LAKE ONTARIO FISH COMMUNITIES AND FISHERIES:

2001 ANNUAL REPORT OF THE LAKE ONTARIO MANAGEMENT UNIT

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Lake Ontario Committee
Great Lakes Fishery Commission

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Introduction

The Lake Ontario Management Unit (LOMU) is part of the Fish and 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 2001 Annual Report documents results of LOMU programs, completed in 2001, 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

Chinook salmon

- Catch, harvest and effort by anglers have been stable since 1997 (Chapter 8)
- Catch rates by anglers indicate abundance has not changed significantly from 1997 to 2001 (Chapter 1)
- Condition factor improved whereas length-at-age declined (Chapter 1)
- Condition factor positively correlated to alewife condition factor (Chapter 1)
- Wild chinook numbers continue to increase in stream surveys (Chapter 1)

Rainbow trout

- Counts of migrating rainbow trout returns at Ganaraska River fishway remained relatively low in 2001 (Chapter 1)
- Exploitation of the Ganaraska River population appears to have declined from 2000 to 2001 (Chapter 1)
- Production of wild young-of-the-year rainbow trout in streams was high (Chapter 1)
- Catch and harvest of rainbow trout in 2001 increased in the boat fishery consistent with spring temperatures (Chapter 8)

Pelagic Prey Fish

- Alewife population in 2001 still dominated by the 1998 year class (Chapter 1)
- The 2000 year class of alewife was weak (Chapter 1)
- Smelt population in 2001 dominated by yearlings, continuing alternating year class pattern (Chapter 1)

Lake trout

- Decline in numbers of adult fish continued (Chapter 2)
- Survival of juvenile stocked fish is low (Chapter 2)
- Continued low but steady level of natural reproduction detected in U.S. waters (Chapter 2)

Lake whitefish

- Growth and body condition stabilized at a lower level (Chapter 2)
- Delayed mean age-at-maturity (Chapter 2)
- Very poor to undetectable levels of recruitment (Chapter 2)
- Continued decline in commercial harvest (Chapter 5)

Eels

- Eel counts at the Moses Saunders dam eel ladder declined further (Chapter 4)
- St. Lawrence River harvests declined further (Chapter 6)
- Continued declines in Lake Ontario commercial fish harvest (Chapter 5)

Walleye

- Biological reference points defined for walleye management (Chapter 13)
- Recruitment since 1995 is at a low level (Chapter 14)
- Modeling of walleye abundance in 2001 was estimated to be about 400,000 fish which is above the critical stock size of 160,000 fish (Chapter 14)
- Exploitation rate is about twice as high as the recommended 10% (Chapter 15)
- Decreased effort and harvest in 2001 winter angling fishery (Chapter 7)
- Open water angling fishery shows reduced effort and increased harvest in 2001 (Chapter 7)
- Increase in commercial harvests in 2001 (Chapter 5)

Yellow perch

- Populations are relatively high in the Bay of Quinte (Chapter 3)
- Populations appear stable in eastern Lake Ontario (Chapter 3) and Thousand Islands (Chapter 4)
- Commercial harvest declined (Chapters 5 and 6)
- Angling catches declined in the Bay of Quinte (Chapter 7)
- New parasite (*Heterosporis sp*.) documented (Chapter 17)

Round goby

- Slowly spreading throughout the Bay of Quinte and eastern Lake Ontario (Chapter 3)
- The diet of all but the smallest gobies was *Driessena spp*. (Chapter 16)

Smallmouth bass

- Year class strength improved in recent years (Chapter 3)
- Adult abundance very low in eastern Lake Ontario and Thousand Islands (Chapters 3 and 4)

Largemouth bass

- Increased angling catches in the Bay of Quinte (Chapter 7)
- New program to assess population (Chapter 9)

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Lake Ontario Offshore Pelagic Fish Community

T. Schaner, J. N. Bowlby, M. E. 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 due to a combination of factors. The nutrients received by the lake decreased in the recent decades due to improved land use and sewage treatment practices. Then, 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, alewife and smelt continued to be the principal prey for 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 by 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 of this report).

Information sources

Alewife and smelt populations are assessed in hydroacoustic surveys conducted cooperatively by OMNR and the New York State Department of Environmental Conservation (NYSDEC). In these surveys we collect hydroacoustic data, as well as mid-water trawl samples that are used to interpret the hydroacoustic data (Schaner and Schneider 1995). Multiple yearly surveys in spring, summer and fall were conducted in the past, however, starting in year 2000 we have reduced the program to a single survey in the summer as the most practical means of assessing the prey population. A full survey consisting of seven transects was conducted in 2001.

The methodology used to estimate prey fish abundance from the hydroacoustic information is currently under review, based on new information on target strength characteristics of alewife (Warner et al. 2002). The results from previous years' surveys are being revised, but the process has not yet been completed. No population size estimates are therefore given at this time, and the information provided here is only intended to outline the latest trends observed in the prey fish populations.

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

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spawn collection for the Ringwood Fish Culture Station. Spawning rainbow trout 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 in this report). Wild juvenile salmon and trout populations are assessed by electrofishing randomly selected sites in Lake Ontario tributaries

Alewife

The 2001 mid-water trawl catches of alewife showed that the strong 1998 year-class still dominated the age structure as 3-year olds (Fig. 1, prominent peak around 125 mm). The 1999 year-class, which was fairly evident as yearlings in the previous summer, was not distinguishable in 2001 as an age-2 peak, although it may have been obscured by fish from the dominant 1998 year-class, which are only slightly larger. We also caught practically no fish in the 80-100 mm range, which indicates an absence of yearlings. Young-of-the-year alewife (20-40 mm) were also found in the trawl catches, although the low efficiency of our gear for fish of this size precludes any meaningful interpretation.

Preliminary analysis of the 2001 acoustic data (not shown here) suggests a slight decrease in the yearling-and-older population of alewife from the previous year. This is consistent with the notion that the alewife population is currently dominated by the 1998 year-class, which is gradually declining. Small targets in the –60 dB region were prominent in the acoustic data, similar to our observations in 1998. We believe that this suggests a strong 2001 year-class of alewife. Combined with the unusually mild winter of 2001/2002, this could boost the alewife population in the next several years.

The body condition of adult alewife, expressed as predicted weight of 120 mm fish, was higher in 2001 than in the previous year, but still below the 1990s average (Fig. 2). Long-term data (O'Gorman et al. 2002) suggest that this level of body condition is similar to that observed in mid-1980s.

Rainbow Smelt

The trawl catches of rainbow smelt in 2001 were dominated by fish in the 90 mm size class, which corresponds to yearling fish (Fig. 3). Higher abundance of yearlings in odd numbered years is a well established pattern in Lake Ontario, and seems to have persisted through record low abundances of 1999-2000. Although proper acoustic estimate of smelt abundance for 2001 is not available, an increase in hypolimnetic targets from the previous two years suggests an increase in the adult smelt population.

