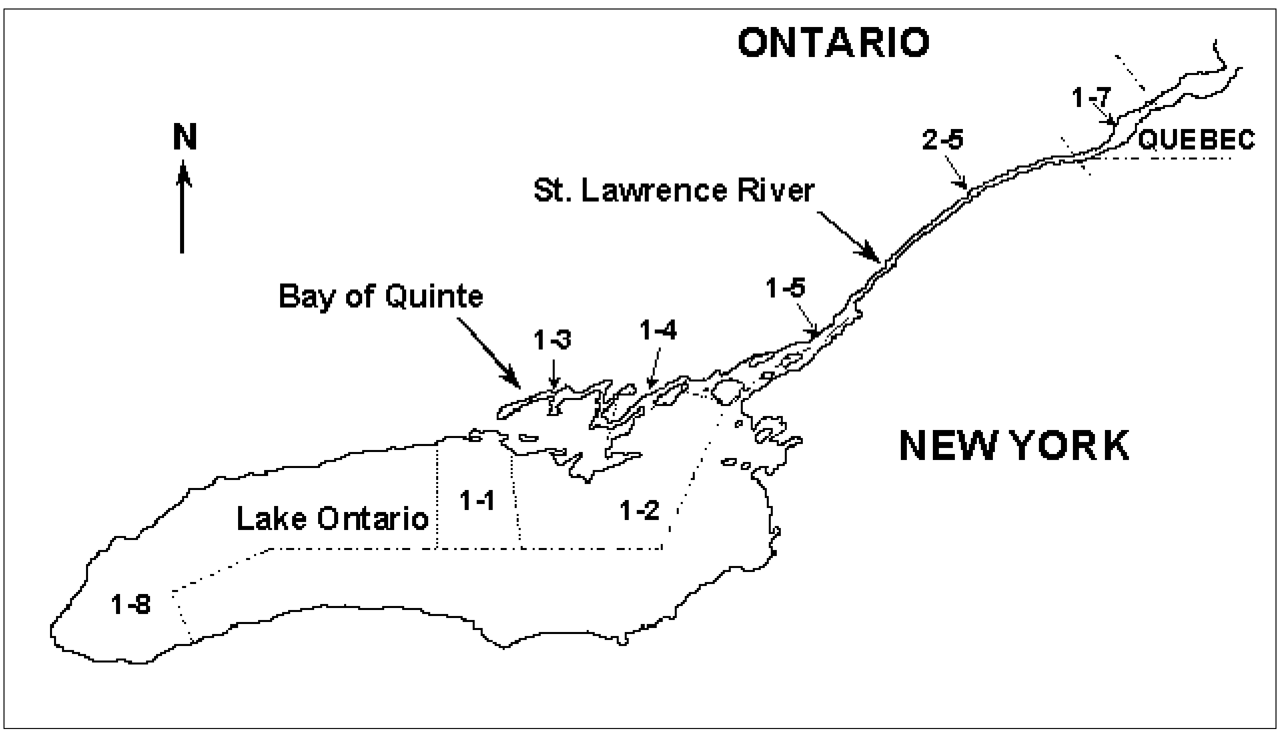

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TABLE 1. Commercial harvest quotas (lb) for the Canadian waters of Lake Ontario, 2000. See Fig. 1 for a map of the quota zones.

	Quota (lb) by Quota Zone					
Species	1-1	1-2	1-3	1-4	1-8	Total
American eel	41,130	220,630	66,130	34,035	3,600	365,525
Black crappie	3,940	2,500	14,710	800	2,400	24,350
Lake herring	15,690	15,300	7,250	7,350	0	45,590
Lake whitefish	34,591	356,190	84,871	107,302	800	583,754
Round whitefish	10,000	0	0	0	0	10,000
Walleye	6,210	51,692	0	14,328	500	72,730
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quota zone basis (Fig. 1). Fish species for which direct harvest controls are necessary to meet fisheries management objectives are placed under quota management (Table 1). These species include premium commercial species (e.g., lake whitefish, eel, black crappie, yellow perch), species with allocations to other users (e.g., walleye), and species at low levels of abundance or requiring rehabilitation (e.g., lake herring). In addition, some species traditionally thought of as coarse fish, have harvest controls for only some areas within a quota zone (e.g., bullheads, sunfish, carp and channel catfish in embayments of Lake Ontario). Quotas in 2000 were similar to 1999 (Hoyle et al. 2000).

Information Sources

Commercial harvest statistics were compiled from daily catch report (DCR) records as stored in the Commercial Fisheries Harvest Information System (CFHIS). This system was developed by the Ministry of Natural Resources in 1998/99 to manage records related to the commercial food fishing industry in Ontario. In addition, a commercial catch sampling program was conducted to obtain biological information on lake whitefish and yellow perch.

Commercial Harvest Summary

Commercial harvest statistics for 2000 are shown in Table 2. In 2000, there were 117 commercial fishing licenses on Lake Ontario. The total harvest of all species was 914,105 lb ($990,561.76) in 2000.

Lake whitefish

Lake whitefish harvest was 293,133 lb, 50% of the quota (Table 3), in 2000. The annual lake whitefish harvest has declined since 1996.

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Eel harvest was 28,812 lb, 8% of the quota, in 2000. Eel harvest had been in decline since 1992 but doubled between 1999 and 2000.

Yellow perch

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Walleye harvest was 12,302 lb 17% of the quota, in 2000. Walleye harvest has declined significantly in the past two years.

Biological Characteristics of the Harvest

Lake whitefish

Lake whitefish were monitored for biological characteristics. Sampling activities focused on the fall spawning run fisheries: October/November trapnet fishery in the Bay of Quinte (Quota Zone 1-3), and the November gillnet fishery on the south shore of Prince Edward County (Quota Zone 1-2). As such, our sampling covered the largest components of the total annual lake whitefish harvest.

TABLE 2. Commercial fish harvest (lb) and value ($) for fish species in the Canadian waters of Lake Ontario, 2000.

Species	Harvest by Quota Zone (lb) 1-1	1-2	1-3	1-4	1-8	Total	Price-per-lb	Value
American eel	2,417	15,141	9,640	1,614	0	28,812	$2.01	$57,911.11
Black crappie	553	113	5,994	3	441	7,103	$2.14	$15,200.42
Bowfin	3,046	351	9,084	0	0	12,481	$0.22	$2,745.82
Brown bullhead	30,977	11,009	127,287	5,551	1,543	176,367	$0.30	$52,909.95
Burbot	15	0	74	0	0	89	$0.20	$17.80
Channel catfish	33	4	788	0	1,120	1,945	$0.54	$1,050.30
Common carp	53	5,824	2,799	2,023	0	10,699	$0.17	$1,818.82
Freshwater drum	714	7,336	19,050	5,397	0	32,497	$0.11	$3,574.67
Goldfish	0	0	0	0	2	2	$0.00	$0.00
Lake herring	17	44	1,056	509		1,626	$0.34	$552.67
Lake whitefish	6,673	209,857	63,069	13,531	3	293,133	$0.67	$196,398.80
Sunfish	5,637	2,460	44,282	412	561	53,352	$0.85	$45,349.20
Rock bass	2,348	4,317	3,492	280	477	10,914	$0.38	$4,147.24
Round whitefish	61	0	0	0	0	61	$0.60	$36.60
Suckers	272	364	6,756	10	0	7,402	$0.10	$740.20
Walleye	1,404	4,897	0	6,001	0	12,302	$1.85	$22,758.70
White bass	0	1	6	44	4	55	$0.92	$50.60
White perch	50	120	7,776	1,368	211	9,525	$0.50	$4,762.25
Yellow perch	4,452	112,718	39,084	96,897	2,592	255,743	$2.27	$580,536.61
Total	58,722	374,555	340,235	133,640	6,954	914,105		$990,561.76

Mean length and age in Quota Zone 1-2, representing the Lake Ontario whitefish stock, were 472 mm and 8.8 yrs-old, respectively (Fig. 2). As was the case in 1999, the 1991 and 1992 year-classes contributed to nearly 50% of the harvest.

In the Bay of Quinte (Quota Zone 1-3), the mean length and age were 472 mm and 9.2 yrs-old, respectively (Fig. 3). For the seventh year in succession, the 1991 year-class dominated the harvest, accounting for over 40%.

The lack of new recruitment to the commercial fishery is problematic, and results from poor survival of young fish, lower growth rates, and delayed age-at-maturity after the mid-1990s (Chapter 2).

Yellow perch

Yellow perch were also monitored in 2000 for biological characteristics. Sampling activities focused on the spring and fall fisheries: April for the hoop and trapnet fishery in Quota Zone 1-3 and for the gillnet fishery in Quota Zone 1-4; and September and October for the gillnet fishery in Quota Zone 1-2, the hoop and trapnet fishery in Quota Zone 1-3 and the gillnet fishery in Quota Zone 1-4. As such, our sampling covered the largest components of the total annual yellow perch harvest.

Mean fork length of yellow perch was smallest in the Quota Zone 1-3 (189 mm, upper Bay of Quinte) and largest in Quota Zone 1-4 in the spring (201 mm,

TABLE 3. Commercial harvest (% of quota) for the Canadian waters of Lake Ontario, 2000.

	Harvest (% of Quota)					
Species	1-1	1-2	1-3	1-4	1-8	Total
American eel	6%	7%	15%	5%	0%	8%
Black crappie	14%	5%	41%	0%	18%	29%
Lake herring	0%	0%	15%	7%		4%
Lake whitefish	19%	59%	74%	13%	0%	50%
Round whitefish	1%					1%
Walleye	23%	9%		42%	0%	17%
Yellow perch	13%	61%	41%	77%	23%	56%

lower Bay of Quinte). Mean age ranged from 3.3 yrs-old in Quota Zone 1-3 (fall) to 4.1 in Quota Zones 1-2 (fall) and 1-4 (spring). The oldest yellow perch were harvested in Quota Zone 1-2 where 6 and 7 yr-old fish were common. Consistent with observations in our index netting program (Chapter 3), the 1994 year-class (6 yrs-old in 2000) appears to have been particularly strong in Quota Zone 1-2. In the other fisheries, 3, 4, and 5 yr-old yellow perch are most common in the commercial harvest.

Management Implications

In spite of a significant decline in the density of whitefish over the past several years, body condition of spawning fish remains poor (Chapter 2). There has also been poor production of young fish for several years, leading to the expectation that lake whitefish populations will continue to decline (Chapter 2). Harvest levels by the commercial fishery have also declined over the past four years. Poor lake whitefish body condition means that more fish must be harvested to achieve quotas. Also, delayed age-at-maturity (Chapter 2) means that fish don't recruit to the spawning run fisheries for two years later than they did only five years ago.

In light of declining abundance, poor recruitment, poor body condition and growth, and declines in the commercial harvest, along with the uncertain future because of ecosystem change, it would be prudent to manage whitefish populations conservatively. Although harvest has not likely contributed to the recent declines in abundance, harvest may be a stress factor in the future if it is unresponsive to population

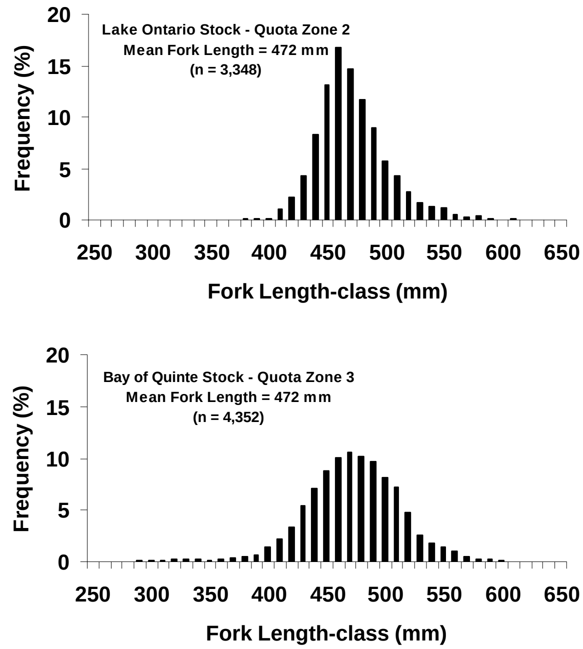

FIG. 2. Fork length (mm) distribution of lake whitefish in Quota Zone 2 and 3 in the 2000 commercial harvest.

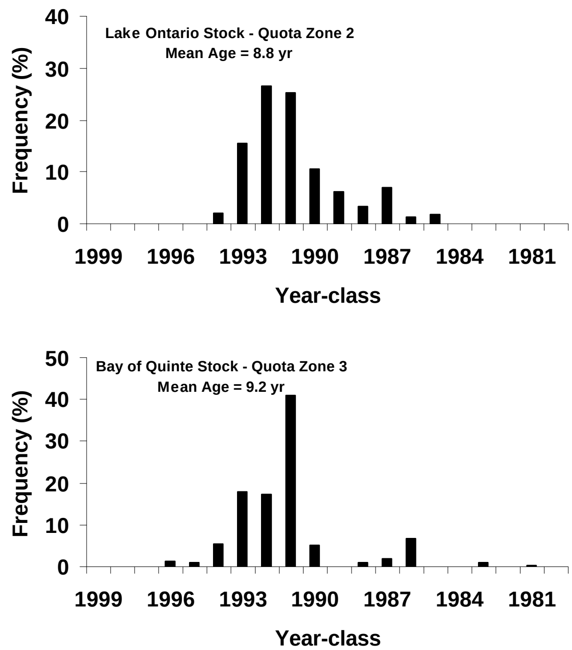

FIG. 3. Age distribution of lake whitefish in Quota Zone 2 and 3 in the 2000 commercial harvest.

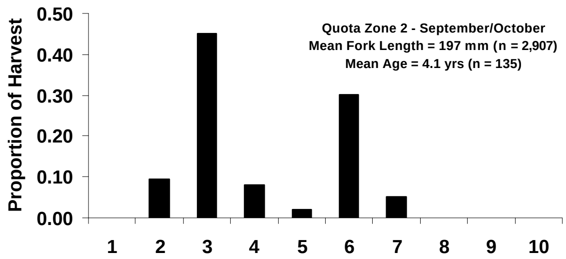

FIG. 4. Age distribution of yellow perch in Quota Zone 2 (September and October) in the 2000 commercial harvest.

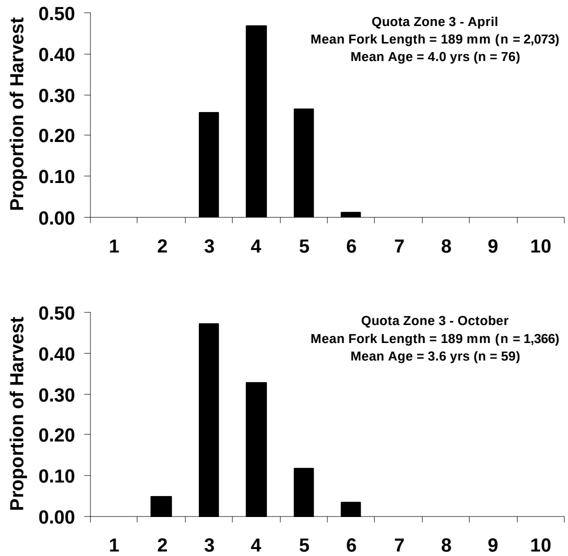

FIG. 5. Age distribution of yellow perch in Quota Zone 3 (April, upper panel; October, lower panel) in the 2000 commercial harvest.

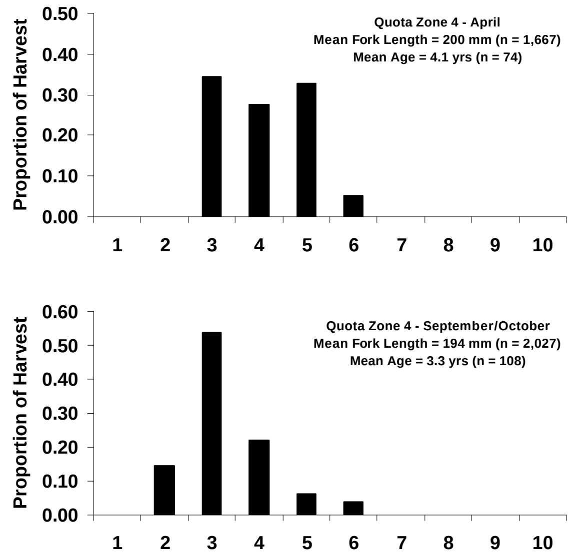

FIG. 6. Age distribution of yellow perch in Quota Zone 4 (April, upper panel; September and October, lower panel) in the 2000 commercial harvest.

declines (Chapter 12). Harvest levels will need to be managed to prevent placing the sustainability of lake whitefish at greater risk.

Eel harvest has been in decline since 1992. The low numbers of new eel recruits passing the eel ladder at the Cornwall dam (Chapter 4) accounts for the continued low harvest in Lake Ontario.

Harvests below the dam (prior to the eels ascending the ladder) now represents the majority of the harvest (including Lake Ontario). If local management actions are deemed appropriate in the face of dwindling eel numbers, then the interactions among the various fisheries and the consequences to eel migration must be considered. A recent international review of global eel status proposes further management actions regarding eel (ICES 2001).

Yellow perch are a valuable commercial species that showed widespread increases in abundance in the 1990s. Pressures to maximize harvest, and therefore commercial benefits, are high. Given the status of yellow perch stocks in eastern Lake Ontario (Chapter 3 and 4), significant increases in harvest cannot likely be supported.

The significantly lower commercial harvest of walleye in 1999 and again in 2000 may signal the first impact on the commercial fishery resulting from a declining walleye population (Chapter 3).

Other species under quota management include lake herring, round whitefish, and black crappie. Lake herring and round whitefish populations are low in eastern Lake Ontario and cannot support a viable commercial fishery. Black crappie harvest occurs primarily in quota zone 1-3, the Bay of Quinte. Recent ecosystem changes in the Bay of Quinte should favor black crappie and the sunfishes generally.

Assessment and Research Needs

For the past decade lake whitefish stock status has been assessed with detailed information on abundance, recruitment and biological attributes. Commercial quota has been increased in conjunction with relative abundance increases. A more precise approach, for example a statistically based catch-age stock assessment, would provide both a more objective method to determine appropriate harvest levels and better predictive capabilities. The recent decline in lake whitefish abundance warrants a more rigorous determination and application of a total allowable catch (TAC). This approach would fit an age-structured population model to a mix of fishery and survey data currently available. The first steps toward a biologically based TAC are presented in Chapter 12.

Biological samples of eels from all commercial fisheries are required to examine changes in the age-structure of the commercial eel harvest to support investigation into the cause of decline, and to assist with the determination of appropriate mitigative measures.

While yellow perch abundance has generally increased, some basic life history details, such as local stock abundance and seasonal distribution patterns, remain to be clarified (Chapter 3). For example, the lack of large yellow perch in the Bay of Quinte is problematic. These observations require further study.

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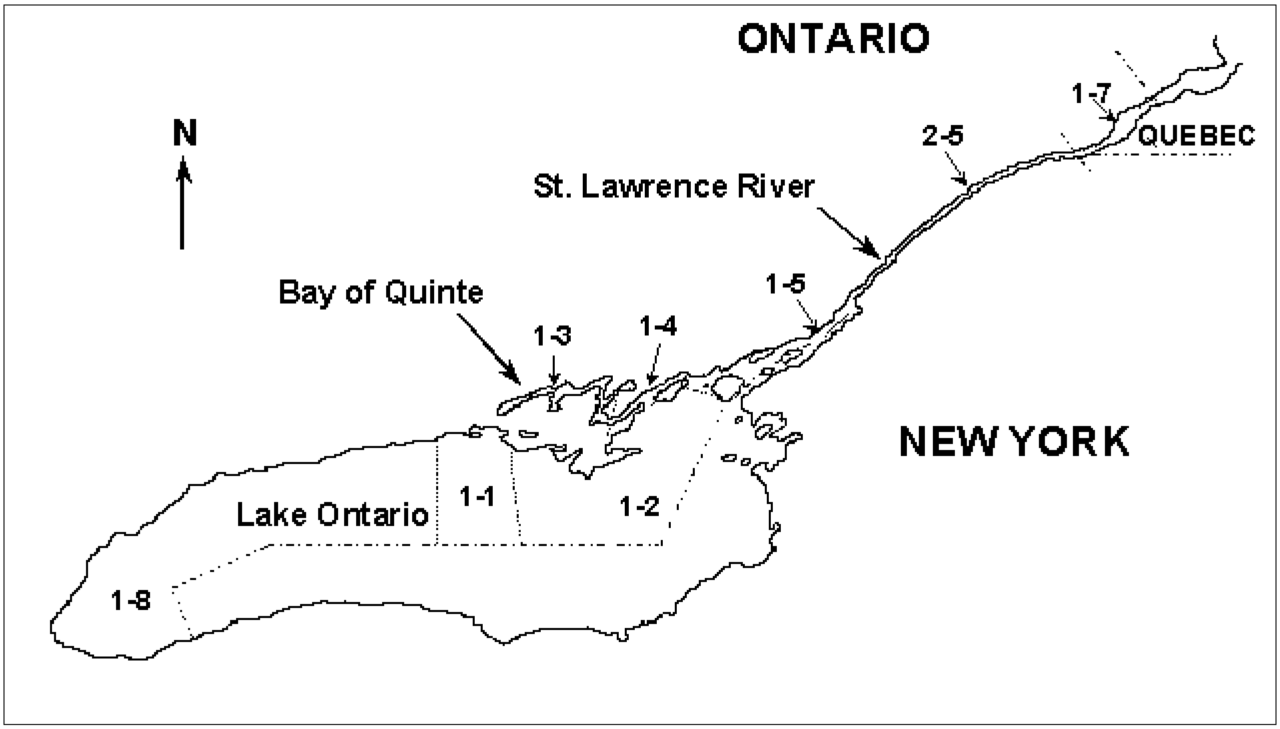

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The lack of new recruitment to the commercial fishery is problematic, and results from poor survival of young fish, lower growth rates, and delayed age-at-maturity after the mid-1990s (Chapter 2).