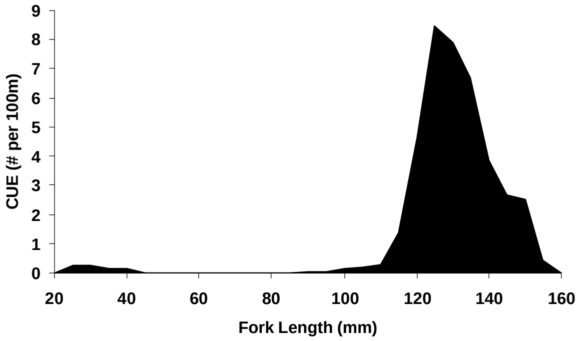

FIG. 1. Length frequency distribution of alewife in mid-water trawls conducted in August 2001.

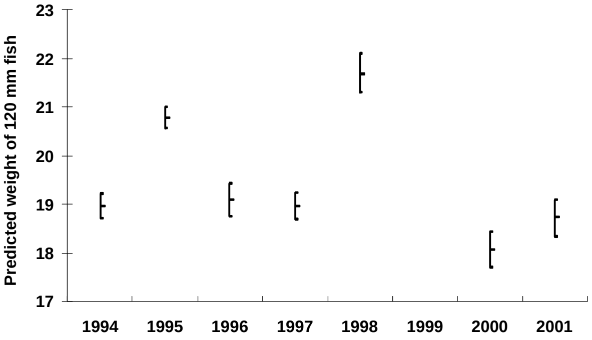

FIG. 2. Predicted weight of 120 mm fork length alewife calculated from length-weight regressions of fish larger than 100 mm captured with mid-water trawls in summer surveys.

The body condition of adult smelt has increased somewhat in 2001 but the measured increase is probably not statistically significant (Fig. 4). Similar to alewife, the condition in smelt fell in 2000, and remained below the 1990s average in 2001.

Other pelagic prey species

Threespine sticklebacks which first appeared in significant numbers in 1993 continue to be found in the mid-water trawl catches (Fig. 5). The frequency of occurrence in trawls suggests a gradual increase in abundance throughout the 1990s. The numbers caught in 2001 were the highest since 1996. The

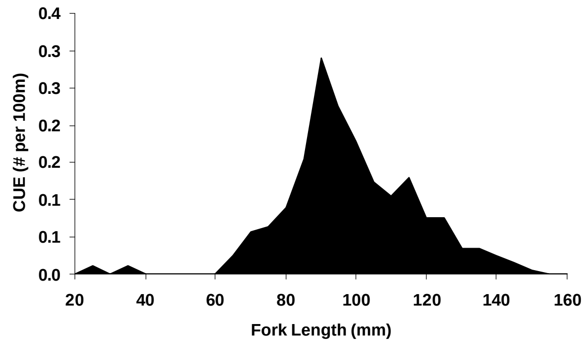

FIG. 3. Length frequency distribution of rainbow smelt in mid-water trawls conducted in August 2001.

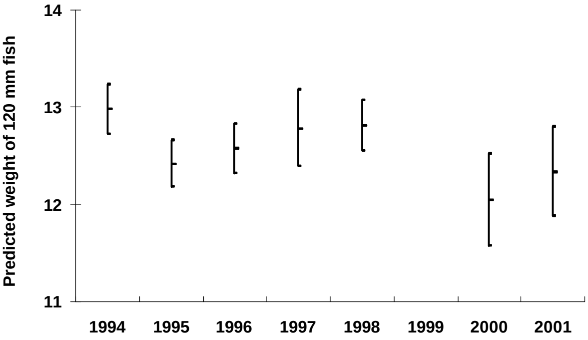

FIG. 4. Predicted weight of 120 mm fork length rainbow smelt calculated from length-weight regressions of fish larger than 100 mm captured with mid-water trawls in summer surveys.

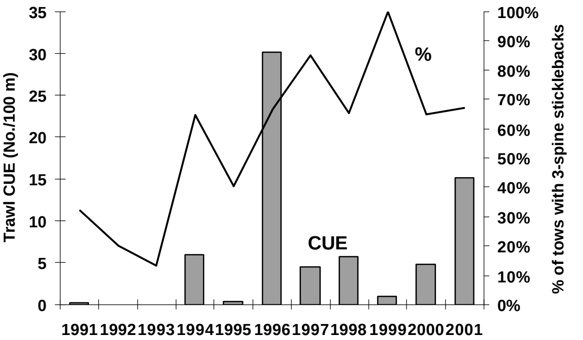

FIG. 5. Catches of threespine stickleback with mid-water trawl in summer surveys. Bars represent yearly catch per unit effort; line shows proportion of tows that contained stickebacks.

catch rates (CUEs) for sticklebacks are generally lower than the alewife CUEs, but higher than the smelt CUEs. Because they are small, however, the sticklebacks probably easily escape through the mesh of our mid-water trawl, and thus their low catch rates may belie an abundant population.

Stocking Program

In 2001, OMNR stocked about 1.9 million salmon and trout into Lake Ontario (Table 1). 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 164,000 coho salmon fall fingerlings and spring yearlings were stocked into the Credit River. Although a portion of the eggs required to meet 2002/2003 production requirements was successfully obtained through an egg collection in the Credit River, the remainder were imported from New York State (Salmon River). About 200,000 Atlantic salmon (mainly fry) were stocked in support of an

TABLE 1. Salmon and trout stocked into Province of Ontario waters of Lake Ontario, 2001, and target for 2002.

		Number Stocked	
Species	Age	2001	2002 Target
Atlantic Salmon	Green eggs	12,000	
	Eyed eggs	28,000	
	Delayed fry	109,390	
	Advanced fry	95,179	200,000
	Fall fingerlings		15,000
	Adults	140	
		244,709	**215,000**
Chinook Salmon	Spring fingerlings	549,909	535,000
	Fall yearlings	5,000	
		554,909	**535,000**
Coho Salmon	Fall fingerlings	67,406	75,000
	Spring yearlings	96,826	75,000
		164,232	**150,000**
Lake Trout	Spring yearlings	**454,247**	**440,000**
Rainbow Trout	Fry	166,500	
	Fall fingerlings	31,477	
	Spring yearlings	111,799	140,000
		309,776	**140,000**
Brown Trout	Fall fingerlings	1,400	
	Spring yearlings	172,340	165,000
		173,740	**165,000**
SALMON AND TROUT TOTAL		**1,901,613**	**1,645,000**

ongoing program to determine the feasibility of restoring self-sustaining populations of this native species to the Lake Ontario watershed. Over 450,000 lake trout yearlings were also stocked as part of an established, long-term rehabilitation program. Efforts are focused in eastern Lake Ontario where most of the historic spawning shoals are found. About 112,000 rainbow trout yearlings were stocked by OMNR, 20% below target because of higher than normal losses of fish from hatchery ponds as a result of wildlife predation. In addition, local community groups reared about 198,000 fry and fingerling rainbows. About 174,000 brown trout yearlings were stocked at various locations to provide shore and boat fishing opportunities.

Detailed information about OMNR's 2001 stocking activities is found in Appendix A. NYSDEC also stocked 3.7 million salmon and trout into Lake Ontario in 2001 (Eckert 2002).

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 2001 (Fig. 6), suggesting that the chinook salmon populations have been steady for the past four years.