Yellow perch

Yellow perch were also monitored in 2000 for biological characteristics. Sampling activities focused on the spring and fall fisheries: April for the hoop and trapnet fishery in Quota Zone 1-3 and for the gillnet fishery in Quota Zone 1-4; and September and October for the gillnet fishery in Quota Zone 1-2, the hoop and trapnet fishery in Quota Zone 1-3 and the gillnet fishery in Quota Zone 1-4. As such, our sampling covered the largest components of the total annual yellow perch harvest.

Mean fork length of yellow perch was smallest in the Quota Zone 1-3 (189 mm, upper Bay of Quinte) and largest in Quota Zone 1-4 in the spring (201 mm,

TABLE 3. Commercial harvest (% of quota) for the Canadian waters of Lake Ontario, 2000.

	Harvest (% of Quota)					
Species	1-1	1-2	1-3	1-4	1-8	Total
American eel	6%	7%	15%	5%	0%	8%
Black crappie	14%	5%	41%	0%	18%	29%
Lake herring	0%	0%	15%	7%		4%
Lake whitefish	19%	59%	74%	13%	0%	50%
Round whitefish	1%					1%
Walleye	23%	9%		42%	0%	17%
Yellow perch	13%	61%	41%	77%	23%	56%

lower Bay of Quinte). Mean age ranged from 3.3 yrs-old in Quota Zone 1-3 (fall) to 4.1 in Quota Zones 1-2 (fall) and 1-4 (spring). The oldest yellow perch were harvested in Quota Zone 1-2 where 6 and 7 yr-old fish were common. Consistent with observations in our index netting program (Chapter 3), the 1994 year-class (6 yrs-old in 2000) appears to have been particularly strong in Quota Zone 1-2. In the other fisheries, 3, 4, and 5 yr-old yellow perch are most common in the commercial harvest.

Management Implications

In spite of a significant decline in the density of whitefish over the past several years, body condition of spawning fish remains poor (Chapter 2). There has also been poor production of young fish for several years, leading to the expectation that lake whitefish populations will continue to decline (Chapter 2). Harvest levels by the commercial fishery have also declined over the past four years. Poor lake whitefish body condition means that more fish must be harvested to achieve quotas. Also, delayed age-at-maturity (Chapter 2) means that fish don't recruit to the spawning run fisheries for two years later than they did only five years ago.

In light of declining abundance, poor recruitment, poor body condition and growth, and declines in the commercial harvest, along with the uncertain future because of ecosystem change, it would be prudent to manage whitefish populations conservatively. Although harvest has not likely contributed to the recent declines in abundance, harvest may be a stress factor in the future if it is unresponsive to population

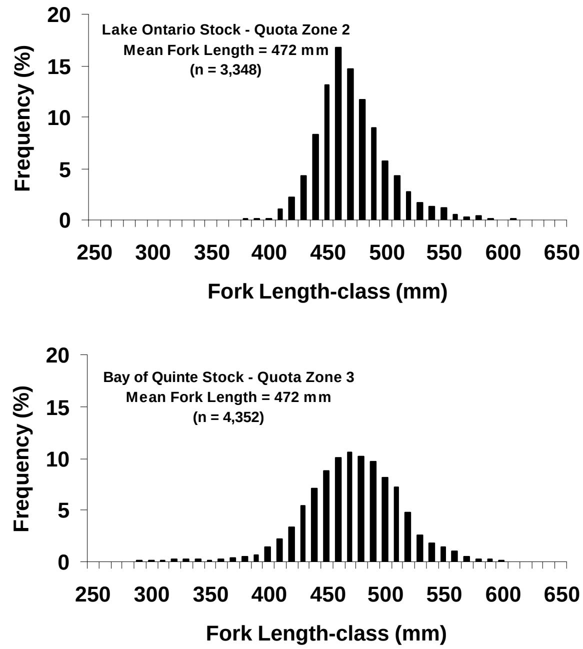

FIG. 2. Fork length (mm) distribution of lake whitefish in Quota Zone 2 and 3 in the 2000 commercial harvest.

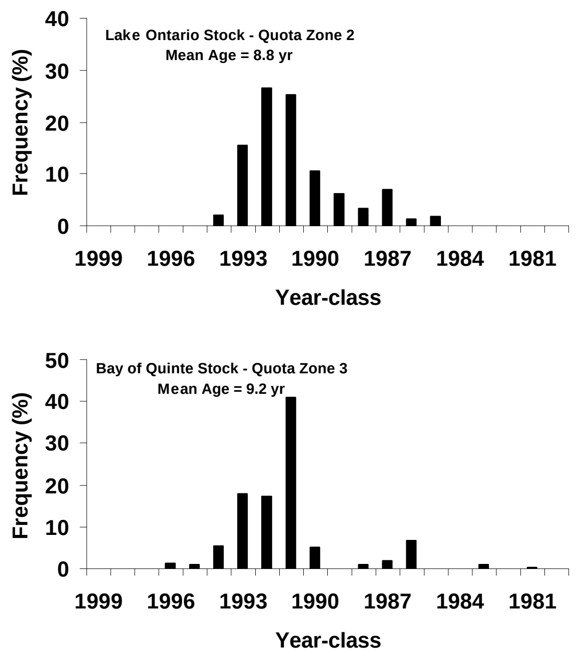

FIG. 3. Age distribution of lake whitefish in Quota Zone 2 and 3 in the 2000 commercial harvest.

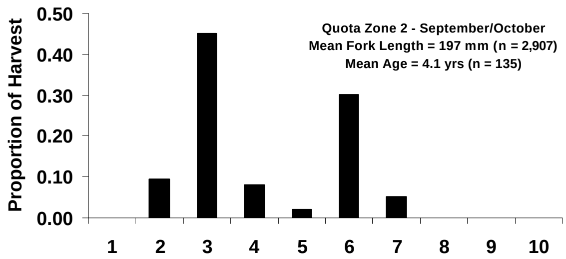

FIG. 4. Age distribution of yellow perch in Quota Zone 2 (September and October) in the 2000 commercial harvest.

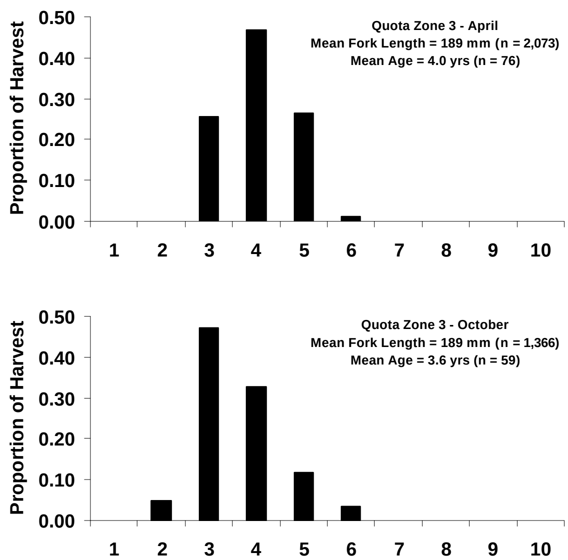

FIG. 5. Age distribution of yellow perch in Quota Zone 3 (April, upper panel; October, lower panel) in the 2000 commercial harvest.

declines (Chapter 12). Harvest levels will need to be managed to prevent placing the sustainability of lake whitefish at greater risk.

Eel harvest has been in decline since 1992. The low numbers of new eel recruits passing the eel ladder at the Cornwall dam (Chapter 4) accounts for the continued low harvest in Lake Ontario.

Harvests below the dam (prior to the eels ascending the ladder) now represents the majority of the harvest (including Lake Ontario). If local management actions are deemed appropriate in the face of dwindling eel numbers, then the interactions

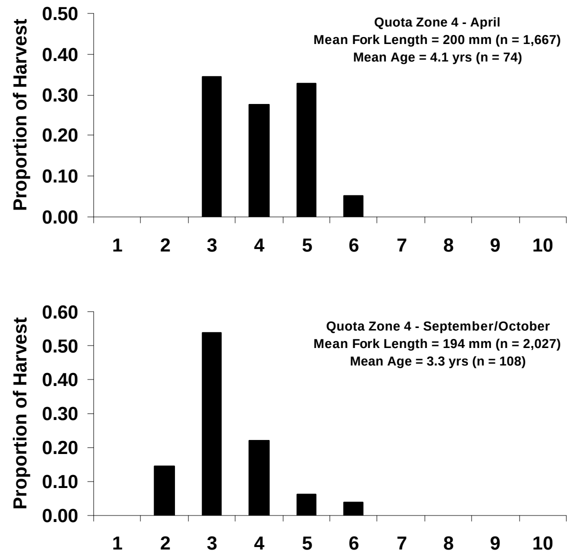

FIG. 6. Age distribution of yellow perch in Quota Zone 4 (April, upper panel; September and October, lower panel) in the 2000 commercial harvest.

among the various fisheries and the consequences to eel migration must be considered. A recent international review of global eel status proposes further management actions regarding eel (ICES 2001).

Yellow perch are a valuable commercial species that showed widespread increases in abundance in the 1990s. Pressures to maximize harvest, and therefore commercial benefits, are high. Given the status of yellow perch stocks in eastern Lake Ontario (Chapter 3 and 4), significant increases in harvest cannot likely be supported.

The significantly lower commercial harvest of walleye in 1999 and again in 2000 may signal the first impact on the commercial fishery resulting from a declining walleye population (Chapter 3).

Other species under quota management include lake herring, round whitefish, and black crappie. Lake herring and round whitefish populations are low in eastern Lake Ontario and cannot support a viable commercial fishery. Black crappie harvest occurs primarily in quota zone 1-3, the Bay of Quinte. Recent ecosystem changes in the Bay of Quinte should favor black crappie and the sunfishes generally.

Assessment and Research Needs

For the past decade lake whitefish stock status has been assessed with detailed information on abundance, recruitment and biological attributes. Commercial quota has been increased in conjunction with relative abundance increases. A more precise approach, for example a statistically based catch-age stock assessment, would provide both a more objective method to determine appropriate harvest levels and better predictive capabilities. The recent decline in lake whitefish abundance warrants a more rigorous determination and application of a total allowable catch (TAC). This approach would fit an age-structured population model to a mix of fishery and survey data currently available. The first steps toward a biologically based TAC are presented in Chapter 12.

Biological samples of eels from all commercial fisheries are required to examine changes in the age-structure of the commercial eel harvest to support investigation into the cause of decline, and to assist with the determination of appropriate mitigative measures.

While yellow perch abundance has generally increased, some basic life history details, such as local stock abundance and seasonal distribution patterns, remain to be clarified (Chapter 3). For example, the lack of large yellow perch in the Bay of Quinte is problematic. These observations require further study.

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6

St. Lawrence River Commercial Fishery

J. A. Hoyle, R. Harvey, and A. Mathers

Introduction

The St. Lawrence River supports a commercial fishery with an annual harvest of about 350,000 lb with a landed value of about $400,000. The most important species in the harvest include yellow perch, sunfish, brown bullhead, and eel. This chapter updates 2000 commercial harvest statistics for the Canadian waters of the St. Lawrence River.

Quota Management

The overall direction of commercial fish management is to support and assist the commercial fishing industry where consistent with the conservation and rehabilitation of fish stocks. In addition to protection of fish stocks, license conditions attempt to reduce problems of incidental catch, and minimize conflicts with other resource users.

Decisions on commercial allocation are made on a quota zone basis (Fig. 1). Fish species for which direct harvest controls are necessary to meet fisheries management objectives are placed under quota management (Table 1). These species include premium commercial species such as eel, black crappie and yellow perch. In addition, some species traditionally thought of as coarse fish, have harvest controls for some areas (e.g., bullheads and sunfish).

Quotas in 2000 were similar to those in 1999 (Hoyle et al. 2000).

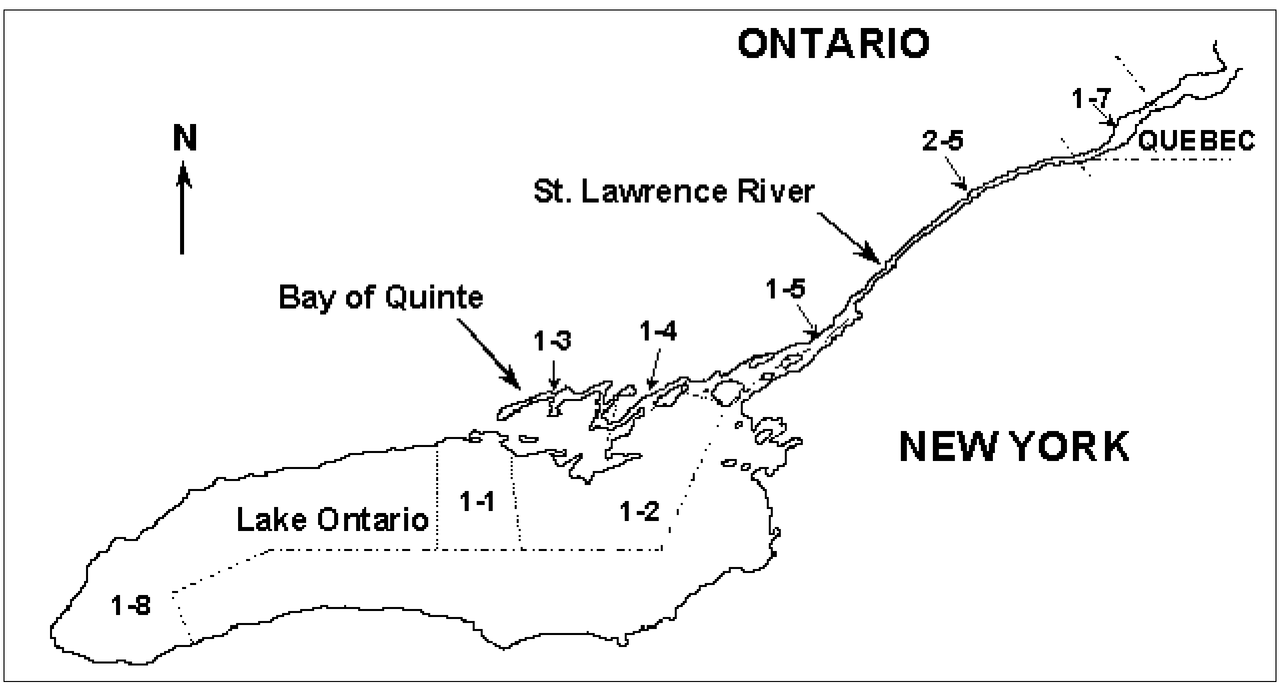

FIG. 1. Commercial fish quota zones on the Canadian waters of Lake Ontario and the St. Lawrence River.

Information Sources

Commercial harvest statistics were compiled from daily catch report (DCR) records as stored in the Commercial Fisheries Harvest Information System (CFHIS). This system was developed by the Ministry of Natural Resources in 1998/99 to manage records related to the commercial food fishing industry in Ontario.

Commercial Harvest Summary

Commercial harvest statistics for 2000 are shown in Tables 2 and 3. In 2000, there were 32 commercial fishing licenses on the St. Lawrence River. The total harvest of all species was 341,672 lb ($407,646.66) in 2000.

TABLE 1. Commercial harvest quotas (lb) for the Canadian waters of the St. Lawrence River, 2000. See Fig. 1 for a map of the quota zones.

	Quota (lb) by Quota Zone			
Species	Napanee (1-5)	Corwall (1-7)	Brockville (2-5)	Total
Eel	30,690	47,986	22,970	101,646
Black crappie	22,590	4,840	18,065	45,495
Yellow perch	67,075	5,760	82,173	155,008
Total	120,355	58,586	123,208	302,149

Table 2. Commercial fish harvest (lb) and value ($) for fish species in the Canadian waters of the St. Lawrence River, 2000.

	Harvest by Quota Zone (lb)					
Species	Napanee (1-5)	Cornwall (1-7)	Brockville (2-5)	Total	Price-per-lb	Value
American eel	4,296	29,817	1,967	36,080	$3.12	$112,569.60
Black crappie	13,792	410	970	15,172	$2.11	$32,012.92
Bowfin	3,741	0	0	3,741	$0.28	$1,047.48
Brown bullhead	45,750	58,269	20,863	124,882	$0.38	$47,455.16
Channel catfish	32	0	0	32	$0.28	$8.96
Common carp	4,412	0	0	4,412	$0.19	$838.32
Freshwater drum	80	0	0	80	$0.12	$9.60
Lake herring	3	0	0	3	$0.60	$1.80
Sunfish	23,405	24,423	21,660	69,488	$0.84	$58,369.92
Rock bass	1,514	0	1,102	2,616	$0.37	$967.92
Suckers	44	9,631	16	9,691	$0.10	$969.13
White perch	2,603	0	0	2,603	$0.70	$1,822.10
Yellow perch	42,302	3,812	26,758	72,872	$2.08	$151,573.76
Total	141,974	126,362	73,336	341,672		$407,646.66

Table 3. Commercial harvest (% of quota) for the Canadian waters of the St. Lawrence River, 2000.

	Harvest (% of Quota)			
Species	Napanee (1-5)	Cornwall (1-7)	Brockville (2-5)	Total
American eel	14%	62%	9%	35%
Black crappie	61%	8%	5%	33%
Yellow perch	63%	66%	33%	47%

Eel

Eel harvest was 36,080 lb in 2000. The majority of the eel harvest comes from below the dam at Cornwall (Quota Zone 1-7) where harvest was about 10% higher in 2000 than in 1999.

Yellow perch

Yellow perch harvest was 72,872 lb in 2000. The harvest declined in all three quota zones compared with 1999, and represented 47% of the total quota (Table 3).

Other species

The commercial harvest of black crappie declined in Quota Zone 1-5 (33% lower in 2000 than 1999), representing 61% of the quota.

Management Implications

The low numbers of new eel recruits passing the eel ladder at the Cornwall dam (see Chapter 4 of this report) account for the low harvest levels above the dam (Quota Zones 1-5 and 2-5), and the continued low harvest in Lake Ontario (Chapter 5). Harvest below the dam (Quota Zone 1-7), prior to the eels ascending the ladder, now represents the majority of the harvest from the upper St. Lawrence River and Lake Ontario. Establishment of an eel ladder at the Beauharnois Dam, downstream of the Moses-Sanders Dam, has been proposed for 2001. This should eventually lead to somewhat higher eel abundance in the upper St. Lawrence River and Lake Ontario. A recent international review of global eel status proposes further management actions regarding eels (Chapter 4).

The decline in harvests of yellow perch in all quota zones of the St. Lawrence River is consistent with the observed decline in yellow perch index gillnetting catches during 2000 (Chapter 4, McCullough 2001). In addition, yellow perch abundance in index netting surveys in eastern Lake Ontario and the Bay of Quinte (Chapter 3) also appear to have declined during 2000. These declines in perch abundance come after a period of increasing abundance in the past few years.

Assessment and Research Needs

Biological samples of eels from all commercial fisheries should be obtained to examine changes in the age-structure of the commercial eel harvest to support investigation into the cause of decline, and to assist with the determination of appropriate mitigative measures.

References

HOYLE, J.A., R. HARVEY, AND T.J. STEWART. 2000. St. Lawrence River Commercial Fishery. 3 p. Part II. Fisheries. *In* Lake Ontario Fish Communities and Fisheries: 1999 Annual Report of the Lake Ontario Management Unit. Ontario Ministry of Natural Resources, Picton, Ontario.

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7

Bay of Quinte Recreational Fishery

J. A. Hoyle

Introduction

The Bay of Quinte supported a large and economically important recreational fishery through the 1980s and much of the 1990s. Walleye have been the dominant species sought and harvested in the fishery since the early 1980s. This recreational fishery developed as the walleye population recovered following production of the large 1978 year-class of fish.

The size of the fishery grew throughout the 1980s and early 1990s, peaking in 1996 at over one million hours of angling effort. Total annual walleye harvest from the recreational fishery peaked earlier, in 1991, at about 220,000 fish.

A major feature of the Bay of Quinte walleye population is that large mature walleye migrate to Lake Ontario following spawning, in the Bay of Quinte, each spring to spend the summer months. Young walleye (e.g., age 1 to 4 yrs-old) reside in the Bay of Quinte year-round. This life history characteristic is important because it influences the size and age of walleye available for harvest in the recreational fishery.

There are two major components to the walleye angling fishery, the winter ice fishery and the open-water fishery.

The ice fishery has traditionally been the smaller than the open-water fishery. There is high annual variation in fishing pressure and success during the ice fishery is due to unpredictable ice conditions. Walleye of all sizes are harvested in the winter fishery.

The open-water fishery is larger and the harvest consists mainly of young immature fish. In contrast to the winter ice fishery, the open-water fishery has shown a steady decline in walleye fishing success and harvest since 1991. The decline in the fishery parallels changes in the walleye population in response to dramatic shifts in the Bay of Quinte ecosystem. These ecosystem changes include increased water clarity and aquatic vegetation, and have favored fish species such as yellow perch and centrarchids (bass and sunfish). To date, these changes have resulted in a decline in the abundance of young walleye—those residing year-round in the Bay of Quinte; thus the greatest impact has been on the open-water recreational fishery.

This chapter updates the results of ice and open-water recreational angling surveys conducted in 2000.

Information Sources

Recreational angling surveys are conducted annually on the Bay of Quinte, from Trenton in the west to Glenora in the east (Fig. 1), during the walleye angling season (January 1 to February 28 and first Saturday in May to December 31). Angling effort is measured using aerial counts during ice fishing surveys, and a combination of aerial counts and on-water counts during open-water surveys. On-ice and on-water angler interviews provide information on catch/harvest rates and biological characteristics of the harvest. Hoyle (1999, 2000) reports detailed survey designs for ice and open-water surveys, respectively.

Fisheries Update

Ice Fishery

Ice angling effort in 2000 was estimated to be 139,047 rod-hours (Table 1), very similar to 1999 (Fig. 2). An estimated 9,949 walleye were caught of which 9,240 were harvested. The number of walleye harvested was down 40% compared with the previous

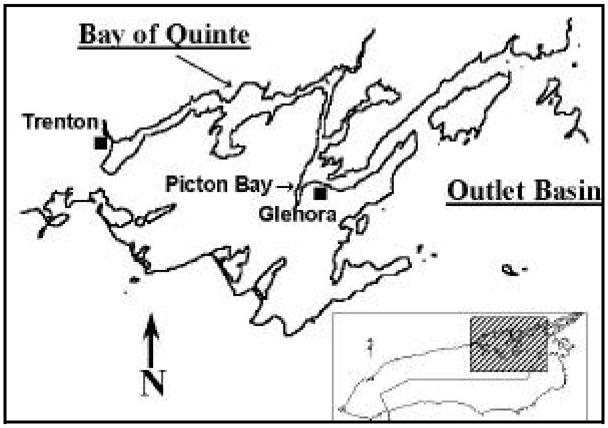

FIG. 1. Map of the Bay of Quinte showing the extent of recreational angling surveys from Trenton in the west to Glenora in the east.

TABLE 1. Bay of Quinte walleye recreational angling effort (angler hours), catch and harvest, 2000.

Season	Effort	Catch	Harvest
Ice Fishery:			
Ice-fishing total	139,047	9,949	9,240
Open-water fishery:			
Opening weekend	55,544	769	588
May	101,220	13,524	11,229
June	23,289	2,104	1,875
July	33,222	2,564	2,109
August	41,693	6,076	5,313
Fall	41,873	2,987	1,697
Open-water total	296,841	28,024	22,811
Annual total	435,888	37,973	32051

year (Fig. 3). Fishing success rate was also down 40% compared to that of the previous year but only slightly less than the previous 5-yr average (Fig. 4). The average walleye harvested during the ice fishery was 563 mm fork length, weighed 2.3 kg and was 8 yrs-old.

Open-water Fishery

Open-water angling effort was estimated to be 296,841 angler-hours (Table 1, Fig. 2). Angling effort has declined for four consecutive years to its lowest level since 1979. Walleye catch was estimated at 28,024 fish of which 22,811 were harvested. The number of walleye harvested was down 21% from last year and has now declined for four consecutive years to its lowest level in 20 years (Fig. 3). Walleye angling success (0.094 and 0.077 walleye caught and harvested-per-rod-hour, respectively, in 2000) has been declining since 1991 (Fig. 4). As fishing success declines, CUE and HUE appear to be converging (Fig. 4), indicating that walleye release rates are also declining—anglers are keeping a higher percentage of their catch. The average walleye harvested during the open-water fishery was 427 mm fork length, weighed 0.94 kg and was 4 yrs-old. Total open-water walleye harvest by weight (21,420 kg) was has now declined 84% from its peak in 1993 (132,560 kg).

Although walleye catch, harvest and success rates have declined dramatically, the Bay of Quinte fishery remains primarily a walleye fishery; over 95% of observed fishing pressure is targeted toward walleye. Other species in the fishery (Table 2) are, for the most

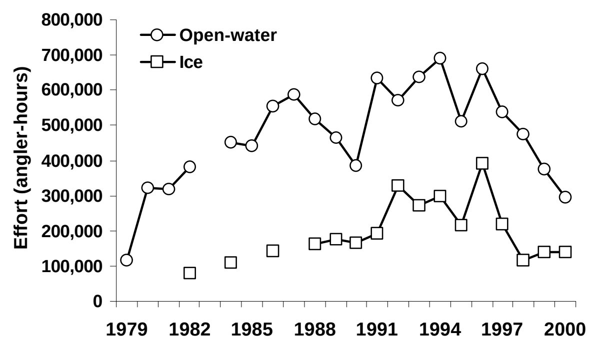

FIG. 2. Angling effort during the Bay of Quinte ice and open-water recreational fisheries, 1979 to 2000.

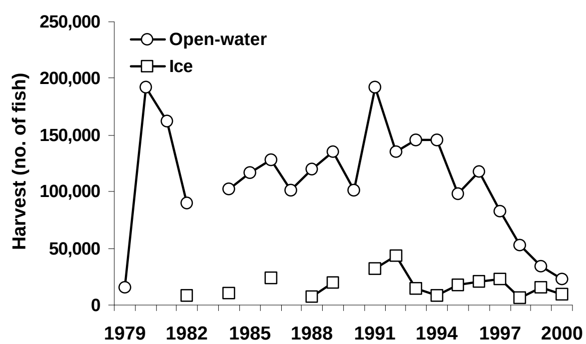

FIG. 3. Walleye harvest during the Bay of Quinte ice and open-water recreational fisheries, 1979 to 2000.

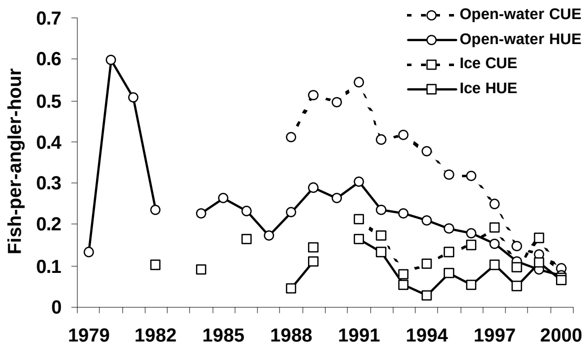

FIG. 4. Walleye catch and harvest-per-unit-effort (CUE and HUE) during the Bay of Quinte ice and open-water recreational fisheries, 1979 to 2000.

Table 2. Angling statistics for the Bay of Quinte open-water fishery, May to November 2000. Catch and harvest are by all anglers; catch and harvest rates (CUE and HUE, the number of fish caught or harvested per angler hour, respectively) are for anglers targeting the specific species.

	Catch	Harvest	CUE	HUE
Northern pike	15,809	2,561	0.417	0.223
Sunfish	25,422	362	0.526	0.187
Smallmouth bass	7,913	1,393	0.331	0.124
Largemouth bass	19,071	4,481	0.879	0.205
Yellow perch	260,029	17,630	2.220	0.628
Walleye	28,024	22,811	0.094	0.077
Total	356,268	49,237		

part, caught incidentally by walleye anglers. However, catch rates for other species have been on the rise as walleye catch rates decline. These trends in catches are consistent with a changing ecosystem. Increased water clarity and aquatic vegetation favour these species.

Management Implications

Fish community objectives for Lake Ontario (Stewart et al. 1999) proposed that walleye fisheries be maintained at early 1990s catch rates. The current Bay of Quinte walleye fishery now falls far short of this objective. Although alternative species appear to be increasing in abundance, anglers have yet to target species other than walleye. Nonetheless, catches of species such as bass and pike will likely continue to increase in the future. Promotion of other species and a review of walleye harvest management may be prudent at this time.

Assessment and Research Needs

The extent to which round gobies, an exotic species first detected in 1999, will become an influence on the Bay of Quinte ecosystem, and thus the recreational fishery, is not known. Largemouth bass, which increased dramatically in anglers' catches in the last few years, are not adequately assessed in the current index netting programs. An index fishing program targeting the nearshore fish community generally, including bass and goby, is urgently needed.

Changes in the Bay of Quinte ecosystem have reduced the potential sustainable yield of walleye. Efforts need to be made to refine estimates of the sustainable level of walleye exploitation. To this end, it is vital to continue to estimate walleye harvest from all fisheries and update estimates of walleye population size.

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8

The Boat Fishery for Salmon and Trout in Western Lake Ontario

J.N. Bowlby

Introduction

The angling fishery for salmon and trout in Lake Ontario entered a modern era with the introduction of coho salmon by New York State in 1968. The Province of Ontario followed suit and began stocking coho the following year. Over the years, stocking of chinook salmon, rainbow trout, brown trout and lake trout also have added significantly to various components of this fishery. Stocked salmon and trout have always been the mainstay of this fishery, although, in recent years natural reproduction of most stocked salmonids has increased. Salmon and trout are an economically valuable recreational species in Lake Ontario. The boat fishery for salmon and trout in western Lake Ontario represents about one-third of the salmon and trout fishery; stream and shoreline fisheries account for the remaining two-thirds. We have monitored various aspects of the salmon and trout fishery of Lake Ontario since the 1970s. However, we have relied on the boat fishery survey in western Lake Ontario to gauge salmonid fish populations and the fishery, since 1982. Efforts to sustain this fishery through management of stocking has important fish community impacts through the influence of predator levels on alewife abundance (Stewart et al. 1999). This chapter describes the status of the boat fishery for salmon and trout in western Lake Ontario. The status of chinook salmon, rainbow trout, and lake trout populations are described in Chapters 1, 2 and 10 of this report.

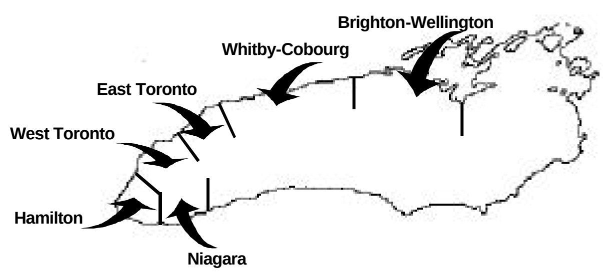

FIG.1. The location of sectors used for stratifying the survey of western Lake Ontario boat anglers.

Information Sources

The portion of the salmon and trout fishery that launches boats from ramps in western Lake Ontario was monitored in 2000. This survey design was consistent with our surveys from 1985 to 1999 (Bowlby and Stewart 2000).

The design was based on seasonal stratification by month from April to September, and spatial stratification into six sectors from the Niagara River to Wellington (Fig. 1). The spatial stratification into these sectors has been based on consistency in the composition of angler catch. However, these sectors coincidentally correspond to temperature zones in Lake Ontario as described by El-Shaarawi and Kwiatkowski (1977). Anglers were interviewed after fishing was completed at six launch ramp locations: St. Catharines Game and Fish, Fisherman's Wharf, Port Credit, Bluffers Park, Port Darlington, and Wellington, each representing catch and harvest statistics for a sector. Boat trailers were counted to estimate effort at all ramps from the Niagara River to Wellington (Table 1), and these counts were used to scale up effort, catch, and harvest, accordingly. Interviews were conducted at each of the four ramps (above) on 4 weekdays and 4 weekend days each month to cover time periods from 0900 to 2100. Estimates for the total fishery were made using the ratio of effort, catch, and harvest between launch daily and marina based fisheries in 1995 (Hoyle et al. 1996).

TABLE 1. Average daily trailer count on weekend days in 2000 during 1000 - 1400 hours at launch ramps along western Lake Ontario (Ontario portion). Ramps (and values) where anglers were counted and interviewed are indicated with ***italics****.*

Sector	Ramp	Apr	May	Jun	Jul	Aug	Sep	Total
Niagara	Queenston Sand Docks	7.5	5.5	6.3	8.0	8.0	9.3	44.5
	Welland Canal	3.5	4.5	2.8	4.5	3.8	1.5	20.5
	St.Catharines Game and Fish	***10.5***	***12.8***	***11.8***	***13.5***	***6.0***	***5.5***	***60.0***
	Beacon Motor Inn	2.3	2.0	4.0	4.5	3.3	2.0	18.0
	Sector total	23.8	24.8	24.8	30.5	21.0	18.3	143.0
Hamilton	Grimsby Municipal Ramp	0.5	0.5	0.3	0.8	0.3	0.3	2.5
	Foran's Marine	4.3	6.0	1.3	5.5	1.0	1.3	19.3
	Lakecourt Marina	0.5	0.3	0.3	0.8	0.0	0.0	1.8
	HRCA 50 Pt. Ramp	7.0	4.0	11.3	17.0	6.5	4.0	49.8
	Fisherman's Wharf	***5.3***	***12.3***	***10.3***	***29.5***	***24.5***	***14.3***	***96.0***
	Bronte Beach	2.3	5.5	7.5	23.0	31.8	13.5	83.5
	Shipyard Park	0.3	3.0	2.8	8.3	6.3	2.3	22.8
	Busby Park	0.5	0.3	1.3	0.3	0.0	0.3	2.5
	Sector total	20.5	31.8	34.8	85.0	70.3	35.8	278.0
West Toronto	***Port Credit Ramp***	***1.0***	***4.5***	***9.8***	***31.8***	***27.8***	***21.0***	***95.8***
	Lakefront Promenade Park	1.0	6.5	8.4	24.0	28.8	9.5	78.2
	Marie-Curtis Park	0.0	0.5	0.6	4.3	3.8	0.3	9.4
	Humber Bay West	1.0	8.0	8.4	22.0	11.5	7.0	57.9
	Sector total	3.0	19.5	27.2	82.0	71.8	37.8	241.2
East Toronto	Ashbridges Bay	1.5	1.3	2.2	20.0	7.8	1.8	34.5
	Bluffers Park	***2.0***	***2.3***	***4.2***	***59.3***	***17.3***	***4.0***	***89.0***
	Frenchman's Bay West	1.3	1.5	0.6	4.3	3.5	1.3	12.4
	Frenchman's Bay East	0.0	0.5	1.3	4.0	0.8	1.3	7.8
	Duffin Creek	0.0	0.0	0.0	1.3	0.8	0.0	2.0
	Sector total	4.8	5.5	8.3	88.8	30.0	8.3	145.5
Whitby-Cobourg	Port Whitby Marina	0.0	1.0	1.5	3.3	2.8	3.3	11.8
	Whitby Ramp	0.8	0.5	0.0	11.3	3.3	3.3	19.0
	Port Oshawa Marina	0.0	0.3	0.3	8.8	3.5	1.3	14.0
	CLOCA P. Darlington Ramp	***0.0***	***1.3***	***0.8***	***16.5***	***11.0***	***3.3***	***32.8***
	Port Newcastle	0.0	0.0	0.3	3.0	1.3	0.5	5.0
	Port Hope Harbour	0.3	1.3	1.5	9.8	8.3	4.5	25.5
	Cobourg Yacht Club	0.5	0.8	1.5	2.0	2.3	1.0	8.0
	Sector total	1.5	5.0	5.8	54.5	32.3	17.0	116.0
Brighton-Wellington	Ontario Street Ramp	0.3	10.8	3.5	8.0	1.5	2.0	26.0
	Brighton Marina	0.0	0.0	0.0	0.3	0.0	0.0	0.3
	Gosport Gov't Ramp	0.0	6.5	0.0	0.8	0.0	0.3	7.5
	Camp Barcovan	0.0	1.3	0.0	0.0	0.8	0.8	2.8
	McSaddens Marina	0.0	0.8	0.8	1.3	1.0	1.0	4.8
	Wellers Bay Marina	0.0	4.3	0.0	2.0	0.3	1.3	7.8
	North Shore Park	0.7	0.0	0.0	2.0	0.3	0.3	3.2
	Wellington Harbour Ramps	***2.3***	***4.3***	***4.3***	***24.5***	***8.3***	***5.8***	***49.3***
	Sector total	5.3	36.0	29.5	82.8	41.0	11.3	205.8
Total		58.8	122.5	130.2	423.5	266.3	128.3	1129.5
Ramps with Angler Interviews		***21.0***	***37.3***	***41.0***	***175.0***	***94.8***	***53.8***	***422.8***
		(36%)	***(30%)***	***(31%)***	***(41%)***	***(36%)***	***(42%)***	***(37%)***

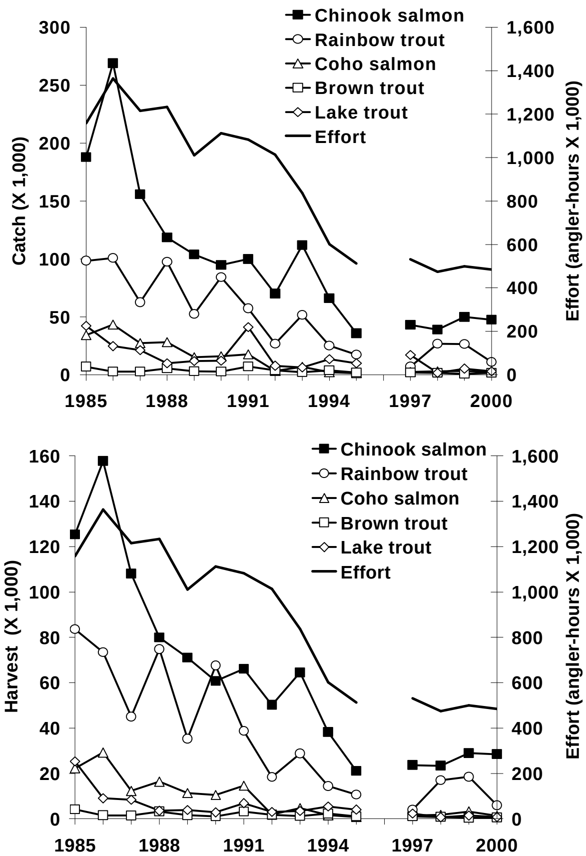

FIG. 2. Catch, harvest and effort in the boat fishery for salmon and trout in western Lake Ontario (Ontario portion), from 1985 to 1999. In 1996 the survey was incomplete.

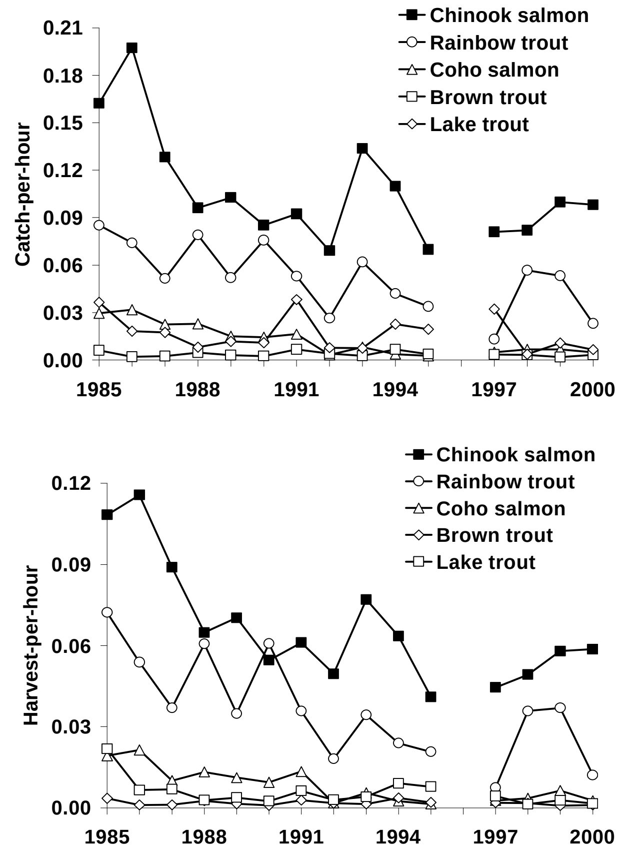

FIG. 3. Catch and harvest rates is the boat fishery for salmon and trout in western Lake Ontario (Ontario portion), from 1985 to 2000.

Fisheries Update

Effort

During 2000, the effort of launch daily anglers and all boat anglers was estimated at 300,549 and 484,727 angler-hours, respectively. Effort in the western Lake Ontario boat fishery has been relatively stable since 1994 (Fig. 2). The largest decline in effort was from 1993 to 1994, despite higher catch rates for chinook salmon than the previous five years (Fig. 3). This decline in effort was most likely a response of anglers to the termination of the Great Salmon Hunt and the announcement of stocking reductions (Savoie et al. 1995). Angler effort did not increase subsequent to reinstatement of the Great Salmon Hunt and stocking increases. More than half of this effort occurred in July and August (Table 1) during the Toronto Star Great Salmon Hunt.

A regulation change allowing two rods per angler in Lake Ontario came into effect during summer 1998. This resulted in effort in rod-hours exceeding angler-hours by 27% in 1999 and 29% in 2000.

Catch and Harvest

Chinook salmon and rainbow trout accounted for about 90% of the salmonid harvest in the western Lake Ontario boat fishery (Table 2). These were the only species that were consistently targeted in this fishery. The catch and harvest of chinook salmon in 2000 were similar to 1999 (Fig. 2). Catch and harvest rates of chinook salmon have been variable over the last 16 years with no recent trend apparent (Fig. 3). Chinook salmon catches vary seasonally around the lake (Fig. 4). These patterns are usually consistent from year to year. Catch peaks in all sectors during July or August (Fig. 4), as a result of the higher fishing effort

TABLE 2. Angling statistics for salmonid boat fisheries in western Lake Ontario (Ontario portion) during April to September 2000.