Growth

The length of male and female 2-yr-old and 3-yr-old chinook salmon in the Credit River during fall 2001 declined from the past several years (Fig. 7). This was inconsistent with the strong 1998 and 1999 year-classes of alewife, chinook salmon's main diet. The pattern of body condition of chinook salmon (Fig. 8) showed no relationship with length-at-age. Rather, condition of chinook salmon increased slightly, consistent with condition of alewife (Fig. 9). Body condition of chinook salmon reflected recent changes in nutrition of prey, whereas, length-at-age integrated growth over the life of the fish.

Year-Class Strength of Wild Chinook and Coho Salmon

Wild chinook and coho salmon were observed during summer in an electrofishing survey of juvenile rainbow trout (see below). Wild chinook salmon continue to increase in these streams About twice as

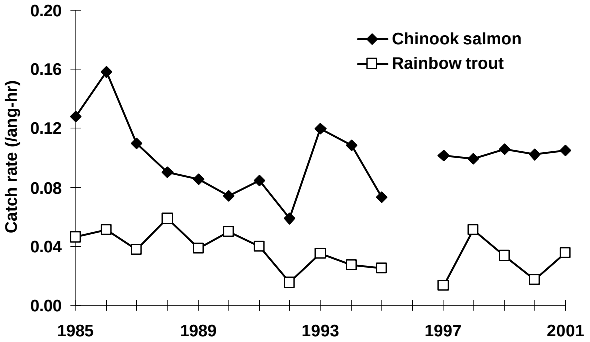

FIG. 6. The catch rate of chinook salmon and rainbow trout in the western Lake Ontario launch daily salmonid boat fishery (Ontario portion) from 1985 to 2001.

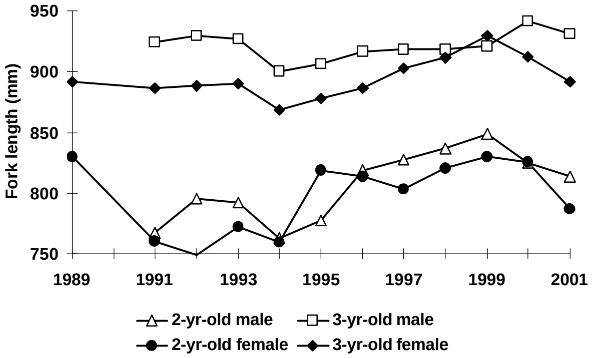

FIG. 7. Fork length of chinook salmon in the Credit River during spawning run in September and October.

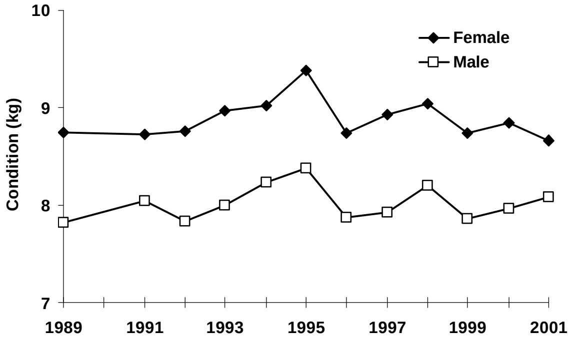

FIG. 8. Condition (mean weight, adjusted for length) of chinook salmon in the Credit River during the spawning run in September and October.

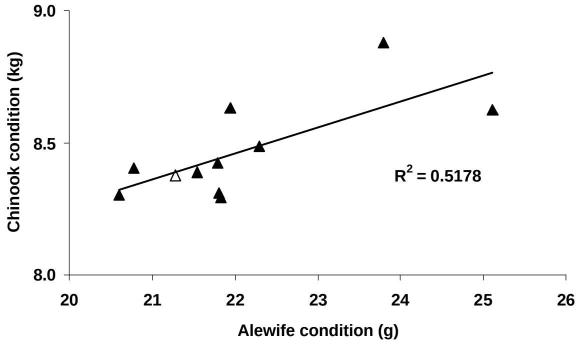

FIG. 9. A plot of condition of chinook salmon in the Credit River during the spawning run in September and October, and condition of alewife in Lake Ontario during the same year from 1991 to 2001. The 2001 data point is indicated with an open triangle.

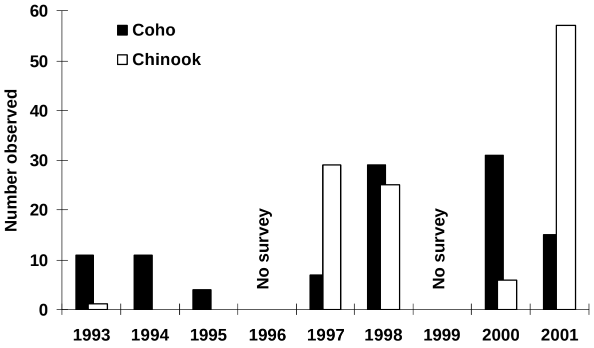

FIG. 10. Number of YOY coho and chinook salmon observed during summer surveys of Lake Ontario tributaries in Ontario. No surveys were conducted in 1996 and 1999.

many chinook salmon were observed in summer 2001, than ever observed previously (Fig. 10). About one-half of these observations came from the Ganaraska River, and another one-third came from Duffins Creek. In 2001, coho salmon numbers declined (Fig. 10). Bowmanville, Sopers, and Duffins Creeks accounted for all of the these observations in 2001 and most of the observations in 2000.

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 2001, the catch rate increased to about the average value recorded since 1985 (Fig. 6). The catch rates of rainbow trout in 2001 were consistent with a spring of average temperature. The seasonal/spatial pattern of catch in 2001 seems to relate to the pattern of warm springs such as in 1998, and of cold springs such as in 2000 (Fig. 11). These catch rates were consistent in timing and location of the post-spawning migration of wild rainbow trout from north shore streams. In cooler springs, such as in 2000, post-spawning rainbow trout did not appear to remain along the north shore of Lake Ontario.

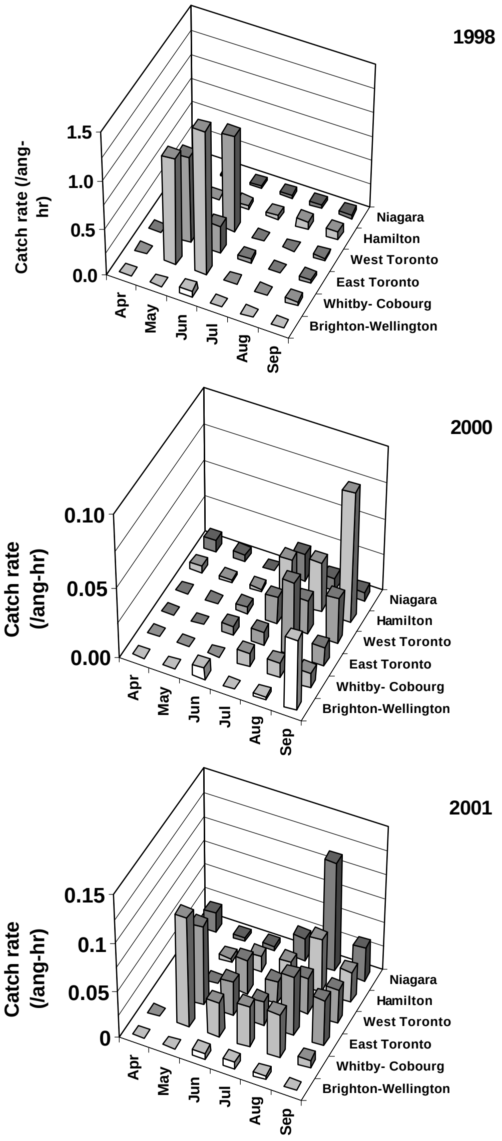

FIG. 11. The seasonal and spatial pattern of catch rates of rainbow trout by launch daily anglers in western Lake Ontario during 1998, 2000, and 2001.