Species	Launch Daily Anglers					All Boat Anglers				
	Catch	Harvest	Catch rate (fish/ angler-hour)	Harvest rate (fish/ angler-hour)	Release Rate (%)	Catch	Harvest	Catch rate (fish/ angler-hour)	Harvest rate (fish/ angler-hour)	Release Rate (%)
Chinook salmon	30,766	16,772	0.1024	0.0558	45	47,536	28,430	0.0981	0.0587	40
Rainbow trout	5,356	2,322	0.0178	0.0077	57	11,171	5,884	0.0230	0.0121	47
Coho salmon	1,612	843	0.0054	0.0028	48	2,354	1,304	0.0049	0.0027	45
Brown trout	1,360	482	0.0045	0.0016	65	1,560	537	0.0032	0.0011	66
Lake trout	2,589	746	0.0086	0.0025	71	3,183	789	0.0066	0.0016	75
Atlantic salmon	20	12	0.0001	0.0000	40	50	30	0.0001	0.0001	40
Pink salmon	7	-	0.0000	0.0000	100	7	-	0.0000	0.0000	100
Unidentified salmonine	951	695	0.0032	0.0023	27	1,359	994	0.0028	0.0020	27
Total salmonines	42,661	21,871	0.1419	0.0728	49	67,221	37,967	0.1387	0.0783	44

(Table 1). In 2000, chinook salmon reappeared in the Niagara sector during spring in usual numbers (Fig. 4). These minor changes in the seasonal and spatial patterns of catch can usually be attributed to yearly variations in weather, particularly how wind speed and direction affect the currents and water temperature in Lake Ontario.

The catch and harvest of rainbow trout declined in 2000 (Fig. 2). Catch and harvest rates of rainbow trout (Fig. 3) were significantly lower than average for the previous 15 years. Rainbow trout catch rates tend to be lower in Ontario waters of Lake Ontario during years with cooler springs (Bowlby 2001). During 2000 the low rainbow trout catches in Ontario waters were consistent with a cool spring

Catch and harvest of coho salmon, brown trout and lake trout remained typically low, because anglers target chinook salmon and rainbow trout. Atlantic salmon catches and harvest remain low because few yearlings are stocked. The reported catch may also be low due to misidentification. The survey technicians have difficulty with Atlantic salmon identification, and tend to report them as unidentified. Anglers also have difficulty with identification of Atlantic salmon. A majority of tag returns in 1998, 1999, and 2000 from stocked adult Atlantic salmon were reported as chinook salmon, coho salmon, brown trout or rainbow trout (L. Carl, Ontario Ministry of Natural Resources, Science and Development and Transfer Branch, 300 Water St., Peterborough, Ontario, K9J 8M5, personal communication).

Management Implications

Catches and effort in the boat fishery for salmon and trout in western Lake Ontario have been stable since 1994. Strong 1998 and 1999 year classes of alewife likely contributed to continued stability in populations and growth of salmon and trout in Lake Ontario during 2000. Continued stability of the predator community, and of the fishery, depends on continued production of alewife and no large increases in abundance of trout and salmon.

Information and Research Needs

We are beginning to understand the seasonal distribution of salmon and trout, and the resulting fishery, particularly for rainbow trout (Chapter 1). Factors influencing the distribution of other salmon and trout remain poorly understood. The influence of variation in weather patterns, including the longer-term impacts of climate warming, on the salmon and trout fishery should be investigated. A comprehensive survey of stream and shoreline fisheries is needed.

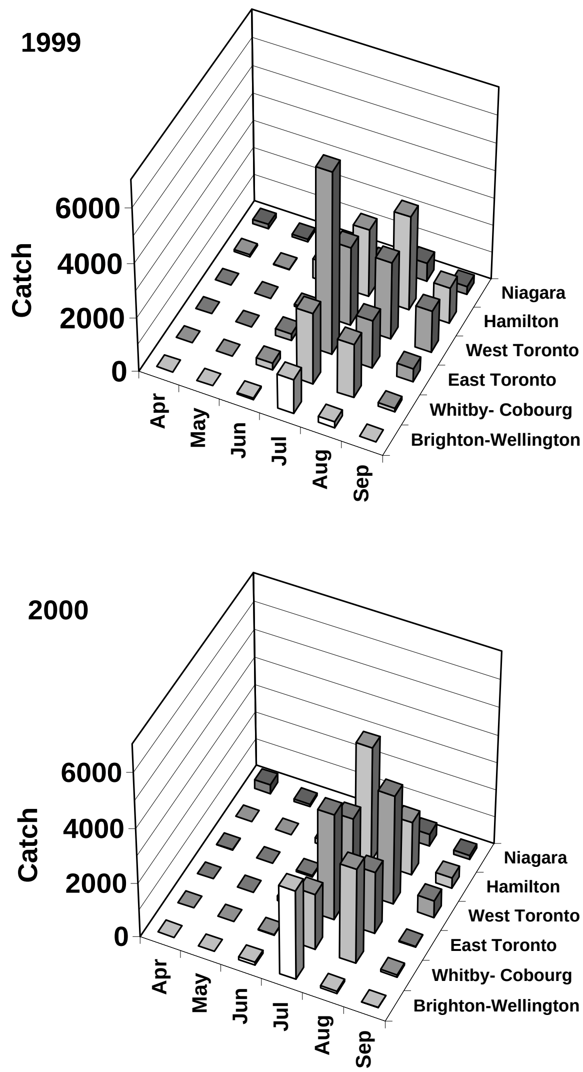

FIG. 4. The seasonal and spatial pattern of catch of chinook salmon by launch daily anglers in western Lake Ontario during 1999 and 2000.

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9

Bay of Quinte Aboriginal Spear Fishery

A. Mathers, D. Walsh
T. Kring[1], M. Maracle[1] and G. Maracle[1]

Introduction

The Mohawks of the Bay of Quinte harvest walleye during spring spawning runs on several Bay of Quinte rivers each year. Since 1994, the Mohawks of the Bay of Quinte and the Ontario Ministry of Natural Resources have conducted surveys of the Napanee and Moira River fisheries. By measuring changes in the harvest rates and biological characteristics of the fish harvested, these surveys provide information on the status of the fish populations that are useful to fisheries managers in their attempts to sustain the walleye population. This chapter updates estimates of fishing effort and walleye harvest by aboriginal spear fisheries in the Bay of Quinte during 2000.

Information Sources

Aboriginal fisheries in the Canadian waters of Lake Ontario include spear fisheries for walleye conducted during the spring in the Napanee, Salmon, and Moira Rivers (Fig. 1). A survey of the Napanee and Moira River spear fisheries was conducted during the spring walleye run between April 10 and May 5, 2000. Fishing effort was measured on randomly selected days, using hourly counts of spearing activity on the rivers between 7 p.m. and 12 p.m. (a total of 290 counts were conducted). Seventy interviews with fishers provided information on catch rates and biological information on the fish harvested.

Based on observations of MNR staff at both the Moira and Napanee Rivers, the spear fishery had started by March 27. Initial estimates were generated for the survey period (26 days – April 10 to May 5). These results were then used to estimate fishing activity that would have occurred between March 27 and May 5 (40 days) assuming that the activity and harvest rates for the unsurveyed period were the same as the surveyed period.

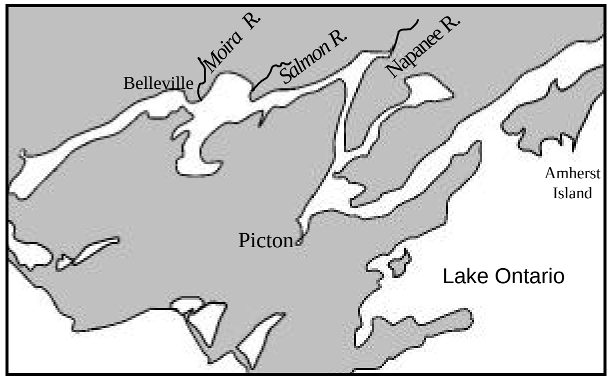

FIG. 1. Map of Bay of Quinte showing locations of Napanee, Salmon and Moira Rivers.

Table 1. Estimates of spearfishing effort and walleye harvest during the spring fisheries in the Napanee and Moira Rivers during 2000. Estimates were generated for the survey period (April 10 to May 5) and for the entire fishing period (March 27 to May 5). Estimates for the longer time period assume that the harvest and effort data collected during the survey are appropriate for the longer time period.

River	Season	Fishing Effort (hours)	Walleye Harvest (number of fish)
Napanee	Apr 10 to May 5	182	1,782
Napanee	Mar 27 to May 5	280	2,746
Moira	Apr 10 to May 5	398	3,588
Moira	Mar 27 to May 5	612	5,790

Fisheries Update

Fishing effort during the 2000 survey period (April 10 to May 5) was estimated to be 182 hours and 398 hours for the Napanee and Moira Rivers respectively (Table 1). The fishing effort for the period of March 27 to May 5 was estimated to be 280 hours and 612 hours for the Napanee and Moira Rivers respectively (Fig. 2). The combined fishing effort for the two

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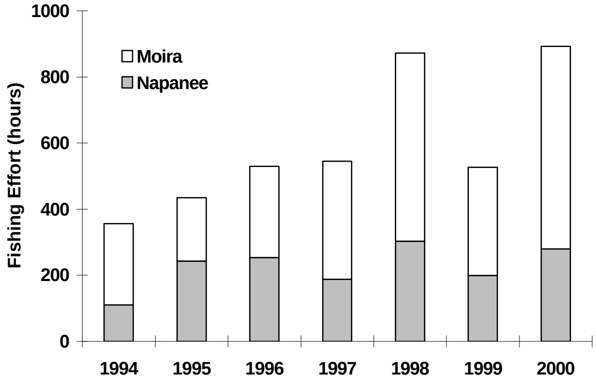

FIG. 2. Spear fishing effort in the Napanee and Moira Rivers for 1994 to 2000.

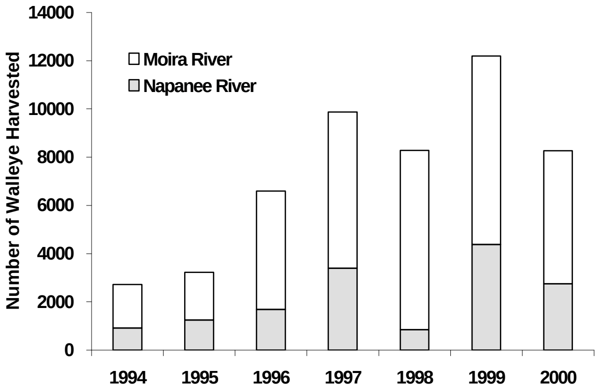

FIG. 3. Walleye harvest during spring spear fisheries in the Napanee and Moira Rivers for 1994 to 2000.

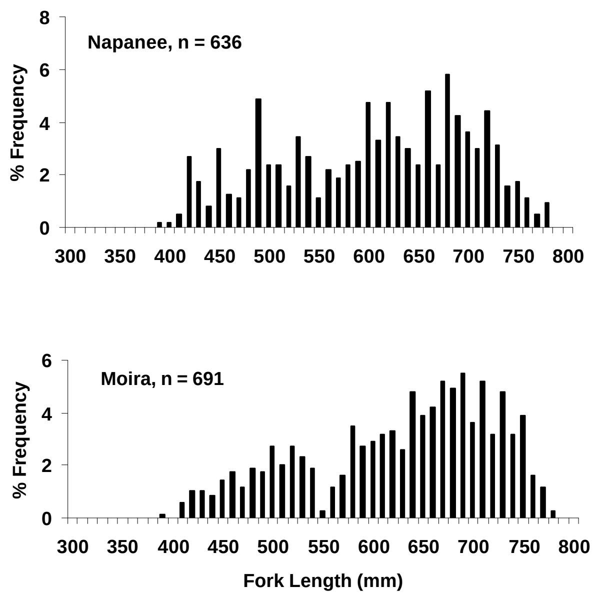

FIG. 4. Fork length of walleye harvested during spring spear fisheries in the Napanee and Moira Rivers during 2000.

rivers has increased since the survey was started in 1994, and the effort levels observed in 2000 were very similar to those observed in 1998. The walleye harvests for the period of March 27 to May 5 was estimated to be 2,742 walleye and 5,790 walleye for the Napanee and Moira Rivers respectively (Fig. 3). These harvest estimates are somewhat lower than observed during 1999, but were similar to those observed since 1997.

The fork length of the walleye harvested during 2000 ranged between 390 mm and 780 mm (Fig. 4). Fish in the Napanee River averaged 605 mm in length while those harvested in the Moira River averaged 627 mm. Previous year's surveys have all shown larger fish being captured in the Napanee River. Female fish from both rivers combined averaged 641 mm while males averaged 585 mm in length. The larger size of female fish has been observed in previous surveys.

Summary

The survey of the Mohawks of the Bay of Quinte spring spear fishery during 2000 provides an update on walleye harvest and fishing effort in the Moira and Napanee Rivers. The combined fishing effort and walleye harvest for the two rivers has increased since the survey was started in 1994. Effort in 2000 was slightly higher than observed in 1999 but very similar to the estimate for 1998. Walleye harvest in 2000, in both rivers combined, was lower than in 1999 but very similar to the estimate for 1998.

Management Implications

As the walleye population declines, it is important that harvest monitoring or reporting occurs for all fisheries. Ongoing monitoring of the spear fishery harvest is an important piece of information to manage walleye in a sustainable manner.

Information and Research Needs

Rapid changes in the Bay of Quinte ecosystem have reduced the potential sustainable yield of walleye. Monitoring of all walleye fisheries is required, along with projects such as the fall mark-recapture study to better estimate the future abundance of walleye.

10

Exploitation of Wild Rainbow Trout Populations in Wilmot Creek and the Ganaraska River

J.N. Bowlby and L.W. Stanfield

Introduction

Lake Ontario anglers value "wild" rainbow trout populations. These anglers supported "increasing the natural reproductive potential for rainbow trout" in the consultation process for the Fish Community Objectives for Lake Ontario (Stewart et al. 1999). Ontario's contribution of rainbow trout to Lake Ontario is probably more than two-thirds wild, and the remainder are hatchery fish. Accordingly, wild rainbow trout are prominent in Ontario's management of Lake Ontario. The spawning run of wild rainbow trout in the Ganaraska River has declined in recent years. The run during the spring of 2000 was the lowest since 1979 (Chapter 1). As this population provides our best index of wild rainbow trout populations in Lake Ontario we are concerned about the cause of this decline. High levels of harvest of rainbow trout were documented in the spring Ganaraska River angling fishery in 1999 (Bowlby and Daniels 2000). Anecdotal information has led us to suspect that high levels of wild rainbow trout harvest are not limited to the Ganaraska River, but may be more widespread.

To understand the patterns in shore based rainbow trout fisheries requires an understanding of rainbow trout life history patterns. Rainbow trout in Lake Ontario and its tributaries follow a diversity of life history patterns. Shore based (including stream) angling is influenced by these patterns, particularly with respect to spawning migrations. In Lake Ontario tributaries, juvenile rainbow trout typically spend one to three years in the stream before migrating to Lake Ontario, where they may spend another one to three years before returning to the same stream to spawn in spring. A majority of rainbow trout follow this pattern, and these fish are often called steelhead. A smaller number of rainbow trout remain resident in streams until maturity. Rainbow trout may migrate upstream at almost any time of the year. We commonly see rainbow trout in Ontario tributaries of Lake Ontario, from October to May. New York State currently stocks a summer-run steelhead strain (Skamania) which strays into Ontario streams primarily from August to October, and a winter-run steelhead strain (Chambers Creek) which runs primarily from November to April. Wild rainbow trout in Ontario have developed from the numerous strains stocked in Lake Ontario since 1873 and are genetically diverse. In Ontario most rainbow trout run upstream during March and April, with a smaller winter-run component in November and December. Moreover, since 1984, we have collected the spring running component of the Ganaraska River strain of rainbow trout for Ontario's only rainbow trout hatchery brood stock, which has further enforced the tendency for spring runs of rainbow trout in Ontario streams.

Lake Ontario has an angling season that is open all year for rainbow trout. On Lake Ontario tributaries west of Trenton, the normal open season for rainbow trout is the last Saturday in April to September 30. In the lower sections of some streams there is an extended fall season for rainbow trout from October 1 to December 31. This extended season allows angling for winter-run rainbow trout. In addition, some harbours and lower sections of some streams are open all year for rainbow trout, where both winter-run and spring-run rainbow trout are vulnerable.

Land based fisheries have played a prominent role in the harvest of Lake Ontario rainbow trout (Bowlby 1993). Although the boat fishery is well surveyed and we have some estimates for shore fisheries, to date we have only surveyed the fisheries on two Lake Ontario tributaries with wild populations of rainbow trout. Wild rainbow trout have colonized close to 30 Lake Ontario tributaries from Hamilton to Brighton. Stanfield et al. (1998) documented the fisheries for rainbow trout in Wilmot Creek, and Bowlby and Daniels (2000) documented the fishery for rainbow trout in the Ganaraska River. In this report we combine population estimates with these surveys to estimate exploitation rates for Ganaraska River and Wilmot Creek rainbow trout.

Information Sources

Rainbow trout harvest information (Table 1) from angler surveys in Lake Ontario (Bowlby and Stewart 2000, Eckert 2000, Hoyle et al. 1999), the Ganaraska River (Bowlby and Daniels 2000), Wilmot Creek (Stanfield et al. 1998), and Port Hope Harbour (Savoie and Bowlby 1992, Lake Ontario Management Unit unpublished data) were combined with population estimates of rainbow trout in Lake Ontario (see below) and the size of the spawning runs in the Ganaraska River (Schaner et al. 2000) and Wilmot Creek (Stanfield et al. 1998) to calculate exploitation rates on the spawning population of rainbow trout in these streams.

Direct population estimates in the Ganaraska River were made with an electronic counter (Fig. 1). In Wilmot Creek populations were estimated with Petersen mark-recapture methods. Adult rainbow trout were captured in Wilmot Creek by seining and angling, and then marked with opercular punches. They were subsequently recaptured in a weir near the mouth of the creek. In the Ganaraska River and Wilmot Creek some fish could not be included in the above estimates because they were harvested during the upstream migration in fall and spring. As well, some fish spawned below the weir or fishway. To avoid overestimating exploitation we accounted for these fish and increased the population sizes (Table 2), accordingly (e.g. Stanfield et al. 1998).

The population of rainbow trout in Lake Ontario was estimated by two methods and then averaged. In the first method we estimated the total number of yearling equivalent rainbow trout in Lake Ontario by adding the average number of rainbow trout yearling equivalents that were stocked from 1993 to 1997 to an estimate of the number of wild rainbow trout yearling

TABLE 1. Harvest statistics and exploitation rates for rainbow trout from selected Wilmot Creek, Ganaraska River, and Lake Ontario angling fisheries. Boat fishery harvest includes both wild and hatchery origin rainbow trout.

Location	Period	Year	Catch	Harvest	Effort (Angler-hr)	Angler survey reference	Exploitation
Wilmot Creek	Feb 17 - Apr 24	1992	2,646	1,219	18,659	Stanfield et al. (1998)	8.6%
Wilmot Creek	Apr 25 (opening) - May 31	1992	3,621	1,307	19,821	Stanfield et al. (1998)	9.2%
Wilmot Creek	March 4 - Apr 29	1994	5,185	2,252	19,678	Stanfield et al. (1998)	15.4%
Wilmot Creek	Apr 30 (opening) - May 31	1994	4,530	1,276	14,628	Stanfield et al. (1998)	8.7%
Wilmot Creek	Oct 20 - Dec 4	1994	1,314	468	6,520	Stanfield et al. (1998)	2.7%
Ganaraska - Port Hope Harbour	March 7 - Apr 30	1992	5,177	1,433	31,766	LOMU (unpublished data)	8.9%
Ganaraska River	Apr 24 (opening) - May 31	1999	10,693	1,707	24,400	Bowlby and Daniels (2000)	18.7%
Ganaraska - Port Hope Harbour	Sept 7 - Nov 17	1991	3,367	2,140	41,544	Savoie and Bowlby (1992)	13.3%
Western Lake Ontario Boats - Ont.	Apr 1 - Sept 30	1998	26,815	16,976	473,843	Hoyle et al. (1999)	3.3%
Lake Ontario Boats - NY	Apr 1 - Sept 30	1998	38,106	28,286	1,117,353	Eckert (2000)	5.4%
Western Lake Ontario Boats - Ont.	Apr 1 - Sept 30	1999	26,539	18,463	499,159	Bowlby and Stewart (2000)	3.5%
Lake Ontario Boats - NY	Apr 1 - Sept 30	1999	29,277	20,351	1,028,516	Eckert (2000)	3.9%

TABLE 2. A comparison of weir and fishway population estimates of rainbow trout with estimates expanded for those removed by harvest during the previous fall and earlier in the spring and also for fish that spawn farther downstream. See Information sources for explanation of Method 1 and 2 population estimates for Lake Ontario.

Location	Year	Weir/fishway estimate	Expanded estimate
Wilmot Creek	1992	10,660	14,189
Wilmot Creek	1994	11,018	14,665
Wilmot Creek	1995	12,993	17,294
Port Hope Harbour	1992	11,332	16,038
Ganaraska River	1999	6,442	9,117
Lake Ontario - method 1	1998	-	456,854
Lake Ontario - method 2	1998	-	586,626

equivalents. The number of wild yearling equivalents was based on the proportion of stocked and wild rainbow trout in samples from the boat Ontario boat fishery using the scale method of Marcogliese and Casselman (1998). From 1989 to 1995 the average proportion of wild rainbow trout in Lake Ontario was 29% (Fig. 2). An annual mortality of 50% was applied to the yearling estimate to obtain a population for rainbow trout from ages 2 to 5. The choice of 50% annual mortality was based on the repeat spawner rates from rainbow trout in Wilmot Creek, the Ganaraska River (Fig. 3), and from a fishway on Bowmanville Creek (50%, Lake Ontario Management Unit unpublished data). Clarkson and Jones (1997) have shown that the repeat spawner rate is equal to the annual survival. The second method was based on estimates of wild rainbow trout runs in Lake Ontario tributaries (Savoie and Bowlby 1991). We assumed that the New York contribution of wild adults was another 20%. Stocked adult rainbow trout were estimated according to the average proportion of stocked and wild rainbow trout in Lake Ontario (as above). Using an annual mortality of 50% an age distribution for ages 3 to 5 was applied to this estimate. Finally, the population of 2 yr-olds was estimated using the same 50% annual mortality rate.

Exploitation Rates

Across all fisheries total exploitation of the Ganaraska River and Wilmot Creek populations of rainbow trout was 48-50% (mean fishing mortality,

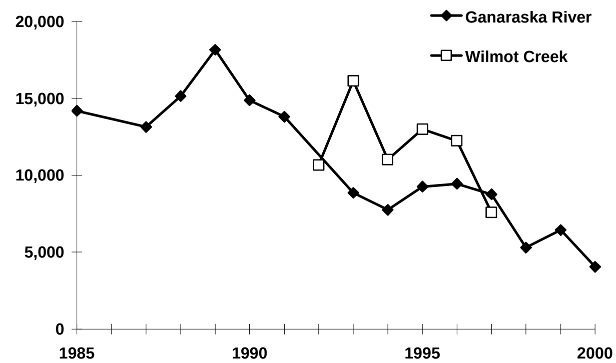

FIG. 1. The estimated run of rainbow trout past the Ganaraska River fishway and Wilmot Creek weir during spring.

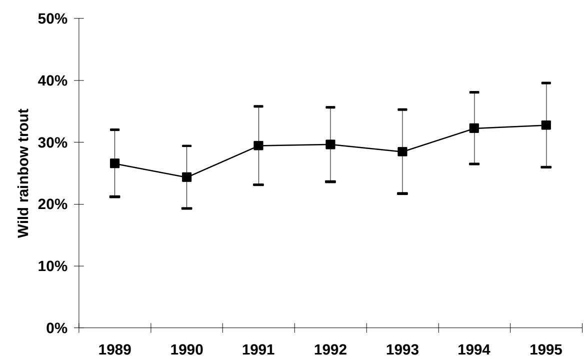

FIG. 2. The percentage of wild rainbow observed in surveys of boat anglers on Lake Ontario. Error bars represent 95% confidence intervals.

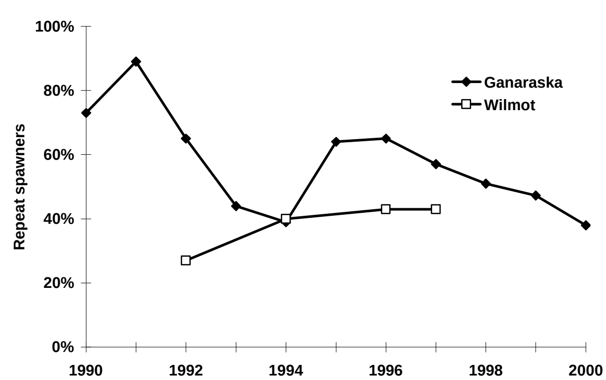

FIG. 3. The percentage of reapeat spawners of female rainbow trout during spring at the Ganaraska River and Wilmot Creek.

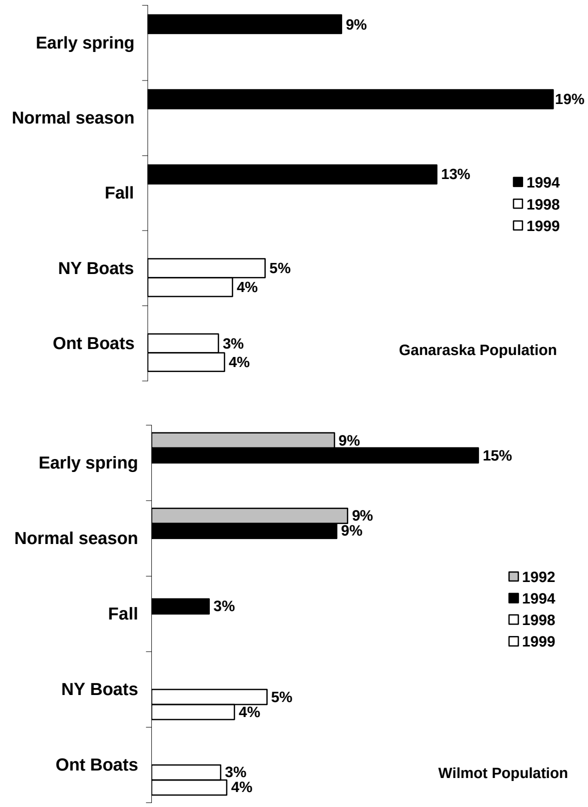

FIG. 4. Exploitation rates for rainbow trout populations from the Ganaraska River and Wilmot Creek. The boat fisheries are on Lake Ontario. Normal season fisheries are for the length of the stream. Early spring and Fall fisheries are in the lower portion of the stream or stream mouth according to extended season regulations.

F=0.68) and 28-35% (mean F=0.39), respectively (Fig. 4). Although the boat fisheries were much larger and harvested more fish in total than shore based fisheries (Table 1), with less than 10% exploitation, the boat fisheries had less impact on Wilmot Creek and Ganaraska River rainbow trout than the shore based fisheries. Most of the harvest in the boat fisheries was stocked rainbow trout (Fig. 1).

The combined spring and fall extended seasons were responsible for higher exploitation on both rainbow trout populations than the normal open season (Fig. 4). However, in the extended season exploitation was higher during early spring for Wilmot Creek, and higher for fall on the Ganaraska River. The highest exploitation was during early spring in Wilmot Creek, but during the normal season in the Ganaraska River. Rainbow trout run earlier in Wilmot Creek, than the Ganaraska River. Wilmot Creek is smaller and warms up faster. Moreover, the fishway on the Ganaraska River delays the run until water temperatures are greater than 5^{o}C and warm enough for rainbow trout to leap into the fishway entrance. Usually, the Ganaraska River still holds a greater proportion of its run than most other Lake Ontario tributaries when the normal trout season opens. Similarly when fall runs enter the Ganaraska River in November, fish are unable to pass through the fishway after water temperatures are less than 5^{o}C.

Cool springs likely result in delayed spawning and higher exploitation rates for rainbow trout after the normal season opens. Higher exploitation rates result in lower survival. Thus, in years following cool springs, lower repeat spawner rates in rainbow trout should result. In the Ganaraska River the coolest two week periods before normal season opening were in 1992, and 1993, which resulted in a low repeat spawner rates the following two years (Fig. 3). Recovery started in 1995 following the warm 1994 spring, and another three cool springs in a row likely stemmed the recovery in rainbow trout, and then contributed to declining repeat spawner rates in the following years (Fig. 3). High recruitment may depress repeat spawner rates, and without population estimates from previous years we cannot exclude higher than normal recruitment as an alternate explanation for the low repeat spawner rates in rainbow trout in Wilmot Creek in 1992.

The exploitation rates for rainbow trout in Wilmot Creek and the Ganaraska River are consistent with the repeat spawner values. Natural mortality was likely about 20-25% for Ganaraska River rainbow trout based on repeat spawner rates in the 1970s when harvest was low (Chapter 1). The repeat spawner rate for sexes combined in 2000 in the Ganaraska River estimated 72% annual mortality (Chapter 1). Thus, the repeat spawner estimate provides independent confirmation of the 50% exploitation for the Ganaraska rainbow trout in 2000. However, the repeat spawner rates were higher in previous years suggesting also that exploitation was lower. In 1999 the spring was cool and so the exploitation rate we measured for Ganaraska River rainbow trout in the normal season is likely lower during warmer springs. The 1994 exploitation rates from Wilmot Creek also are consistent with annual mortality of about 60% as suggested by the repeat spawner rate in the same and subsequent years.

These observed exploitation rates for rainbow trout are high, particularly in the Ganaraska River. The levels observed in Wilmot Creek may be more typical for rainbow trout in most Lake Ontario tributaries along the north shore. What the "best" exploitation rate may be depends on the amount of recruitment or natural production. In the case of wild populations the best exploitation rate depends on the size of the adult population, as well as several considerations of angling quality, such as size of fish in the catch and catch rate. Currently, we have no idea how large the adult rainbow trout population must be to maintain wild populations. However in surveys of juvenile rainbow trout in Lake Ontario tributaries we saw signs in the 2000 year class of the first recruitment failure for the 10 yr period of the data (Chapter 1). If the high levels of exploitation on rainbow trout in 1999 in the Ganaraska River were more widespread, we cannot exclude the possibility that over fishing contributed to the recruitment failure.

Many rainbow trout anglers consider the size of fish and the number of fish caught and released as important as the number of fish harvested. Higher exploitation rates result in fewer older fish in the population and a smaller average size fish caught.

Management Implications

Certainly, cool springs result in higher exploitation rates on rainbow trout during the normal season. As well, the last Saturday in April (normal season opening) may vary from April 24 to April 30. An early opening day may be similar to a cool spring with regard to exploitation rates for rainbow trout. How to manage around varying spawning dates and varying season opening dates will remain a challenge.

Fall-run and winter-run rainbow trout experience higher exploitation than spring-run rainbow trout because they are exposed to angling pressure for a longer period of time, and moreover, to greater angling effort (Table 1). If angling effort is an indicator of preference, then anglers on Wilmot Creek and the Ganaraska River clearly prefer the earlier running rainbow trout. To date the tradeoffs in protecting the earlier runs and still allowing angling opportunities for them have been to restrict the areas of extended open seasons.

The Ontario portion of the boat fishery was responsible for less than 4% of the exploitation on rainbow trout (Table 1). With such a small impact on rainbow trout populations in Lake Ontario, it is unreasonable to expect restrictions in this fishery, as it currently operates, to have a major impact on wild populations. However, during warm springs, wild rainbow trout may be extremely vulnerable to this fishery (Chapter 1), and shifts in fishing pressure could potentially impact wild rainbow trout populations severely.

Wild populations of rainbow trout in Lake Ontario are expected to decline further due to the poor 2000 year-class. It is not clear whether the low recruitment in 2000 is related to the reduced spawning population. If so, recruitment may continue to be impaired until exploitation is reduced. However, we still cannot exclude low stream flows during spring 2000 as an alternative cause for the poor year class of rainbow trout (Chapter 1).

Assessment and Research Needs

We are in the process of parameterizing a management model of the Wilmot Creek and Ganaraska River rainbow trout populations and their fisheries to assess the impact of various management options. To test the generality of the model to other Lake Ontario rainbow trout populations will require additional information about some of these populations. Some of the assumptions implied by the above analyses need to be better tested. In particular, our assumptions related to combining exploitation rates from different years need to be verified.

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11

Genetic Structure of Spawning Walleye (*Stizostedion vitreum*) Populations in and near the Bay of Quinte, Lake Ontario

C. Wilson and M. Gatt

Introduction

The walleye fishery in the Bay of Quinte has been of significant cultural and economic importance for over a century (Schneider and Leach 1979). Past declines of walleye in Lake Ontario have highlighted the sensitivity of these stocks, and underscore the management information needs in order to balance sustainable use among commercial, recreational, and aboriginal fisheries. Recent reduced catches in commercial and recreational fisheries, and long-term stock assessments , indicate that walleye populations are again in decline (Chapter 3 and Chapter 12). In addition, aboriginal harvests during spawning runs have raised concerns that genetically distinct stocks may be unintentionally being depleted.

To address genetic concerns over the sustainable use and potential stock structure of walleye populations spawning in and near Bay of Quinte, we used high-resolution DNA techniques to assess the potential stock structure of walleye captured during spawning. Mitochondrial DNA (mtDNA) and microsatellite-DNA markers were used to determine if the sampled populations represented discrete reproductive units (genetically recognizable stocks), and quantify overall levels of genetic variation. These complementary genetic marker systems provide high-resolution data on genetic stock structure, gene flow among stocks, and overall genetic diversity of populations. The purpose of this study was to specifically address several management issues relating to the Bay of Quinte populations:

- What stock structure exists within the Bay of Quinte?
- Do the different fisheries target distinct stocks?
- Do spawning populations represent discrete genetic stocks (i.e., separate management units that are recognizably distinct with genetic markers)? If so, what stock structure exists, and how much gene flow or interbreeding among populations occurs?
- Are river versus shoal spawning groups distinct?
- How strong is natal homing or breeding philopatry in walleye? Does it differ between male and female fish?
- What is the genetic "health" of the populations, i.e., how much variation is present? How does this compare to other (allopatric) walleye populations?

To address these questions, male and female walleye were collected from a variety of spawning areas in and near the Bay of Quinte (Fig. 1). Although the small spatial scale limited the resolution of the genetic data, the results show that from a genetic perspective, walleye in the Bay of Quinte have recovered well from the population declines during the 1960s.

Methods

Sample collections

Tissue samples were obtained from nine spawning walleye populations in and near the Bay of Quinte in 1999 through the cooperation of aboriginal spear fisheries, commercial fishing operations, and the OMNR Fish Culture Section (Table 1). Finclip samples were taken from sexed adult fish, and separately preserved by sex from each site. Finclip samples were preserved in 80% ethanol and sent to the OMNR Fisheries Genetics lab in Peterborough for analysis. Sample collections and sites are summarized in Table 1 and Fig. 1. Once brought into the lab, samples were sorted and coded by individual, sex and

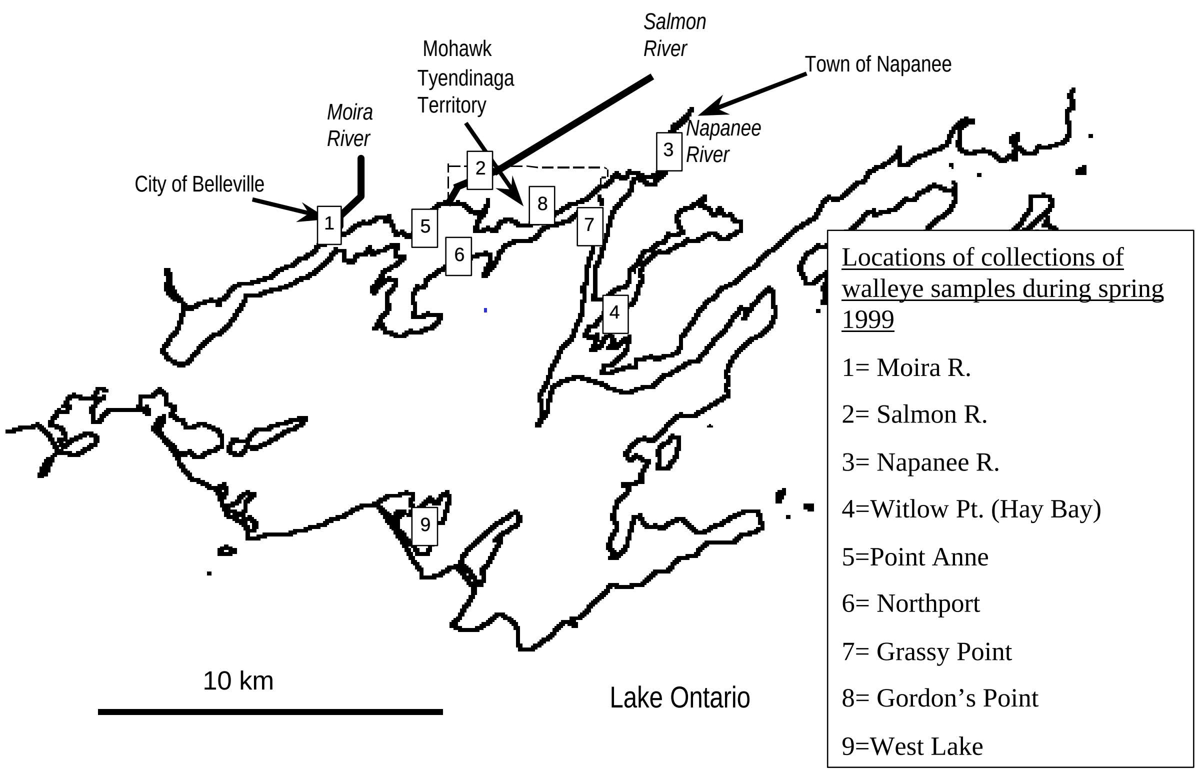

FIG. 1. Sampling area (Bay of Quinte region), showing sampling locations and geographic scale.

site to facilitate intersex comparisons for philopatry as well as variation among spawning populations.

DNA extraction

Total DNA was extracted from 40 to 60 milligrams preserved finclip tissue per fish, using a standard organic extraction protocol (Bardakci and Skibinski 1994). Minced tissue was broken down in a lysis buffer of 500 L STE with the addition of 30 L SDS (10% w/v) and 30 L of proteinase K (2 mg/mL). Proteins were removed using sequential extraction with phenol and chloroform. DNA was precipitated using 1 mL 95% ethanol, rinsed with 500 L 70% ethanol, and resuspended in 200 L of TE. Resuspended DNA was quantified using a GeneQuant II spectrophotometer (Pharmacia-Amersham). Standardized working solutions were made to a concentration of 30 ng/L, and the original DNA extractions (stock solutions) were archived for potential future studies.

Mitochondrial DNA analysis

Variation of mitochondrial DNA (mtDNA) among the Bay of Quinte walleye populations was examined using a nucleotide segment approximately 715 bases long of the control region or D-loop. This region is well documented as being highly variable, and has proven informative in other studies of walleye and percid stock structure (Stepien and Faber 1998, Gatt et al. 1998, 2000). The phylogenetic resolution obtained from sequence data of this region is comparable to PCR-RFLP analyses, and is more time- and cost-effective than restriction enzyme digestion of larger mtDNA fragments (Gatt et al. 2000).

A portion of the mitochondrial control region in size was amplified from walleye mtDNA via the polymerase chain reaction (PCR), using primers LN20 (Bernatchez et al. 1992) and HW1 (Gatt et al. in press). Each 25-L PCR contained sterile deionized water, 1X manufacturer buffer, 1.8 mM MgCl2, 0.400 M of each primer, 0.300 mM dNTP's, 1.5 units *Taq* polymerase, and 30 ng genomic DNA. Thermal cycling conditions were comprised of an initial denaturation step at 94C for 1 minute, followed by 30

Table 1. Summary of walleye collection sites in and near the Bay of Quinte, listing locations and collection samples sizes by sex and total.

Site	Location	River / Shoal	# Males	# Females	Total # (N)
1	Moira River	river	72	63	135
2	Salmon River	river	77	79	156
3	Napanee River	river	50	51	101
4	Hay Bay	shoal	36	15	51
5	Point Anne	shoal	12	10	22
6	North Port	shoal	2	4	6
7	Grassy Point	shoal	48	5	53
8	Gordon's Point	shoal	12	19	31
9	West Lake	shoal	72	38	110

cycles of 92C for 1 minute, 1 minute at 52C, and 1 minute at 72C, with a final extension time of 2 minutes at 72C. Amplified products were purified using the Qiagen QiaQuick PCR Purification Kit and verified via horizontal gel electrophoresis prior to being sequenced. Cycle sequencing of the amplified DNA was carried out using the HW1 primer with the Big Dye dye-terminator cycle sequencing Ready Reaction kit (Applied BioSystems Inc.), using conditions recommended by the manufacturer. The thermal program for cycle sequencing was 2 minutes at 96C, followed by 25 cycles of 30 seconds at 96C, 15 seconds at 50C, and 4 minute at 60C. The resulting DNA sequences were electrophoresed in an ABI Prism 377 DNA Sequencer using 5% Long Ranger polyacrylamide gels. By using HW1 in the sequencing reaction we were able to resolve 513 bp near the 5' end in each of the walleye processed. Each electropherogram displayed heavy strand sequence that was then translated into the light strand sequence in SeqPup (Gilbert 1998) for analysis. Unique sequences were given letter designations.

Microsatellite DNA analysis

DNA from microsatellite loci was amplified in multiplex PCR reactions using primers from five variable loci (*Svi* 2, 4, 6, 7, and 14) that were developed for walleye (Borer et al. 1998). One primer from each primer pair was labeled with a fluorescent dye to enable visualization of multiple loci within single visualization runs on the ABI sequencer. Each 10-L PCR contained sterile deionized water, 1X manufacturer buffer, 1.5 mM MgCl2, 0.060 M *Svi* 2, 0.050 M *Svi* 4, 0.200 M *Svi* 6, 0.170 M *Svi* 7, 0.300 M *Svi* 14, 0.200 mM dNTP's, 0.75 units *Taq* polymerase, and 30 ng genomic DNA. The thermal program was 2 minutes denaturation at 94C, followed by 30 cycles of 30 seconds at 94C, 1 minute at 60C, 2 minutes at 72C. A final extension time of 40 minutes at 72C was necessary to ensure clean PCR product. The amplified products were diluted to a volume of 80 L with sterile deionized water; 0.8 L of the diluted PCR product was then combined with 0.8 L of an internal lane standard composed of formamide, loading buffer, and the Rox 500 size standard (Applied Biosystems Inc.). Microsatellite products were denatured at 96C for 2 minutes and then loaded (0.3-L) into a 5% Long Ranger gel and electrophoresed with an ABIPrism 377 DNA Sequencer. Alleles were scored manually in GeneScan3.1 (Applied Biosystems Inc.).