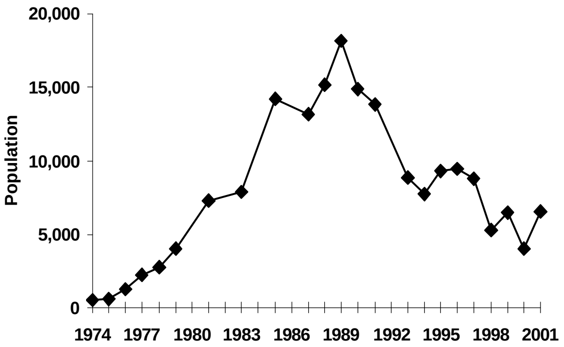

FIG. 12. The estimated upstream count of rainbow trout at the Ganaraska River fishway at Port Hope, Ontario during April and May.

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 2001, the estimated run past the fishway during spring increased to 6,527 fish (Fig. 12). Although this increase is encouraging, the run had been relatively constant from 1993 to 1997 at a level about 50% higher than in 2001. Earlier declines in the run after 1991 were related to increases in the age of maturity (Bowlby et al. 1998). However, this most recent decline after 1997 may be related to high exploitation by shoreline and stream fisheries (Bowlby and Stanfield 2001).

In 2001 the repeat spawner rate of Ganaraska rainbow trout increased to a combined estimate of 55% for both sexes (Fig. 13). Clarkson and Jones (1997) have shown that the repeat spawner rate is equivalent to the survival rate. This was above the recommended limit of 50% (Swanson 1985), suggesting a decline in harvest of the population in the previous year.

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. 14). Body condition of rainbow trout was consistent with past observations by Bowlby et al. (1994) that

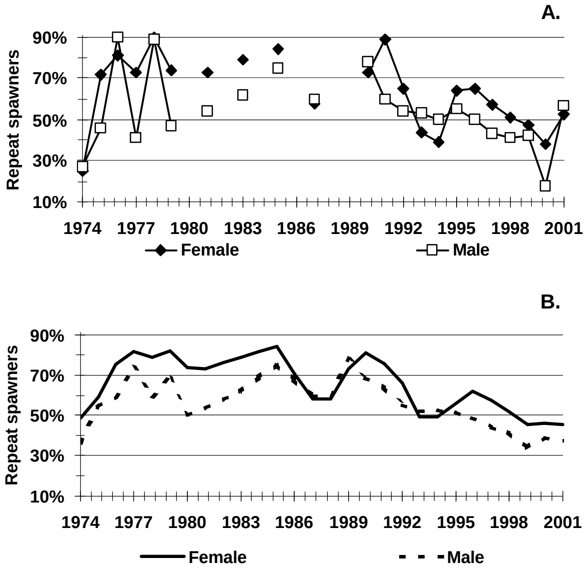

FIG. 13. The repeat spawner rate of rainbow trout in April at the Ganaraska River fishway, Port Hope, Ontario. A. Raw annual values. B. Smoothed, three-year running averages to reduce the effect of strong and weak year-classes.

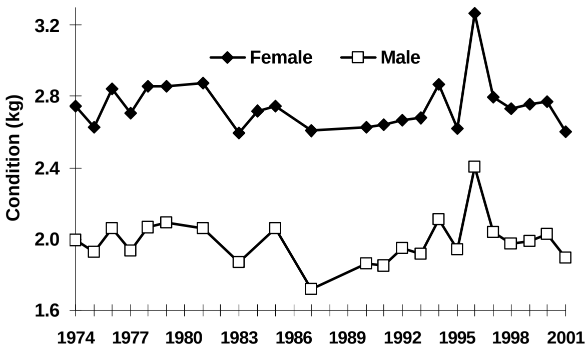

FIG. 14. Condition (mean weight, adjusted for length) of rainbow trout in April at the Ganaraska River fishway, Port Hope, Ontario.

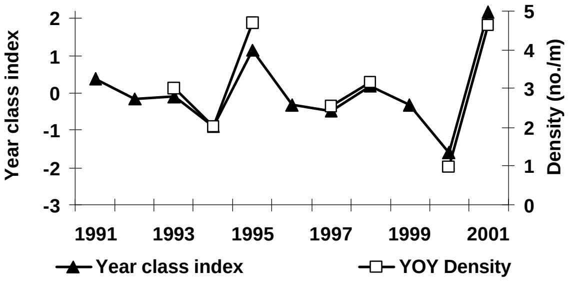

FIG. 15. Density of young-of-the-year (YOY) and year-class strength of rainbow trout in Ontario tributaries of Lake Ontario.

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 rainbow trout harvest of the boat fishery in Lake Ontario. To evaluate these wild 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. In 2001, rainbow trout year-class strength rebounded from a low in 2000 to one of the highest levels recorded since 1991 (Fig. 15). Sampling was not done in 1996 and 1999, and this has reduced our confidence in the year-class strength estimates from these years. However, additional sampling of the 1999 year-class in 2001 has not altered the interpretation of the data presented last year. The mean density of young-of-the-year rainbow trout in these tributaries continues to be a good predictor of year-class strength (Fig. 15). However, the year-class strength estimate for the poor 2000 year-class has improved, suggesting better survival of these fish to age one, perhaps in a density-dependent manner. The reasons for good year-classes in 1995 and 2001 as yet remain unclear.

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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 include 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 remnant population sizes by the 1960s and 1970s.

Regulated harvest, 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 during 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—especially 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 in this report. 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.

In the early-1990s, *Dreissena sp*. (zebra and quagga mussels) invaded and proliferated throughout Lake Ontario. The concurrent disappearance of *Diporeia hoyi* (Dermott 2001), an important diet item for benthic fish (e.g., juvenile lake trout, lake whitefish, slimy sculpin and deepwater sculpin), implicates dreissenid mussels as having at least one direct negative impact to the deep-water benthic food web. Lake whitefish have negatively responded to the loss of *Diporeia* by showing reduced body condition and growth, delayed age-at-maturity, and poor reproductive success.

This chapter updates the status of lake trout, lake whitefish, slimy sculpin, burbot and deepwater sculpin for 2001.

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 2001a), and also, in the case of lake whitefish, from commercial catch sampling during lake whitefish spawning (Hoyle 2001b). For a complete list of species-specific catches in this program, see Appendix B.

Lake Trout

Abundance

In 2001 the abundance of mature lake trout in the Canadian waters of eastern Lake Ontario declined by

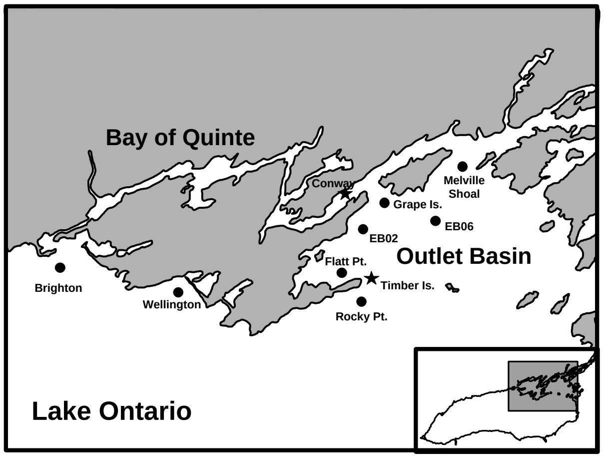

FIG. 1. Map of northeastern Lake Ontario showing fish community index gillnetting (circles) and trawling (stars) locations in the Outlet Basin and the lower Bay of Quinte.

14% from the previous year, continuing the downward trend in population size (Fig. 2). The decline started in the mid-1990s, and can partly be attributed to a 50% reduction in stocking level in 1993. In Canadian waters, however, the reduction was implemented mainly in the western portion of the lake, while in the east, where our data are collected, the stocking continued at levels that were only slightly reduced. As lake trout tend to remain near their stocking location, the reduced stocking level is unlikely to account for the magnitude of the decline observed in the 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 the survival dropped precipitously (Fig. 3). Over the last four years, however, survival of young fish has remained fairly constant, and it appears that the downward trend has ceased. If early survival was the major cause of the decline in adult numbers, we should soon see the decline in adults stop as well.

The trend in the mean size of adult lake trout provides another hopeful sign. Throughout the 1990s the mean size of adult lake trout increased (Fig. 4). This was consistent with a population structure dominated by older fish, which in turn was indicative of decreasing recruitment. In 2001 the mean size of adult fish decreased. This suggests that recruitment has stabilized.

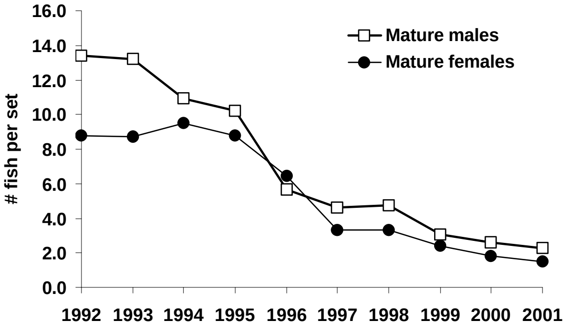

FIG. 2 Catch of mature lake trout per standard gillnet set in the community index gillnetting program (1992 to 2001). Only catches from July-September made at bottom temperatures less than 12 ^{o}C were used.

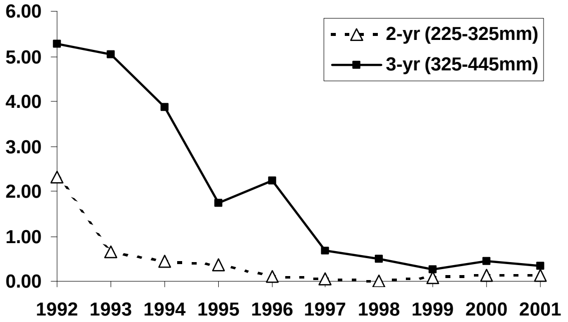

FIG. 3. Survival of stocked fish to ages 2 and 3. Based on information from the recently discontinued coded wire tags, and from length frequency distributions, fish in the ranges of 225-325 and 325-445 mm were assumed to be 2-year old and 3-year old respectively. The graph shows the catches per standard set in the community index gillnetting program (1992 to 2001) divided by the number of yearlings (in millions) of the corresponding year class stocked in the Canadian waters east of Brighton.

Body condition and growth

The body condition of large lake trout in 2001 was somewhat lower than in the previous year, but overall it appears to have remained stable since the early 1990s (Fig. 5, 680 mm fish). Higher values were observed in 1995-96 and 1999, which may be attributed to strong 1995 and 1998 year classes of alewife. The condition of juvenile lake trout (Fig. 5, 430 mm fish) appears to have decreased over the mid-1990s. A similar decrease occurred in lake whitefish (see below in this chapter), and the decrease in condition in both species was probably linked to changes in availability of invertebrate prey. There is some indication, that since 1997 the condition of juvenile lake trout has improved, although low catches of juvenile lake trout in the monitoring program in recent years limit the statistical significance of our observations.

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. 6). The lamprey wounding rates in 2001 were close to the average rate observed since 1995, suggesting that lake trout mortality due to sea lamprey has remained constant since 1995.

Natural reproduction

No naturally produced lake trout were detected in the Canadian waters of Lake Ontario in 2001. Young lake trout are best captured with bottom trawls, which is a common assessment technique in the U.S. waters but not so in Canadian waters, where bottom morphology makes trawling difficult or impossible in most areas. Thus only 15 naturally produced lake trout were detected in Canadian waters of Lake Ontario since regular sightings of naturally produced fish began in 1994.

In the U.S. waters young naturally produced lake trout were first observed in 1994, and fish of every year-class starting with 1993 were captured since then. The numbers are low but steady; the highest number ever captured was 58 in 1995, while 30 were captured in 2001 (Lantry et al. 2002). The earliest of these year classes are now mature, and should start producing the second generation of naturally produced fish.

Lake Whitefish

Abundance

Lake whitefish abundance (1 yr-olds 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 equally rapidly through the mid- to late-1990s. Abundance remained low in 2000 and 2001 (Fig. 7). Recent trends in lake whitefish abundance were age specific (Fig. 8). Immature fish abundance

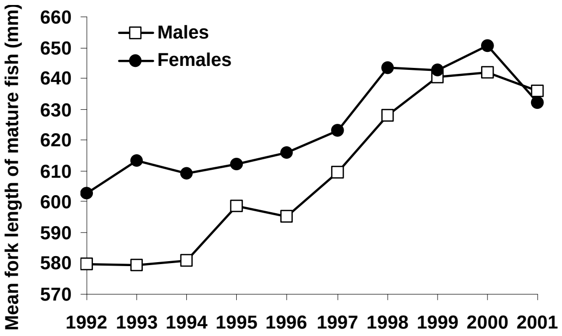

Fig. 4. Mean fork length of mature fish, 1992 to 2001.

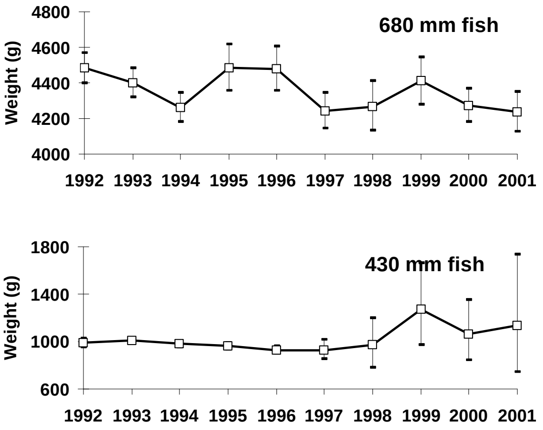

FIG. 5. Weights of 430 and 680 mm fish. The weights were calculated from regression of log transformed round weight on log transformed fork length, and only data from 50 mm brackets around the shown values of fork length were used in the regressions (405-455 mm and 655-705 mm). The error bars represent 95% confidence intervals on the estimated weight.