Statistical analysis

MtDNA-Differences in mitochondrial haplotype composition (presence / absence and frequency differences) among populations and between males and females collected from each population were assessed with a pairwise contingency *X* 2 test in CSRXCPRW (Danzmann and Ihssen 1995). When pairwise comparisons yielded more than 20% of the cells as having a count less than five individuals, a *X* 2 Monte-Carlo bootstrapping algorithm with 1000 randomizations was implemented in CHI2MCS (Danzmann and Ihssen 1995). As no significant differences in haplotype composition between males and females from the same site were detected ($p > 0.05$), within-site mtDNA data were subsequently pooled for among-population comparisons. Geographic structure among populations was assessed using pairwise genetic distances, *F*ST estimates, and analysis of molecular variance (AMOVA), using the Arlequin ver 2.0 software package (Schneider et al. 1998).

Microsatellite DNA- Potential geographic genetic structure among microsatellite DNA loci was also assessed using AMOVA in Arlequin ver 2.0, including all populations with sample sizes greater than 20. Pairwise genetic distances, gene flow (Nm) and *F*ST estimates, and genic differentiation among populations were calculated using the GenePop program (Raymond and Rousset 1995). The resulting pairwise interpopulation genetic distances were used to produce a neighbour-joining tree (Saitou and Nei 1987) in MEGA v1.02 (Kumar et al. 1993).

In addition to using population data for assessing stock structure, individual assignment tests were run to match multilocus genotypes of individual walleye to the different sampling sites, based on within-population allele frequencies at the five microsatellite loci examined. Simulations and resampling statistics were calculated using the GeneClass program (Cornuet et al. 1999).

Results

A total of 13 mitochondrial DNA haplotypes were observed among Bay of Quinte walleye (Table 2). Of these, six haplotypes had not been previously observed in other studies of Great Lakes walleye (Gatt 1998, Gatt et al. 2000). Mitochondrial diversity varied considerably among sites, with the Napanee River run being the most diverse and West Lake holding the least diversity (Fig. 2, Table 2). No significant differences in mtDNA composition were apparent between males and females within sites. Data from both sexes within each site were therefore pooled for subsequent analyses.

An analysis of molecular variance (AMOVA) for geographic partitioning of mtDNA diversity detected limited structuring among the three river populations and West Lake (Table 3). Although the amount of variation among populations was less than 10%, resampling statistics confirmed that this contribution was significant. *F*ST and gene flow estimates indicated that this spatial structural component was due to differences between the West Lake population from those within the Bay of Quinte (Table 4).

All populations were highly variable at the five microsatellite DNA loci examined, with allelic diversity ranging from 7 alleles (*Svi*4) to 26 alleles (*Svi*14) across all populations (data available from authors on request). No significant deviations from Hardy-Weinberg equilibrium expectations were observed within site collections or the pooled dataset. Tests for linkage disequilibrium did not show any evidence of linkage among loci, validating their use as independent measures for diversity and stock structure.

Analysis of molecular variance for the microsatellite DNA data supported the mtDNA findings, and showed that nuclear genetic diversity within the sampled populations accounted for virtually all (>99%) of the variation observed (Table 5). This was confirmed via pairwise *F*ST estimates, which showed no significant structuring between populations, other than differentiation between walleye from West Lake versus those from all other sites (Table 6). Comparison among sampling sites within the Bay of Quinte itself resulted in low *F*ST values and high gene flow estimates. Hay Bay appeared to be somewhat intermediate between West Lake and the inner Bay sampling sites, with a higher Nm and lower *F*ST estimate (Table 6). The Napanee River collection in turn produced values between those for Hay Bay and the inner Bay populations. These values likely reflect the geographic positioning of the sampling locations, with Hay Bay at the mouth of the Bay and the Napanee River spawning area being the next major site within the Bay (Fig. 1).

Clustering of populations based on genetic distances calculated from the microsatellite DNA data confirmed the divergence of the West Lake population and the intermediate position of fish collected from Hay Bay (Fig. 3). Although no structure could be observed within the Bay itself, there is overall good correspondence between geographic and genetic distances among populations, suggesting that some degree of structuring and philopatry may occur within the Bay. Whether this is actually the case or coincidental cannot currently be resolved.

The overall lack of stock structure was reinforced by the poor predictability of assigning individuals to populations (Table 7). Of the 415 walleye included in the individual assignment analysis, only 94 (22.7%) were assigned to the sites they were collected from. In almost all cases, the number of fish assigned to their harvest location as their genetic population of origin were greatly outnumbered by fish that were assigned to other harvest locations. The only exception to this was

TABLE 2. Mitochondrial DNA control region sequence haplotypes by site, listed by sex and total, using haplotype designations from Gatt et al. (2000). Haplotypes u-z are unique genotypes that have not been previously documented (Wilson and Gatt unpubl. data).

	Moira River			Salmon River			Napanee River			West Lake		
Haplotype	F	M	Total	F	M	Total	F	M	Total	F	M	Total
a	9	10	19	9	12	21	9	14	23	22	20	42
c	2	3	5		1	1		1	1			
d	2	3	5	1	2	3	1	2	3	1	1	2
f	2	1	3	2		2	1		1			
h					1	1						
j	4		4	2	1	3	4	2	6			
k											2	2
u	1		1				1		1			
v								1	1			
w		1	1		2	2	1		1			
x					1	1	1	1	2			
y							1		1			
z				1		1						
Sample Size (N)	20	18	38	15	20	35	19	21	40	23	23	46
# Haplotypes (Nh)	6	5	7	5	7	9	8	6	10	2	3	3

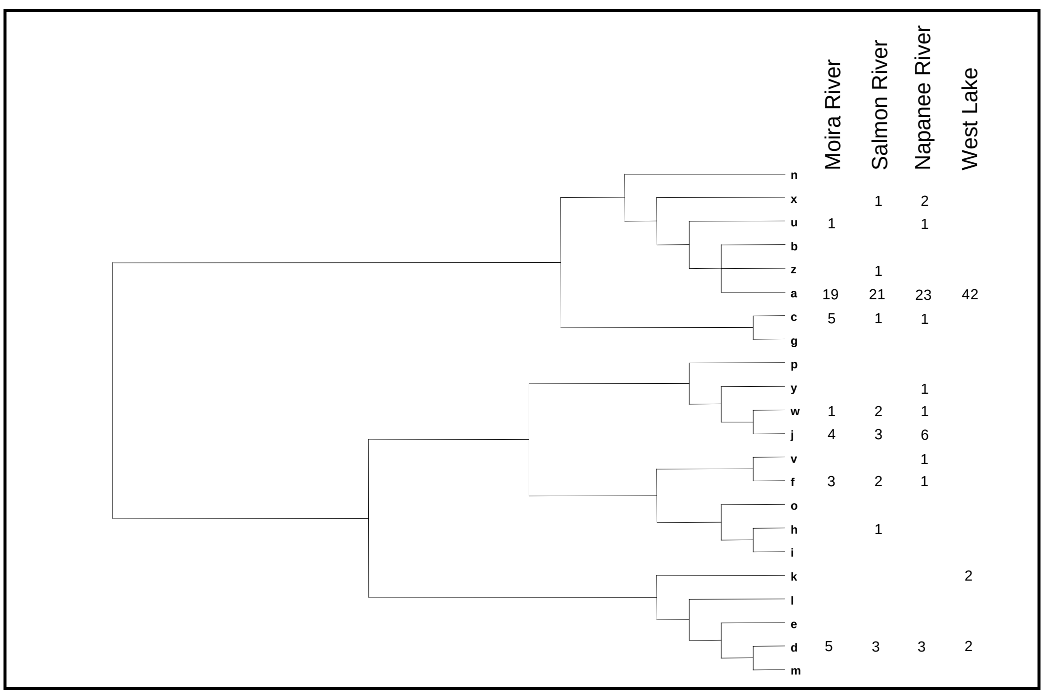

FIG. 2. UPGMA dendrogram showing phylogenetic relationships among known Great Lakes mitochondrial (mtDNA) haplotypes, and their occurrences among Bay of Quinte sample collections from West Lake and the three major rivers. Additional haplotypes are from Gatt (1998) and Gatt et al. (2000).

TABLE 3. AMOVA results for mtDNA-based stock structure for major collections (West Lake, Napanee River, Salmon River, and Moira River), with male and female walleye pooled within each site.

Source of Variation	d.f.	Sum of Squares	Variance Components	Percentage of Variation	Significance (p)
Among Populations	3	10.814	0.06999 *Va*	7.76	0.0029
Within Populations	155		0.83208 *Vb*	92.26	
Total	158		0.90207		
Fixation Index	F_{ST}:	0.07759			

TABLE 4. Pairwise differentiation estimates among populations based on mtDNA haplotype data, showing pairwise estimates of gene flow (Nm) estimates (above diagonal) and Fst (below diagonal) for West Lake and the three major rivers within the Bay of Quinte. Asterisks (*) indicate Fst values that are significantly different from zero (p<0.05).

	Moira	Salmon	Napanee	West Lake
Moira		inf	inf	1.72282
Salmon	-0.01387		inf	2.75024
Napanee	-0.01309	-0.02448		2.53554
West Lake	0.22494*	0.15383*	0.16472*	

TABLE 5. AMOVA results for microsatellite DNA-based stock structure among all sampled sites, with male and female walleye pooled within each site.

Source of Variation	d.f.	Sum of Squares	Variance Components	Percentage of Variation	Significance (p)
Among Populations	7	23.997	0.01396 *Va*	0.70	0.000
Within Populations	836	1656.021	1.98089 *Vb*	99.30	
Total	843	1680.018	1.99485		
Fixation Index	F_{ST}:	0.00700			

West Lake, where 41 of the 72 walleye analysed were identified as originating from the site. Even so, only 20 of these 41 fish could be assigned to the West Lake population with more than 90% certainty, reinforcing the low level of genetic differentiation among fish from the Bay of Quinte sampling sites.

Discussion and Conclusions

The levels of genetic diversity observed within this dataset are comparable to those from other Great Lakes walleye populations (Stepien and Faber 1998, Gatt 1998, Gatt et al. 2000, Wilson and Gatt unpubl. data). Although Billington and Hebert (1988) observed higher levels of mitochondrial DNA diversity in western Lake Erie, this difference likely reflects historical (phylogeographic) causes rather than exploitation outcomes (Billington et al. 1992). Although reduced levels of mtDNA diversity related to exploitation pressure have been reported elsewhere (Gatt et al. 2001), this was not apparent in this study.

The reduced mtDNA diversity present within West Lake as compared to sites within the Bay of Quinte may reflect initial colonization of West Lake by a small founding population. These initial founders would have a numerical advantage over other immigrants within a short time span (e.g. 2-5 generations). Alternate factors that could account for the differences between West Lake and the other sites could be limited spawning habitat or selective differences within West Lake, although no data is available to support the latter possibility.

Comparison of the microsatellite data with other studies is difficult, since no studies of walleye microsatellite data have been published to date.

*TABLE 6. Pairwise differentiation estimates among populations based on microsatellite DNA data, showing (a) pairwise estimates of gene flow (2Nm) estimates (above diagonal) and F_{ST} (below diagonal) among sample sites in and near the Bay of Quinte; (b) graphic representation of significant differentiation (p<0.05) among populations based on F_{ST} values. inf = unmeasurably high levels of gene flow; * = p < 0.05; *** = p < 0.001; --- = no significant difference between populations.*

(a)	Moira	Salmon	Napanee	Hay Bay	Pt. Anne	Grassy Pt.	Gordon's Pt.	West Lake
Moira		500.88	inf	inf	166.77	235.34	285.71	23.40
Salmon	0.0010		241.46	inf	inf	110.32	211.93	23.22
Napanee	-0.0006	0.0021		inf	369.73	inf	281.74	28.31
Hay Bay	-0.0022	-0.0006	-0.0043		inf	inf	inf	34.91
Pt. Anne	0.0030	0.0017	0.0014	0.0016		83.71	50.70	18.42
Grassy Pt.	0.0021	-0.0045	-0.0032	-0.0031	0.0060		351.97	23.64
Gordon's Pt.	0.0018	-0.0024	0.0018	-0.0014	0.0098	0.0014		20.98
West Lake	0.0209	0.0219	0.0173	0.0141	0.0264	0.0207	0.0232	

(b)	Moira	Salmon	Napanee	Hay Bay	Pt. Anne	Grassy Pt.	Gordon's Pt.	West Lake
Moira								
Salmon	---							
Napanee	---	---						
Hay Bay	---	---	---					
Pt. Anne	---	---	---	---				
Grassy Pt.	---	*	---	---	---			
Gordon's Pt.	---	---	---	---	---	---		
West Lake	***	***	***	***	***	***	***	

However, unpublished data from eastern and western basin Lake Erie populations show comparable levels of within-population diversity (Wilson and Gatt unpubl. data). The amount of variation present within the Lake Ontario populations indicates that the resident genetic diversity was not significantly affected by previous population declines, as no evidence of population bottlenecks was observed.

The overall lack of stock structure within the Bay of Quinte made it impossible to resolve the other issues that the study aimed to address. For example, it was not possible to compare spawning fidelity or philopatry of male versus female walleye, due to the inability to discriminate among populations. Although sex-specific analysis of spatial structure among spawning sites resulted in slightly higher F_{ST} and lower gene flow estimates among female versus male walleye (data not shown), these differences were not statistically significant.

Similarly, no differences between river- versus shoal-spawning populations were detectable in this study. However, this should not be interpreted as indicating that no differences exist between these two spawning types within the Bay of Quinte, as previous work has demonstrated that spawning habitat preferences have a heritable component in walleye (Jennings et al. 1996). Finally, the absence of detectable stock structure among spawning sites within the Bay of Quinte precluded an assessment of different spawning populations to mixed-stock fisheries. With the exception of West Lake walleye, the separate contributions of different spawning aggregates to fisheries could not be resolved, and the limited divergence between West Lake and other sites would

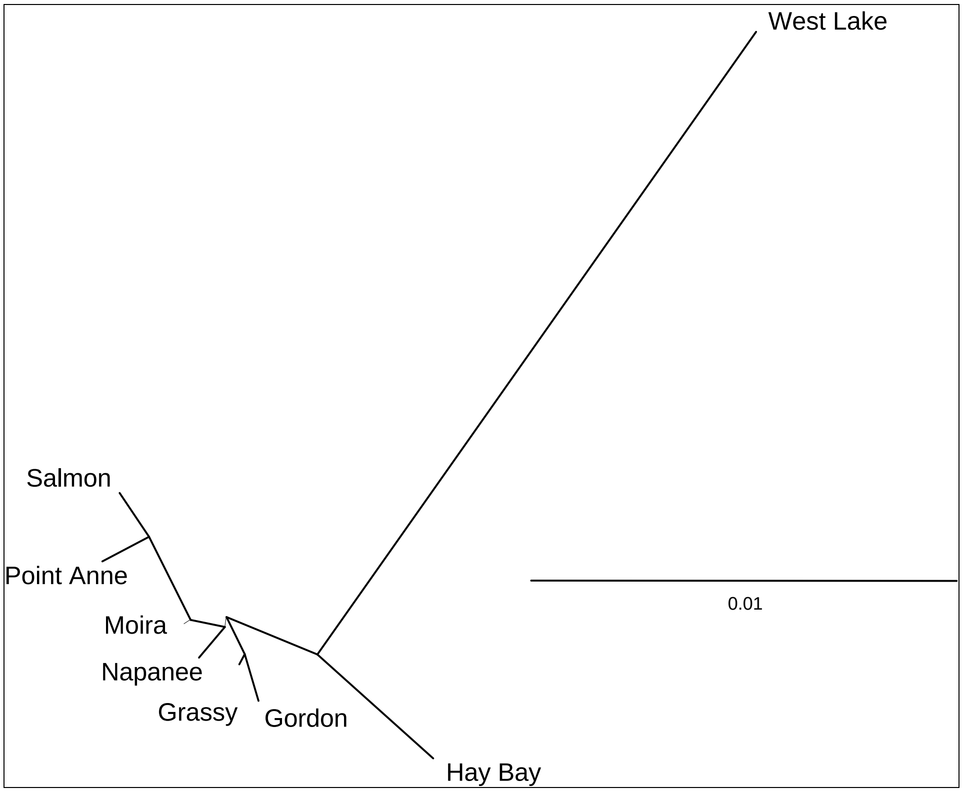

FIG. 3. Pairwise divergences among sampled walleye populations based on microsatellite DNA allele frequencies. Note the close similarity between genetic differences and geographic distances as indicated in Fig. 1.

make an assessment of its fishery contribution expensive and impractical.

Several possible scenarios could account for the limited genetic structuring observed. The most probable explanation is that sufficiently high levels of gene flow occur among spawning sites, through either straying or non-specific targeting of spawning sites. This seems likely, given the vagility of walleye and the small spatial scale involved. This hypothesis is also supported by the indirect estimates of spatial structure and gene flow among populations (F_{ST} and Nm) in Tables 4 and 6.

A related possibility could be high levels of movement within the Bay during the spawning period, either by transient walleye enroute to their target spawning sites or by fish assessing or exploring for suitable spawning habitat. It may be that the lack of structure detected within the Bay resulted from fish being harvested at locations other than their target spawning site, which could account for the high levels of potential "straying" in Table 7. However, Hardy-Weinberg tests for random mating within sample sets showed no evidence of heterozygote deficiency, which should be apparent if members of separate populations were unintentionally pooled by sampling.

Another possibility is that the sampled walleye represent newly-established spawning populations that have rebounded from a historical crash. This would result in these populations sharing too recent a common ancestry to detect genetic differences among populations. This would not preclude the existence of ecological differences or separate reproduction among populations, as fixed differences between populations could take up to 4Neì generations (4 times the product of the genetic effective population size of component populations by the marker mutation rate) to be apparent for microsatellite DNA markers. Obviously, significant ecological and/or life history differences could develop among separate populations in that time.

Recommendations

Based on the genetic data, the West Lake walleye spawning population should be recognized as a

TABLE 7. Maximum likelihood assignment of individual walleye to collection sites / populations, based on resampling of multilocus genotypes without replacement and assigning probable sources of origin from allelic frequency data at five microsatellite DNA loci. Bold numbers along diagonal represent numbers of fish assigned to the sampling site where they were collected.

	Moira	Salmon	Napanee	Hay Bay	Pt. Anne	Grassy Pt.	Gordon's Pt.	West Lake
Moira	**17**	4	9	10	8	4	11	5
Salmon	13	**7**	6	6	14	11	10	4
Napanee	12	5	**4**	7	9	9	6	5
Hay Bay	10	3	10	**3**	4	7	6	3
Pt. Anne	1	7	4	1	**5**	1	2	0
Grassy Pt.	6	5	10	6	5	**9**	4	2
Gordon's Pt.	7	3	1	3	3	3	**8**	2
West Lake	5	6	5	3	0	8	2	**41**

separate, if closely related, stock. Where opportunities exist, efforts should be made to characterize this population in terms of population size, demographics and recruitment, as well as the availability and quality of spawning habitat within West Lake.

We recommend that the Bay of Quinte spawning walleye populations be collectively managed as conservatively as possible to ensure a future for the fishery. Our failure to detect genetic differences among spawning site collections within the Bay of Quinte does not preclude the existence of multiple stocks or spawning populations. Evidence for separate spawning groups such as different spawning times or substrate type should be considered as potential indicators of separate breeding groups. At present, spawning walleye within the Bay of Quinte retain healthy levels of genetic diversity, indicating their prospects for long-term viability and future adaptive potential. Managing this renewable resource for the future as well as the present will help ensure its persistence as a sustainable fishery for future generations as well as our own.

Summary

This study used mitochondrial DNA (mtDNA) and microsatellite DNA to assess potential stock structure of walleye spawning in and near the Bay of Quinte on Lake Ontario. Samples were collected at walleye spawning areas from eight Bay of Quinte sites as well as from West Lake. In addition to assessing overall stock structure, specific research questions targeted potential differences in philopatry between male and female walleye, possible genetic differences between river- and shoal-spawning populations, and levels of differentiation and/or gene flow among populations / stocks.

Both mtDNA and microsatellite analyses revealed surprising levels of diversity, with most variation occurring within populations. Sequencing analysis of a 513-base segment of the mtDNA control region (D-loop) detected a variable number of haplotypes per population, with the Napanee River having the greatest richness (10 haplotypes) and West Lake the lowest (3 haplotypes). Allelic diversity among the microsatellite DNA loci ranged from 7 to 18 alleles per locus, with more even distribution among populations.

Little significant structure was observed among the sampled populations. Both mtDNA and microsatellite analyses indicated that more than 90% of genetic variation occurred within populations, rather than among them. Both methods, however, indicated that West Lake comprised a distinct stock, and suggested that the harvested Hay Bay fish were a mixture of fish from multiple sources within the Bay of Quinte. Genetic differentiation among other populations were not well supported statistically, although some differences were detected. Although no differences in stock structure were observed for male versus female walleye, this may be an artefact of little detectable stock structure. Similarly, it was not possible to distinguish between shoal- and river-spawning populations except for West Lake, and differences appeared to be based more on spatial distances than spawning type.

The low levels of divergence among populations

were interpreted as indicative of high levels of gene flow among spawning sites and/or a recent shared ancestry of these populations. As detectable genetic differences can lag behind ecological / reproductive divergence of populations, these results cannot be interpreted as showing that walleye within the Bay of Quinte comprise a single stock. Instead, we recommend that spawning populations be managed conservatively, using demographic or life history data where available to indicate separate stocks or management units.