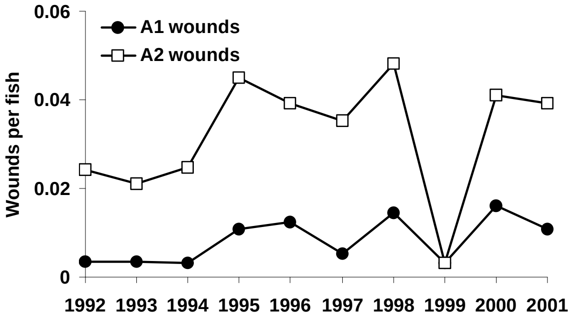

FIG. 6. Number of A1 and A2 (International Joint Commission classification) lamprey wounds per lake trout observed in the index gillnetting program, 1992 to 2001.

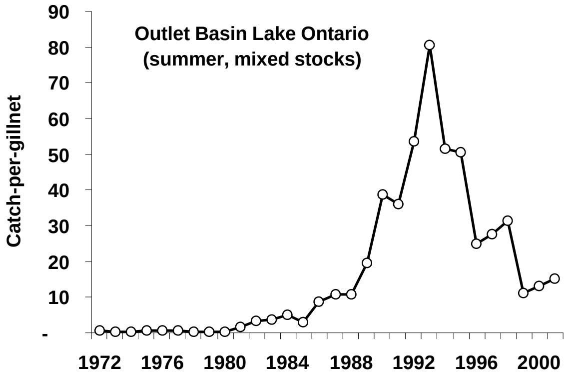

FIG. 7. Lake whitefish catch-per-gillnet (sum of catch adjusted to 100 m of each mesh size, 1½ to 6 in), during summer in the Outlet Basin of Lake Ontario, 1972 to 2001.

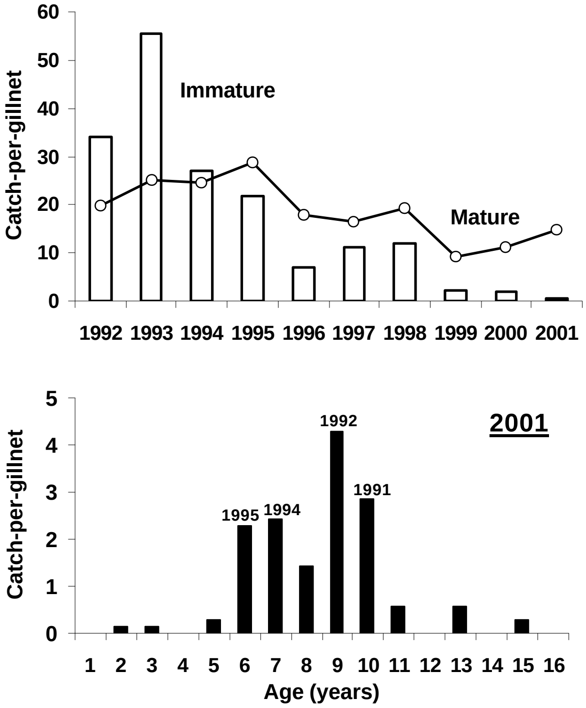

FIG. 8. Lake whitefish catch-per-gillnet for immature (open bars) and mature (line) fish in the Outlet Basin of Lake Ontario, 1992 to 2001 (top panel), and lake whitefish age distribution in 2001 (lower panel). Strong year-classes are indicated.

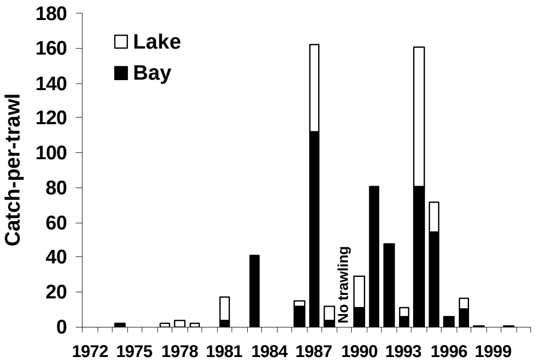

FIG. 9. Young-of-the-year lake whitefish catch-per-trawl (adjusted to 12 min duration) for Lake (Timber Island) and Bay (Conway) stocks (stacked bars), 1972 to 2001 (no trawling in 1989).

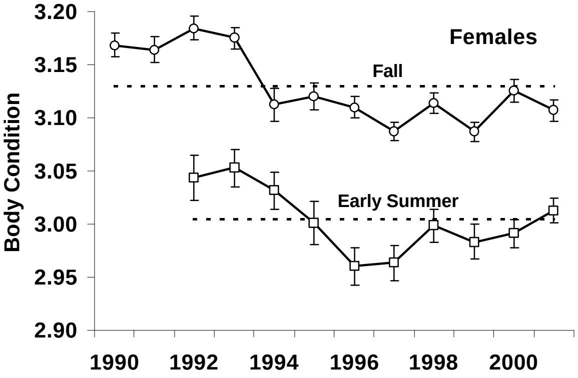

FIG. 10. Lake whitefish (females) body condition (least-squares mean $\log_{10}$ round weight adjusted for differences in length among years) in samples collected during: fall spawning runs for Lake Ontario and Bay of Quinte stocks (combined), 1990 to 2001 (upper panel), and mid-summer index gillnetting for mixed stocks in the Outlet Basin, 1992 to 2001 (lower panel). Error bars are +/- 2 SE. Mean values for fall and early summer samples are indicated (dotted lines).

has declined significantly since 1993; indicating that recent year-class strength was poor. Because age-at-maturity increased over the same time period (see below), more age-classes are grouped as immature fish in the later years. This makes the decline that much more dramatic. The decline of mature fish was less than that of immature fish. The mature fish can be thought of as a index of fish available to the lake whitefish commercial fishery that primarily exploits spawning stocks. Several strong year-classes are present including the 1987, 1991, 1992, 1994 and 1995 year-classes (Fig. 8).

Year-class Strength

Lake whitefish year-class strength 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. 9). No YOY fish have been observed at Timber Island (Lake stock) during the past

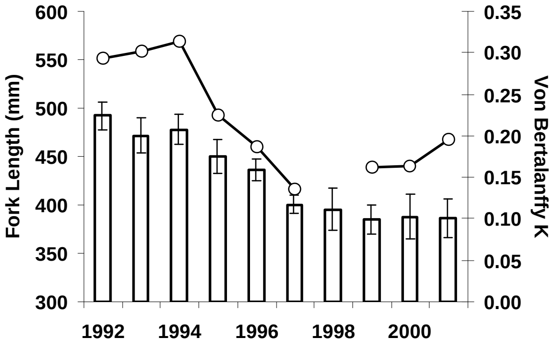

FIG. 11. Mean fork length at age-6 (open bars, +/- 2SE) and von Bertalanffy growth coefficient K (line, ages 1 to 12 yr; no value for 1998), for lake whitefish caught during mid-summer index gillnets in the Outlet Basin, Lake Ontario, 1992 to 2001.