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12

Lake Whitefish Populations in Eastern Lake Ontario

J. A. Hoyle

Introduction

The lake whitefish is the only remaining native salmonid in Lake Ontario abundant enough to support a fishery. The species has shown tremendous resilience. Lake whitefish stocks bounced back from the critically low levels of the 1960s and 1970s following relaxation of a variety of stresses including over-fishing, predation, and eutrophication. By the 1990s, lake whitefish had recovered to historically high levels of abundance, had accumulated a large spawning stock biomass comprised of several strong year-classes, and were once again the most important commercial species in Lake Ontario (Casselman et al. 1996).

But dramatic changes to Lake Ontario and Bay of Quinte ecosystems generally and to the offshore benthic food web particularly, following dreissenid mussel invasion (Hoyle et al. 1999), do not bode well for the species' future. In spite of a significant decline in the density of lake whitefish over the past several years, body condition remains poor and growth rate has slowed, indicating that food resources are limiting. Most recently, there has been a succession of very poor year-classes (Chapter 2). These results are symptomatic of a stressed population and suggest that lake whitefish populations will continue to decline (Hoyle et al. 2001).

The Lake Ontario commercial fishery for lake whitefish was managed to allow for recovery in the late 1980s and early 1990s. Harvest quotas were gradually increased as the relative abundance of lake whitefish increased in index netting surveys. The resulting harvest levels have allowed for sufficient escapement of the spawning stocks that, in unstressed populations, would not threaten their sustainability.

The very poor body condition observed in these fish, following the arrival of dreissenid mussels, means that more fish now need to be harvested to achieve quota (weight). Slow growth and delayed age-at-maturity (see Chapter 2) mean that age of recruitment to the fishery is two years later than it was only five years ago. It is not clear what level of exploitation, if any, is appropriate for stocks experiencing such extreme food web disruption. What is clear is that a more precise determination of stock size is essential. This would at least provide a basis on which to propose a "safe" harvest level.

To this end, this chapter is a progress report. Catch-at-age models (Pope's cohort analysis and CAGEAN) were used to make preliminary population estimates for Lake Ontario and Bay of Quinte lake whitefish spawning stocks. Several new findings (including relative stock size) made reporting these preliminary results worth while. However, it must be stressed that several major analysis issues (mainly the need to explicitly model the dramatic changes in lake whitefish biological attributes) need to be addressed before these population estimates are used as the basis for determining and applying a total allowable catch (TAC). The next steps toward a better model description of these lake whitefish stocks are identified; and so too is the urgent need to determine a critical stock size below which no harvest could be supported.

Methods

Commercial Harvest

Lake whitefish harvest was determined from Daily Catch Reports (1994 to 2000) and CF1 forms (monthly summary reports, 1993), and summarized based on the two major lake whitefish stocks: the Lake Ontario or 'lake' spawning stock and the Bay of Quinte or 'bay' spawning stock. Quota Zones 1 and 2 were assumed to represent the lake stock while Quota Zones 3 and 4 represented the bay stock. Catch sampling, to determine biological attributes of the harvest, focused on the seasons and areas of greatest harvest. Large numbers of lake whitefish were length-tallied and smaller numbers (length-stratified sample) were examined for more detailed biological attributes (e.g., weight, sex, maturity, and age). Age was determined using otoliths.

Index Netting

Bottom set index gillnets ($1^1/_2$ to 6 inch graded mesh size panels) set during summer in the Outlet Basin of Ontario (Melville Shoal, Grape Island, Flatt Point, EB02 and EB06; see Fig. 1, Chapter 2) were used to monitor trends in relative abundance of the 'mixed' stocks from 1992 to 2000. Gillnet catches were standardized to 100 m of each mesh size. All fish were length-tallied and, as for the commercial harvest sampling, a length-stratified sample was taken for more detailed biological sampling including age determination. Age-specific catch indices were summarized for fish aged 1, 2, 3, and 4 and older.

Catch-at-age Modeling

Natural Mortality

Natural mortality was considered to be constant through time (1993 to 2000), and the same for both lake whitefish stocks. Natural mortality was estimated based on life history parameters using Pauly's equation (Quinn and Deriso 1999):

$$\ln M = -0.0152 - 0.279*\ln L_{inf} + 0.6543*\ln K + 0.4634*\ln T,$$

where L_{inf} and K are von Bertalanffy growth parameters and T is the water temperature experienced by the stocks. The units are yr^{-1} for M and K, ^oC for T, and cm for L_{inf}. Growth parameters were estimated annually for mixed lake whitefish stocks, aged 1 to 10 yrs-old and caught in index gillnets. I used a weighted (by lake whitefish catch rate) mean bottom water temperature (9.7 ^oC) at index gillnet sites where lake whitefish were caught during May to October and the average surface water temperature in eastern Lake Ontario during the remaining months. The final water temperature used in Pauly's equation was 6.4 ^oC.

Natural mortality was also estimated by subtracting fishing mortality (F), determined by cohort analysis, from total mortality (Z) determined by catch curve analysis (Ricker 1975) for strong year-classes in commercial gillnets (Quota Zone 2, lake stock) and index gillnets (mixed stocks).

Cohort Analysis

Pope's cohort analysis as described by Ricker (1975) was used to estimate lake whitefish population size based on age-specific commercial harvest statistics for Lake Ontario and Bay of Quinte spawning stocks. I used a natural mortality of 0.27 (see below) for both stocks and a terminal fishing mortality of 0.06 for the lake stock and 0.15 for the bay stock.

CAGEAN

CAGEAN (Deriso et al. 1985) was used to supplement the cohort analysis in an attempt to overcome assumptions of constant selectively and catchability in the fisheries over the time-period of this study. Two selectivity and catchability stanzas were identified (1993 to 1996 and 1997 to 2000) on the basis of changes in lake whitefish growth and age-at-maturity (see Chapter 2). Natural mortality and terminal fishing mortality values were the same as those used in the cohort analysis. Fishing effort data was not available for the bay stock; an index of effort was developed based on known trends in the fishery.

Results and Discussion

A summary of commercial harvest (1993 to 2000), index gillnetting (1992 to 2000) and biological sampling statistics is presented in Table 1. Harvest levels ranged from 216,359 lb to 485,794 lb for the lake stock and from 160,180 lb to 275,994 lb for the bay stock. Nearly 40,000 fish were length-tallied and about 2000 fish were aged over the 8-yr period.

Lake whitefish relative abundance in index gillnets declined from 1993 to 2000. Age-specific trends in abundance are shown in Fig. 1. Catches of young fish declined over the study period such that very few 1, 2 or 3 yr-old fish were observed in 1999 or 2000. Therefore, year-class strength and potential recruits to the spawning stock fisheries have been very low in recent years. The abundance of fish 4 yrs-old and older has remained much more constant over the study period, although lowest catches were observed in the last two years.

Natural Mortality

Natural mortality based on index gillnetting data and calculated using Pauly's equation is shown in Fig. 2. Predicted natural mortality (M) estimates average 0.28 but declined over the study period because of the dramatically declining growth rate (Chapter 2). This

TABLE 1. Summary statistics for lake whitefish harvested (lb) and sampled (numbers lengthed and aged) for Lake Ontario and Bay of Quinte spawning stocks, and caught and sampled in index netting (catch-per-gillnet and aged) for mixed stocks during mid-

	Lake Stock			Bay Stock			Index Netting (mixed stocks)	
Year	Harvest (lb)	Length-tallied	Aged	Harvest (lb)	Length-tallied	Aged	CUE	Aged
1992	n/a	n/a	n/a	n/a	n/a	n/a	54	
1993	234,873	4,160	191	160,180	1,660	180	81	159
1994	308,991	2,638	63	178,800	1,438	306	52	128
1995	287,344	2,957	79	209,610	1,055	102	50	140
1996	485,794	2,784	103	275,994	1,001	97	25	123
1997	319,703	1,347	100	250,638	1,946	92	28	120
1998	222,141	2,067	122	218,889	3,917	119	31	80
1999	221,858	3,298	100	228,967	1,516	102	11	58
2000	216,359	3,348	114	174,712	4,352	129	13	67
Total		22,599	872		16,885	1,127		1,005

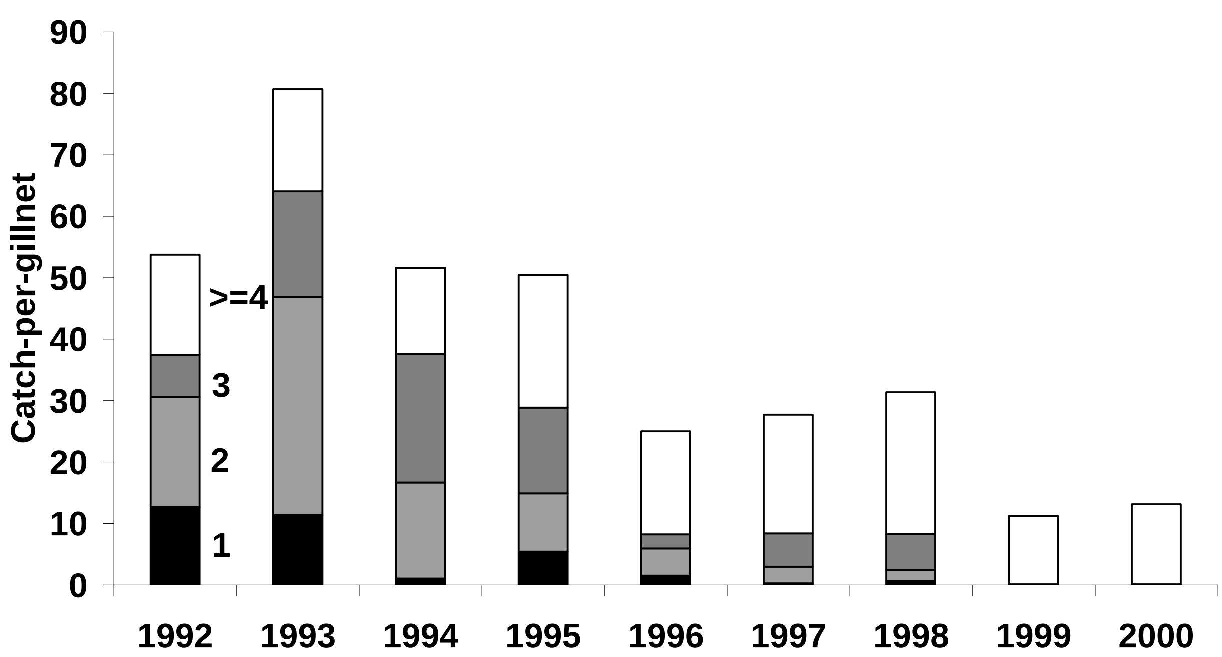

FIG. 1. Age-specific relative abundance trends in index gillnets, Outlet Basin Lake Ontario, 1992 to 2000. Stacked bars represent catches of fish aged 1, 2, 3 and 4 and older, as indicated.

result does not imply that the true natural mortality declined over the study period since the calculation is only appropriate for a stable population.

Mortality parameters for fish caught in index gillnets (mixed stocks) and commercial gillnets (lake spawning stock) are shown in Table 2. Average total annual mortality (A) was 0.33 for the mixed stock index netting results and 0.28 for the lake stock commercial gillnet results. Given the assumption that natural mortality was the same for both stocks, these results suggested that total annual mortality for the Bay stock was higher than 0.33. A value of 0.34 produced a natural mortality estimate of 0.27, the same as for the lake stock, using fishing mortality values of 0.06 for the lake stock and 0.15 for the bay stock. This natural mortality value (0.27) agreed well with that obtained from Pauly's equation (0.28).

A natural mortality value of 0.27 was used in the cohort and CAGEAN analyses described below.

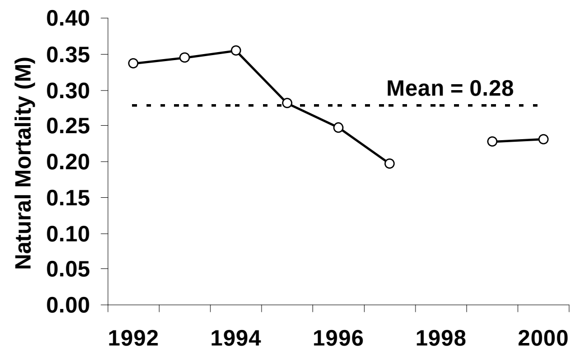

FIG. 2. Lake whitefish natural mortality (M) calculated for mixed stocks using Pauly's equation. Average values for L_{inf} and K were 59.2 cm and 0.223 yr^{-1}, respectively, and T was 6.4 ^oC. The average natural mortality was 0.28.

TABLE 2. Natural mortality estimates for lake and bay stocks of lake whitefish. Total mortality was estimated by catch-curve analysis (Ricker 1975), and was based on 1990 to 1992 year-classes over the ages 3 to 10 yrs-old in index gillnets (mixed stocks), and on 1987 to 1990 year-classes over the ages 6 to 13 yrs-old in the commercial gillnet fishery in Quota Zone 2 (lake stock). Total mortality for the Bay stock was estimated based on the assumption that natural mortality was the same for both stocks and using fishing mortality determoined from the cohort analysis.

	Index Gillnets	Commercial Gillnets	Estimated
	Mixed Stocks	Lake	Bay
A	0.33	0.28	0.34
S	0.67	0.72	0.66
Z	0.40	0.33	0.42
F		0.06	0.15
M		0.27	0.27

Population Estimates

Cohort and CAGEAN population estimates for lake and bay lake whitefish stocks (age-4 and older) are shown in Fig. 3. CAGEAN estimates averaged 30 to 90% higher than cohort analysis estimates for bay and lake stocks respectively. Both models showed that both stocks increased to peak numbers in 1995 (bay stock) or 1996 (lake stock), and then declined. The decline was less rapid for CAGEAN results (decline of 61% from 1996 to 2000 for the lake stock and 66% from 1995 to 2000 for the bay stock) than for cohort analysis (67% and 78% for lake and bay stocks respectively). These results are consistent with the attempt, using CAGEAN, to model changes in selectivity and catchability in the fisheries due to changes in lake whitefish growth and age-at-maturity. Therefore, the trends in population size were likely better modeled with CAGEAN. However, it is less clear which model gave more accurate estimates of true population size. More work needs to be done in this regard.

Fishing mortality estimates averaged 0.05 (exploitation rate = 4%) across age-classes and years for the lake stock and 0.14 (exploitation rate = 11%) for the bay stock (cohort analysis). These low fishing mortality estimates indicate that the stocks have not been over-exploited to date.

The trends in population estimates (CAGEAN estimates for age-4 and older) for the two stocks correlate only loosely with relative abundance trends of mixed stocks in index gillnets for the same age-group ($r = 0.55$, $p = 0.15$ for the lake stock; and $r = 0.67$, $p = 0.07$ for the bay stock). Certainly, the dramatic downward trend in population size for each stock was not seen in the index netting results for mixed stocks. However, the last two years of index gillnetting had the lowest catches, and catches in subsequent years may improve the correlation.

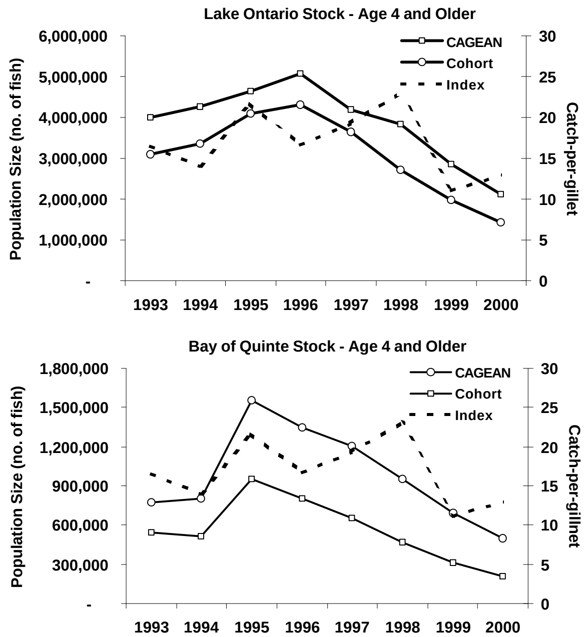

FIG. 3. Lake whitefish population estimates (no. of fish aged 4 and older) determined by Pope's cohort analysis and CAGEAN for Lake Ontario stock (upper panel) and Bay of Quinte stock (lower panel). Natural mortality rate was set at 0.27 for both stocks and terminal fishing mortality rate was set at 0.06 for the lake stock and 0.15 for the bay stock. Index gillnetting catches of fish age-4 and older (mixed stocks in Outlet Basin of Lake Ontario during summer) are also shown (dotted line).

Management Implications and Next Steps

Because of dramatic changes in lake whitefish biological attributes (e.g., slower growth rate and delayed age-at-maturity) over the course of this investigation, it is unlikely that even the CAGEAN model used here could adequately account for changes in selectivity and catchability. A model that could incorporate functions describing the observed trends in these attributes needs to be developed to give more accurate population estimates (e.g., AD Model Builder Quinn and Deriso 1999). Still, even these preliminary population estimates are the best available indicator of relative stock size, and indicate that the lake stock is considerably larger than the bay stock. The estimates suggest that both lake whitefish stocks are declining, and together with the observation of very poor recruitment in recent years, also suggest that the stocks will continue to decline in the future.

Although, fishing mortality has not been a factor causing stock decline, harvest levels must be prevented from putting these stocks at even greater risk. Identification of a critical stock size, below which no harvest could be supported, is urgently needed.

A mark-recapture program would give independent estimates of population size and natural mortality, would allow calibration of the catch-at-age models, and would increase confidence in the absolute population estimates.

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Appendix A

Fish stocked in the Province of Ontario waters of Lake Ontario in 2000

Appendix A

Atlantic salmon stocked in the Province of Ontario waters of Lake Ontario, 2000.

SITE NAME	MONTH STOCKED	YEAR SPAWNED	HATCHERY/ SOURCE	STRAIN/ EGG SOURCE	AGE (MO.)	MEAN WT (G)	MARKS	NUMBER STOCKED
			ATLANTIC SALMON - EGGS					
SHELTER VALLEY CREEK								
Doig Property	12	2000	Partnership	LaHave/Normandale	0		None	**13,618**
			ATLANTIC SALMON - DELAYED FRY					
BARNUM HOUSE CREEK								
Barnum House	5	1999	Ringwood	LaHave/Normandale	3	0.2	None	**10,000**
COBOURG CREEK								
Ball's Mill	5	1999	Ringwood	LaHave/Normandale	3	0.2	None	20,000
Cobourg Cr Dale Rd	5	1999	Ringwood	LaHave/Normandale	3	0.2	None	48,450
								68,450
CREDIT RIVER								
Black Cr Limehouse	4	1999	Ringwood	LaHave/Normandale	2	0.2	None	**29,800**
ROUGE RIVER								
Little Rouge River	5	1999	Partnership	LaHave/Normandale	2	0.4	None	**22,000**
WILMOT CREEK								
Below 5th Concession	5	1999	Ringwood	LaHave/Normandale	3	0.2	None	**10,063**
			ATLANTIC SALMON - ADVANCED FRY					
CREDIT RIVER								
Black Cr 6th-15th Lines	4	1999	Ringwood	LaHave/Normandale	5	0.8	None	19,387
Black Cr Limehouse	4	1999	Ringwood	LaHave/Normandale	5	0.7	None	82,381
Black Cr Stewarttown	4	1999	Ringwood	LaHave/Normandale	5		None	10,000
Glen Williams	4	1999	Ringwood	LaHave/Normandale	5		None	5,000
								116,768
			ATLANTIC SALMON - ADULTS					
HUMBER RIVER								
Albion Hills CA	10	1992	Codrington	LaHave/Normandale	72	2500.0	None	12
Bolton Res. Mgt. Tract	10	1992	Codrington	LaHave/Normandale	72	2500.0	None	10
Lower Humber River	10	1992	Codrington	LaHave/Normandale	72	2500.0	None	6
Palgrave	10	1992	Codrington	LaHave/Normandale	72	2500.0	None	2
								30
WILMOT CREEK								
Orono Creek	10	1992	Codrington	LaHave/Normandale	72	2500.0	None	**142**
TOTAL - ATLANTIC SALMON EGGS								**13,618**
TOTAL - ATLANTIC SALMON DELAYED FRY								**140,313**
TOTAL - ATLANTIC SALMON ADVANCED FRY								**116,768**
TOTAL - ATLANTIC SALMON ADULTS								**172**
TOTAL - ATLANTIC SALMON								**270,871**

Brown trout stocked in the Province of Ontario waters of Lake Ontario, 2000.

SITE NAME	MONTH STOCKED	YEAR SPAWNED	HATCHERY/ SOURCE	STRAIN/ EGG SOURCE	AGE (MO.)	MEAN WT (G)	MARKS	NUMBER STOCKED
				BROWN TROUT - YEARLINGS				
BRONTE CREEK								
Bronte Beach Park	3	1998	Normandale	Ganaraska/Normandale	16	55.6	Ad	**15,019**
DUFFIN CREEK								
401 Bridge	5	1998	Harwood	Ganaraska/Normandale	17	60.3	Ad	**10,018**
LAKE ONTARIO								
Ashbridge's Bay Ramp	3	1998	Harwood	Ganaraska/Normandale	15	49.9	Ad	6,999
	5	1998	Harwood	Ganaraska/Normandale	17	62.1	Ad	8,472
Bluffer's Park	3	1998	Harwood	Ganaraska/Normandale	15	47.4	Ad	7,020
	5	1998	Harwood	Ganaraska/Normandale	17	68.8	Ad	9,337
Burlington Canal	3	1998	Normandale	Ganaraska/Normandale	16	47.4	Ad	15,521
Fifty Point CA	3	1998	Normandale	Ganaraska/Normandale	16	45.6	Ad	15,465
Humber Bay Park West	3	1998	Normandale	Ganaraska/Normandale	16	53.3	Ad	10,036
Jordan Harbour	3	1998	Normandale	Ganaraska/Normandale	16	56.4	Ad	10,016
Lakeport	5	1998	Harwood	Ganaraska/Normandale	17	74.1	Ad	8,800
Millhaven Wharf	3	1998	Harwood	Ganaraska/Normandale	15	58.2	Ad	6,159
	5	1998	Harwood	Ganaraska/Normandale	17	67.9	Ad	9,012
Oshawa Harbour	5	1998	Harwood	Ganaraska/Normandale	17	59.2	Ad	10,137
Port Dalhousie East	3	1998	Normandale	Ganaraska/Normandale	16	55.2	Ad	25,012
								141,986
TOTAL - BROWN TROUT								**167,023**

Appendix A

Chinook salmon stocked in the Province of Ontario waters of Lake Ontario, 2000.