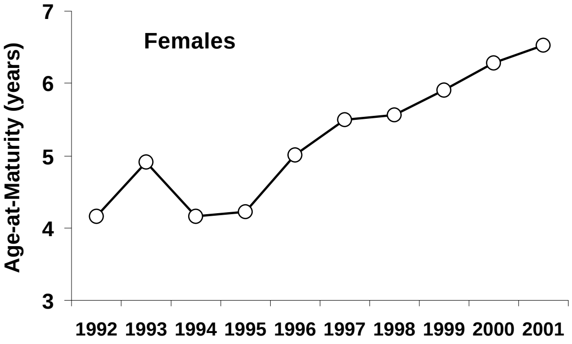

FIG. 12. Mean age-at-maturity (Lysak's method) for female lake whitefish caught during mid-summer index gillnets in the Outlet Basin, Lake Ontario, 1992 to 2001.

four years, and only small numbers have been observed for the Bay stock at Conway.

Body condition and growth

Body condition of spawning lake whitefish declined from 1993 to 1994. The body condition of spawning lake whitefish (both major spawning stocks combined) declined from 1993 to 1994 and subsequently remained stable, including in 2001 (Fig. 10). The decline in body condition was attributed to the dramatic decline in *Diporeia* abundance—formerly the most important prey type 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 four years with 2001 being the highest since 1994 (Fig. 10).

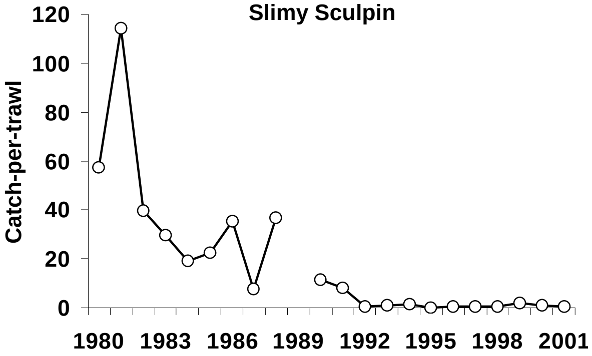

FIG. 13. Slimy sculpin abundance (catch-per-trawl at EB02 and EB06) in the Outlet Basin, Lake Ontario, 1980 to 2001 (no trawling in 1989).

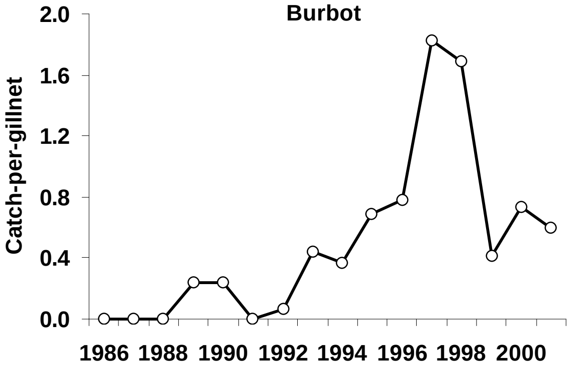

FIG. 14. Burbot abundance (catch-per-gillnet) in the Outlet Basin, Lake Ontario, 1986 to 2001.

Lake whitefish growth rate (von Bertalanffy growth coefficient K, Fig. 11) was high in the early 1990s, declined from 1994 to 1997 and remained low subsequently. This pattern of decline in growth is also apparent in the mean length for age-6 fish (Fig. 11). Growth rate appears to have stabilized at a new lower level.

Age-at-maturity

Lake whitefish age-at-maturity (females) was 4 to 5-yrs-old in the early 1990s but gradually increased after 1995 to over age-6 by 2001 (Fig. 12). Whereas lake whitefish growth rate appeared to have stabilized, age-at maturity continued to increase.

Slimy Sculpin

Slimy sculpin abundance remained low in the

Outlet Basin of Lake Ontario (Fig. 13), and has now been low since the early 1990s. The decline in abundance was likely related to intense predation pressure by stocked lake trout. Most recently, low abundance levels are 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 steady for the past three years (Fig. 14).

Deepwater sculpin

No deepwater sculpin have been captured in the past three years, although only a small amount of bottom trawling was conducted in areas suitable for this species. No deepwater sculpins were captured in U.S. programs on Lake Ontario during 2001 (compared with three in 1999 and one in 2000; Randy Owens, U. S. Geological Survey, Great Lakes Science Center, Lake Ontario Biological Station, Oswego, New York, personal communication).

Discussion

The lake trout population in Lake Ontario is currently maintained through stocking. Natural reproduction seems to be well established, but only at low levels. The first cohorts of naturally produced fish are now mature, and the second generation of naturally produced should be appearing in the lake. Having achieved this landmark in the rehabilitation initiative, we shall now need to focus on the production of wild fish— monitoring the reproduction rates, the success of the wild fish, and the factors that control it. Until we see a dramatic increase in the wild production, however, the lake trout population will still need to be maintained through stocking of hatchery fish.

The future outlook for lake whitefish is extremely uncertain. The carrying capacity of eastern Lake Ontario's native benthic food-web has been severely reduced (Dermott 2001, see also Nicholls et al. 2001). Although the density of whitefish declined significantly for several years, body condition (as measured for spawning fish) remained poor, indicating that food resources were still limiting. In addition, lake whitefish are now maturing two years later than they did less than a decade ago.

An optimistic prediction would be 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 signaled by improvements in body condition, and a new growth regime of smaller, slower growing and later maturing fish. There is evidence to suggest that lake whitefish geographic and bathymetric distribution and feeding patterns have changed (personal observations and, Randy Owens, U.S. Geological Survey, Great Lakes Science Center, Lake Ontario Biological Station, Oswego, New York, personal communication) probably in response to the disappearance of *Diporeia* from traditional feeding areas. Improved body condition, as measured in early summer samples of lake whitefish, is consistent with these observations.

However, apparent lake whitefish reproductive failure for several consecutive years is extremely disconcerting, especially since the cause is unknown. One hypothesis is that the observed poor body condition is symptomatic of poor nutritional status, and that this has led to reduced egg/fry survival. Another plausible hypothesis is that year-class strength has been poor due to unfavorable environmental conditions. Specifically, unusually warm fall and winter water temperatures, observed in recent years, have caused the poor egg/fry survival.

These results make lake whitefish harvest level recommendations very difficult. Harvest levels during the mid-1990s of the recently recovered whitefish stocks matched the historical long-term average harvest, but clearly, without improved reproductive success, current harvest levels cannot be sustained beyond a few more years. 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, such as those now documented for lake whitefish, will make achievement of management objectives for the offshore benthic food web much more difficult.

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3

Lake Ontario Nearshore Fish Community

J. A. Hoyle and T. Schaner

Introduction

The fish community in the coastal nearshore areas surrounding the main body of Lake Ontario is relatively sparse. However, diverse assemblages of species inhabit major embayments such as the Bay of Quinte, and eastern Lake Ontario's relatively shallow Outlet Basin. In these latter areas 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 alewife, primarily an offshore pelagic species, utilizes the nearshore as a spawning and nursery area and can be very abundant seasonally in nearshore areas. The lake sturgeon—which inhabits a wide-range of water depths—is a formerly common species showing a modest resurgence in recent years.