SITE NAME	MONTH STOCKED	YEAR SPAWNED	HATCHERY/ SOURCE	STRAIN/ EGG SOURCE	AGE (MO.)	MEAN WT (G)	MARKS	NUMBER STOCKED
				CHINOOK - SPRING FINGERLINGS				
BOWMANVILLE CREEK								
CLOCA Ramp	4	1999	Ringwood	Wild - Credit River	5	3.6	None	**25,222**
BRONTE CREEK								
2nd Side Rd Bridge	4	1999	Ringwood	Wild - Credit River	5	3.4	None	25,216
5th Side Rd Bridge	4	1999	Ringwood	Wild - Credit River	5	3.4	None	25,217
								50,433
COBOURG BROOK								
South of King St	5	1999	Ringwood	Wild - Credit River	6	4.4	None	**15,311**
CREDIT RIVER								
Eldorado Park	4	1999	Ringwood	Wild - Credit River	5	4.1	None	34,446
Huttonville	4	1999	Ringwood	Wild - Credit River	5	3.9	None	34,472
Norval	4	1999	Ringwood	Wild - Credit River	5	3.6	None	34,471
								103,389
LAKE ONTARIO								
Ashbridge's Bay Ramp	4	1999	Ringwood	Wild - Credit River	5	4.1	None	25,843
Bluffer's Park	4	1999	Ringwood	Wild - Credit River	5	3.8	None	51,707
Burlington Canal	4	1999	Ringwood	Wild - Credit River	5	3.8	None	51,707
Consecon	5	1999	Ringwood	Wild - Credit River	6	4.8	None	25,838
Jordan Harbour	5	1999	Ringwood	Wild - Credit River	6	4.6	None	25,836
Oshawa Harbour	4	1999	Ringwood	Wild - Credit River	5	3.6	None	25,223
Port Dalhousie East	4	1999	Ringwood	Wild - Credit River	5	4.3	None	51,691
	5	1999	Ringwood	Wild - Credit River	6	4.8	None	51,663
Wellington Channel	5	1999	Ringwood	Wild - Credit River	6	4.8	None	25,838
Whitby Harbour	5	1999	Ringwood	Wild - Credit River	6	4.4	None	25,854
								361,200
TOTAL - CHINOOK SALMON								**555,555**

Coho salmon stocked in the Province of Ontario waters of Lake Ontario, 2000.

SITE NAME	MONTH STOCKED	YEAR SPAWNED	HATCHERY/ SOURCE	STRAIN/ EGG SOURCE	AGE (MO.)	MEAN WT (G)	MARKS	NUMBER STOCKED
			COHO - SPRING YEARLINGS					
CREDIT RIVER								
Huttonville	2	1998	Ringwood	Wild - Salmon River	15	17.9	RV	17,895
Norval	2	1998	Ringwood	Wild - Salmon River	15	19.9	RV	17,896
Eldorado Park	3	1998	Ringwood	Wild - Blue Jay Creek	15	20.4	Ad	9,680
	3	1998	Ringwood	Wild - Salmon River	15	19.3	RV	8,005
								53,476
			COHO - FALL FINGERLINGS					
CREDIT RIVER								
Eldorado Park	10	1999	Ringwood	Wild - Salmon River	10	19.1	AdRV	45,999
Huttonville	10	1999	Ringwood	Wild - Salmon River	10	19.7	AdRV	45,825
Norval	10	1999	Ringwood	Wild - Salmon River	10	19.1	AdRV	15,325
	10	1999	Normandale	Wild - Salmon River	11	18.2	AdRV	14,922
								122,071
TOTAL - COHO SPRING YEARLINGS								**53,476**
TOTAL - COHO FALL FINGLERINGS								**122,071**
TOTAL - COHO SALMON								**175,547**

Appendix A

Lake trout stocked in the Province of Ontario waters of Lake Ontario, 2000.

SITE NAME	MONTH STOCKED	YEAR SPAWNED	HATCHERY/ SOURCE	STRAIN/ EGG SOURCE	AGE (MO.)	MEAN WT (G)	MARKS	NUMBER STOCKED
				LAKE TROUT - YEARLINGS				
LAKE ONTARIO								
Fifty Point CA	3	1998	Harwood	Seneca Lake/Harwood	13	21.1	AdLP	30,055
	3	1998	Harwood	Slate Islands/Hills Lake	15	23.4	AdLP	29,279
Cobourg Harbour Pier	4	1998	Harwood	Slate Islands/Hills Lake	16	25.4	AdLP	34,967
N of Main Duck Sill	4	1998	Harwood	Mishibishu Lakes/Tarentorus	16	32.4	AdLP	19,836
	4	1998	Harwood	Seneca Lake/Harwood	14	26.1	AdLP	76,395
	4	1998	Harwood	Slate Islands/Dorion	16	26.2	AdLP	10,307
Pigeon Island	4	1998	Harwood	Slate Islands/Dorion	16	32.9	AdLP	15,270
S of Long Point	4	1998	Harwood	Mishibishu Lakes/Tarentorus	16	30.4	AdLP	20,207
	4	1998	Harwood	Seneca Lake/Harwood	14	27.1	AdLP	88,106
	5	1998	Harwood	Slate Islands/Dorion	17	28.1	AdLP	17,799
Scotch Bonnet Shoal	5	1998	Harwood	Mishibishu Lakes/Tarentorus	17	33.8	AdLP	9,179
	5	1998	Harwood	Seneca Lake/Harwood	15	30.0	AdLP	65,289
	5	1998	Harwood	Slate Islands/Dorion	17	31.9	AdLP	27,079
TOTAL - LAKE TROUT								**443,768**

Rainbow trout stocked in the Province of Ontario waters of Lake Ontario, 2000.

SITE NAME	MONTH STOCKED	YEAR SPAWNED	HATCHERY/ SOURCE	STRAIN/ EGG SOURCE	AGE (MO.)	MEAN WT (G)	MARKS	NUMBER STOCKED
			RAINBOW TROUT - EGGS					
GANARASKA RIVER								
Corbett's Dam	5	2000	Normandale	Ganaraska	0		None	84,276
Kendal	5	2000	Normandale	Ganaraska	0		None	96,024
Unnamed Site	5	2000	Normandale	Ganaraska	0		None	66,922
								247,222
			RAINBOW TROUT - FRY					
CREDIT RIVER								
Papermill Dam	7	2000	Partnership	Wild - Credit River			None	115,000
	8	2000	Partnership	Wild - Credit River			None	4,000
Stewarttown Dam	7	2000	Partnership	Wild - Credit River			None	15,000
Silver Creek	7	2000	Partnership	Wild - Credit River			None	85,000
								219,000
ROUGE RIVER								
Berczy Creek	6	2000	Partnership	Wild - Rouge River	1	0.2	None	2,500
Bruce Creek	6	2000	Partnership	Wild - Rouge River	1	0.2	None	2,500
Carlton Creek	6	2000	Partnership	Wild - Rouge River	1	0.2	None	2,500
Leno Park	6	2000	Partnership	Wild - Rouge River	1	0.2	None	7,500
Morningside Creek	6	2000	Partnership	Wild - Rouge River	1	0.2	None	2,500
Robinson Creek	6	2000	Partnership	Wild - Rouge River	1	0.2	None	2,500
								20,000
			RAINBOW TROUT - YEARLINGS					
BRONTE CREEK								
5th Side Rd Bridge	4	1999	Normandale	Ganaraska/Normandale	14	24.7	RV	9,997
Lowville Park	4	1999	Normandale	Ganaraska/Normandale	14	23.7	RV	10,017
								20,014
CREDIT RIVER								
Huttonville	4	1999	Normandale	Ganaraska/Normandale	14	28.1	RV	10,012
Norval	4	1999	Normandale	Ganaraska/Normandale	14	28.1	RV	10,012
								20,024
HUMBER RIVER								
E B Rutherford	4	1999	Normandale	Ganaraska/Normandale	14	30.3	RV	10,018
King Vaughan Line	4	1999	Normandale	Ganaraska/Normandale	14	30.1	RV	10,027
								20,045
LAKE ONTARIO								
Glenora	5	1999	Harwood	Ganaraska/Normandale	14	25.4	RV	9,393
Jordan Harbour	3	1999	Normandale	Ganaraska/Normandale	13	23.2	RV	20,004
Port Dalhousie East	4	1999	Normandale	Ganaraska/Normandale	14	28.9	RV	29,372
Long Pt - P.E. Bay	4	1999	Harwood	Ganaraska/Normandale	13	18.4	RV	5,033
Millhaven Wharf	4	1999	Harwood	Ganaraska/Normandale	13	18.4	RV	5,011
								68,813
ROUGE RIVER								
Bruce Creek	4	1999	Normandale	Ganaraska/Normandale	14	29.7	RV	7,061
Robinson Creek	4	1999	Normandale	Ganaraska/Normandale	14	28.2	RV	7,437
Silver Spring Farms	4	1999	Normandale	Ganaraska/Normandale	14	29.7	RV	7,061
								21,559
TOTAL - RAINBOW TROUT EGGS								**247,222**
TOTAL - RAINBOW TROUT FRY								**239,000**
TOTAL - RAINBOW TROUT YEARLINGS								**150,455**
TOTAL - RAINBOW TROUT								**636,677**

Appendix B

Catches in the index netting program in eastern Lake Ontario and the Bay of Quinte in 2000

Appendix B

Species-specific catch-per-standard-gillnet lift, Northeast Lake Ontario, 2000.

	Brighton					Middle Ground	Rocky Point									Wellington				
Species/ Site Depth (m)	08	13	18	23	28	05	08	13	18	23	28	60	80	100	140	08	13	18	23	28
Alewife	-	54.3	25.0	21.7	10.9	-	54.3	282.6	369.6	1,641.3	227.3	1.6	-	1.6	-	-	76.1	119.6	155.5	184.8
Brown bullhead	16.4	-	-	-	-	3.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Brown trout	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.3	6.6	3.3	-	-
Burbot	-	-	-	-	-	-	-	-	-	3.3	6.6	-	-	-	-	-	-	-	-	6.6
Common carp	3.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Freshwater drum	-	-	-	-	-	3.3	-	-	-	-	-	-	-	-	-	3.3	3.3	-	-	-
Lake herring	-	-	-	-	-	-	-	-	-	-	-	-	1.6	-	1.6	-	-	-	-	-
Lake trout	17.4	3.3	3.3	19.7	9.9	1.6	-	1.6	26.3	52.6	85.5	67.4	18.1	32.9	-	-	3.3	-	85.5	66.8
Lake whitefish	-	-	-	-	-	-	-	-	4.9	3.3	-	-	-	1.6	-	-	-	-	-	-
Pumpkinseed	3.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rainbow smelt	-	-	-	-	-	-	-	-	-	-	-	-	1.6	1.6	-	-	-	-	-	-
Rock bass	21.7	-	-	-	-	27.2	-	-	-	-	-	-	-	-	-	3.3	24.0	-	-	-
Slimy sculpin	-	-	-	-	-	-	-	-	-	-	-	-	-	1.6	-	-	-	-	-	-
Smallmouth bass	-	-	-	-	-	-	1.6	-	-	-	-	-	-	-	-	-	3.3	-	-	-
Walleye	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.9	-	3.3	-	-
White sucker	-	-	-	-	-	8.2	-	-	-	-	-	-	-	-	-	-	3.3	-	-	-
Yellow perch	3.3	-	-	-	-	423.7	-	-	-	-	-	-	-	-	-	460.4	654.7	32.6	-	-

Species-specific catch-per-standard-gillnet lift, Outlet Basin Lake Ontario, 2000.

	Eastern Basin		Flatt Point					Grape Island					Melville Shoal				
Species/ Site Depth (m)	30 (02)	30 (06)	08	13	18	23	28	08	13	18	23	28	08	13	18	23	28
Alewife	113.3	201.4	256.7	883.2	195.3	226.1	127.0	184.3	454.4	237.0	119.6	57.6	104.9	271.2	258.7	2,053.3	1,141.3
Brown bullhead	-	-	1.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Burbot	-	2.2	-	-	-	-	-	-	-	-	3.3	-	-	-	-	-	-
Channel catfish	-	-	-	-	-	-	-	-	-	-	-	-	1.6	-	-	-	-
Chinook salmon	-	0.7	-	-	-	-	3.3	-	-	-	-	-	-	-	1.6	-	-
Freshwater drum	-	-	5.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lake trout	18.3	27.0	-	-	4.9	16.4	19.7	-	-	1.6	6.6	6.6	-	-	-	-	16.4
Lake whitefish	4.0	8.4	-	-	-	13.2	85.5	-	-	-	3.3	9.9	-	-	-	-	3.3
Moxostoma sp.	-	-	-	-	-	-	-	-	-	-	-	-	1.6	-	-	-	-
Northern pike	-	-	1.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rock bass	-	-	11.5	21.7	-	-	-	5.4	-	7.1	-	-	33.8	6.6	10.9	-	-
Smallmouth bass	-	-	-	-	-	-	-	5.4	-	1.6	-	-	6.6	-	-	-	-
Stonecat	-	-	-	-	-	-	-	1.6	1.6	-	-	-	-	-	1.6	-	-
Trout-perch	0.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Walleye	-	-	-	-	-	-	-	6.6	-	-	-	-	134.9	23.0	1.6	-	-
White sucker	-	-	6.6	6.6	-	-	-	-	-	-	-	-	-	-	5.4	-	-
Yellow perch	1.1	-	267.0	146.0	1.6	-	-	65.4	101.3	189.4	90.2	42.5	46.3	343.3	150.3	59.2	14.2

Species-specific catch-per-standard-gillnet lift, Bay of Quinte, Lake Ontario, 2000.

	Big Bay	Hay Bay		Conway				
Species/ Site Depth (m)	05	08	13	08	15	20	30	45
Alewife	1.6	32.9	24.7	49.3	194.1	103.6	32.9	-
Bluegill	11.5	-	-	-	-	-	-	-
Brown bullhead	42.8	9.9	1.6	-	-	-	-	-
Channel catfish	-	-	-	-	1.6	-	-	-
Common carp	-	1.6	-	-	-	-	-	-
Freshwater drum	90.5	16.4	3.3	11.5	3.3	1.6	-	-
Gizzard shad	3.3	16.4	-	-	-	-	-	-
Lake herring	-	19.7	4.9	-	1.6	3.3	6.6	-
Lake trout	-	-	-	-	-	-	9.9	32.9
Lake whitefish	-	-	-	-	-	1.6	6.6	1.6
Longnose gar	4.9	-	-	-	-	-	-	-
Northern pike	4.9	3.3	4.9	-	-	-	-	-
Pumpkinseed	82.2	3.3	-	8.2	-	-	-	-
Rock bass	3.3	1.6	-	29.6	6.6	-	-	-
Slimy sculpin	-	-	-	-	-	-	-	-
Smallmouth bass	4.9	-	-	6.6	1.6	-	-	-
Walleye	49.3	18.1	1.6	100.3	19.7	6.6	-	-
White perch	302.6	34.5	4.9	-	1.6	-	-	-
White sucker	24.7	16.4	19.7	28.0	42.8	42.8	1.6	-
Yellow perch	1,044.4	731.9	962.2	1,572.4	988.5	592.1	115.1	13.2

Species-specific catch-per-trawl, Lake Ontario and Bay of Quinte, 2000.

	Lake Ontario				*Bay of Quinte*					
Species	EB02	EB03	EB06	Rocky Point	Trenton	Belleville	Big Bay	Deseronto	Hay Bay	Conway
3-Spine stickleback	75.4	76.8	9.7	-	-	-	-	-	-	-
Alewife	871.6	721.4	-	0.3	25.6	13.4	0.5	9.6	700.0	248.6
American eel	-	0.1	-	-	-	-	-	0.5	-	-
Black crappie	-	-	-	-	-	2.6	0.8	-	-	-
Bluegill	-	-	-	-	4.3	119.9	11.6	-	-	-
Brown bullhead	-	-	-	-	3.0	22.5	19.9	3.8	20.4	-
Chinook salmon	-	0.1	-	-	-	-	-	-	-	-
Common carp	-	-	-	-	-	-	0.4	-	-	-
Freshwater drum	-	-	-	-	0.5	5.8	10.3	5.1	1.8	-
Gizzard shad	-	-	-	-	68.4	1,762.4	12.8	-	46.0	-
Johnny darter	-	0.3	-	-	-	0.3	-	1.0	-	-
Lake trout	0.1	-	0.1	0.5	-	-	-	-	-	0.1
Lake whitefish	0.2	-	0.1	0.8	-	-	-	-	-	2.3
Largemouth bass	-	-	-	-	1.0	1.3	-	-	-	-
Logperch	-	-	-	-	0.6	0.6	0.1	0.5	-	-
Northern pike	-	-	-	-	0.1	-	0.1	-	-	-
Pumpkinseed	-	-	-	-	372.9	145.8	87.6	49.6	24.5	-
Rainbow smelt	29.6	5.1	115.9	220.5	-	-	-	-	0.1	-
Rock bass	-	-	-	-	4.1	0.6	-	-	-	-
Slimy sculpin	2.0	0.1	-	5.8	-	-	-	-	-	-
Smallmouth bass	-	-	-	-	1.5	0.9	-	1.4	-	-
Spottail shiner	-	0.3	-	-	0.3	19.4	4.0	-	4.9	-
Trout-perch	0.8	1,049.8	0.1	-	-	13.6	1.8	14.5	1.6	82.1
Walleye	-	-	-	-	-	5.5	2.9	2.1	2.3	-
White bass	-	-	-	-	-	-	-	-	0.1	-
White perch	-	0.1	-	-	1.5	205.0	368.1	704.1	59.3	-
White sucker	-	-	-	-	-	0.5	0.4	0.4	1.5	15.3
Yellow perch	-	-	0.1	-	234.8	429.8	63.0	176.6	658.1	41.0

Appendix C

Catches in the index netting program in the Lake St. Francis area of the St. Lawrence River in 2000

Appendix C

Species-specific catch-per-standard-gillnet lift, Lake St. Francis area, St. Lawrence River 1984 to 2000.

Survey year	1984		1986		1988		1990		1992		1994		1998		2000	
Number of Nets	36		35		36		36		36		36		35		36	
	CUE	SE	CUE	SE	CUE	SE	CUE	SE	CUE	SE	CUE	SE	CUE	SE	CUE	SE
Yellow Perch	13.53	1.85	10.31	1.28	13.19	1.86	10.47	1.92	10.00	2.25	8.67	1.67	7.51	1.60	5.89	0.90
Northern Pike	2.64	0.49	2.49	0.32	2.81	0.36	2.42	0.28	2.61	0.32	2.47	0.27	2.34	0.31	2.10	0.32
Walleye	0.31	0.10	0.29	0.11	0.61	0.15	0.27	0.11	0.22	0.10	0.17	0.06	0.23	0.08	0.19	0.08
Smallmouth Bass	0.56	0.29	0.40	0.13	0.17	0.06	0.17	0.14	0.39	0.19	0.39	0.16	0.86	0.30	0.28	0.13
Largemouth Bass	0.03	0.03	0.00	-	0.06	0.04	0.06	0.04	0.00	-	0.03	0.03	0.06	0.04	0.08	0.05
Muskellunge	0.00	-	0.00	-	0.03	0.03	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-
Rock Bass	2.25	0.30	2.20	0.51	1.83	0.35	0.86	0.17	1.36	0.26	1.33	0.40	1.63	0.36	1.12	0.21
Pumpkinseed	3.14	0.99	1.09	0.34	0.53	0.13	0.47	0.19	0.94	0.26	1.11	0.25	0.97	0.29	0.67	0.17
Bluegill	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-	0.03	0.03	0.03	0.03
Black Crappie	0.03	0.08	0.06	0.06	0.03	0.05	0.06	0.06	0.06	0.04	0.08	0.05	0.00	-	0.06	0.04
Brown Bullhead	0.72	0.30	0.77	0.30	0.39	0.23	0.25	0.13	0.44	0.34	0.28	0.13	0.60	0.21	2.10	1.20
White Sucker	1.08	0.21	1.37	0.24	0.64	0.17	1.06	0.19	0.89	0.18	1.06	0.18	1.26	0.31	1.02	0.18
Redhorse Sucker	0.00	-	0.00	-	0.03	0.03	0.11	0.11	0.03	0.03	0.06	0.39	0.11	0.05	0.06	0.40
Fallfish	0.00	-	0.00	-	0.00	-	0.06	0.06	0.00	-	0.00	-	0.00	-	0.00	-
Creek Chub	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-	0.06	0.04	0.00	-
Longnose Gar	0.00	-	0.14	0.09	0.06	0.03	0.00	-	0.42	0.28	0.17	0.07	0.09	0.05	0.08	0.06
TOTAL	24.29		19.12		20.38		16.26		17.36		15.82		15.74		13.68	