Several nearshore species of particular management interest have shown dramatic changes in abundance in the past decade. Smallmouth bass, abundant throughout the 1980s in eastern Lake Ontario's Outlet Basin, declined dramatically after 1992. The decline appears to be largely due to unfavorable summer water temperatures during the 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 increased during the 1990s in the Bay of Quinte and to a lesser degree in eastern Lake Ontario. This species appears to have benefited from changes in habitat (i.e., increased water clarity, increased levels of aquatic vegetation) and a decline in competitor and predator following the invasion and proliferation of dreissenid mussels in the early to mid-1990s. Walleye abundance, having recovered to very high levels through the early 1980s and early 1990s, has declined in recent years. The decline has been associated with changes in habitat (see above) and, most recently, over-harvest.

This chapter focuses on there species in the nearshore areas of eastern Lake Ontario and the Bay of Quinte, smallmouth bass, yellow perch, and walleye, all of which are important to fisheries management. More detailed information on walleye status can be found in Chapters 13, 14 and 15 in this report. Also included are an update on lake sturgeon status in 2001, 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 2001). For a complete list of species-specific catches in this program, see Appendix B. In 2001, a trapnet program was initiated in the upper Bay of Quinte to better assess the fish community in nearshore areas. Results of this new program are highlighted in Chapter 9 in this report.

Additional information on round goby was obtained from the Bay of Quinte angler survey (see Chapter 7 in this report) that was initiated following the first reported sighting of round goby in the summer of 1999.

Smallmouth bass

Eastern Lake Ontario

Abundance

Smallmouth bass support a modest-sized warm-water recreational fishery in eastern Lake Ontario's Outlet Basin (Fig. 1). Here their abundance 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 three 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 two decades.

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 that strong year-classes were produced 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, the 1991 year-class, was only of moderate strength. Direct and complete estimates of year-class strength were not possible beyond 1997. 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 1998 to 2001 (1995, 1996 and 1997 predicted year-class strength also shown for comparison (Fig. 4). The 1998, 1999 and 2001 year-classes were predicted to be above average. The 2000 year-class was predicted to be poor. 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).

Greater year-class strength since 1995 (predicted and observed, Fig. 4) should have resulted in increased smallmouth bass abundance in our assessment gillnets (Hoyle et al. 1999) but this has not occurred to date (Fig. 2). The strength of the 1995 year-class at age-2 and age-3 was one of the highest observed during the past two decades. However, unlike previous strong year-classes, the initial strength of the 1995 year-class did not persist past age-3 (Fig. 5). This observation is consistent with a previous report that mortality of young smallmouth bass had increased in New York

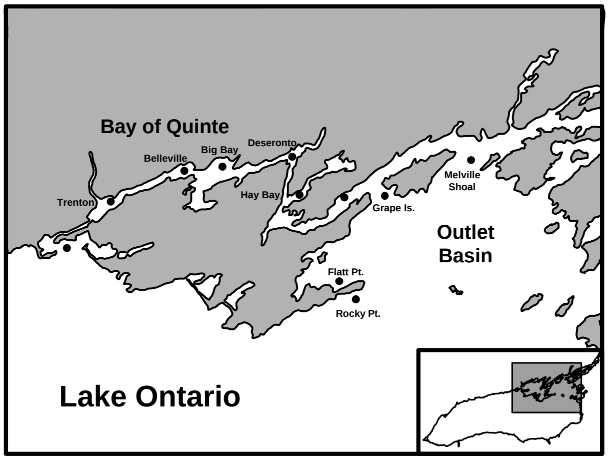


FIG. 1. Map of northeastern Lake Ontario showing fish community index gillnetting and trawling locations in the Outlet Basin and the Bay of Quinte.

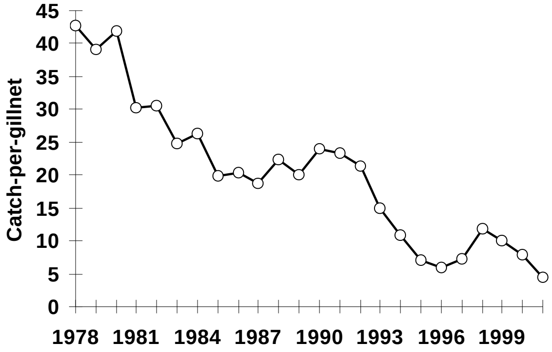


FIG. 2. Smallmouth bass abundance (3-yr running average) in Outlet Basin index gillnets during mid-summer, 1978 to 2001. One site (Simcoe Island) was sampled for the years 1978 to 1985, while three sites (Melville Shoal, Grape Island, and Rocky Point, Fig. 1) were sampled from 1986 to 2001.

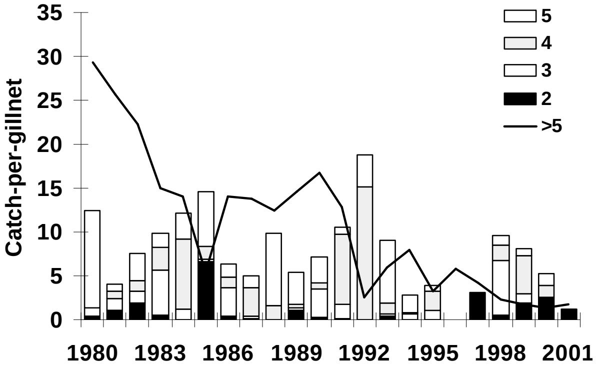


FIG. 3. Smallmouth bass age-specific abundance trends for ages 2, 3, 4, 5 (stacked bars) and >5 yrs-old (solid line) in Outlet Basin Lake Ontario index gillnets during mid-summer, 1980 to 2001.

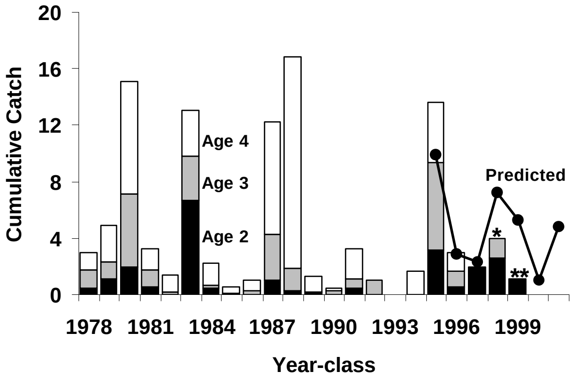


FIG. 4. Smallmouth bass year-class strength measured as the cumulative catch-per-gillnet (Outlet Basin, Lake Ontairo) of ages 2 to 4 yrs-old for the 1978 to 1997 year-classes (ages 2 to 3 yrs-old for 1998, and age 2 yrs-old for 1999** are also shown; stacked bars). Year-class strength for the 1995 to 2001 year-classes was also estimated (solid line) based on the following water temperature vs. year-class strength relationship: Log_{10}(CUE) = 0.329*(Water Temperature) - 6.241, r = .74, p = .003, N = 14).*

waters of eastern Lake Ontario (Schneider et al. 1999). The authors of the New York study attributed the increased mortality to increased levels of cormorant predation.

Bay of Quinte

Smallmouth bass abundance in the Bay of Quinte (Big Bay, Fig. 6) 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. Abundance increased during the mid-1990s but has declined again for the last three years. 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 nearly 50% originated from the 1995 year-class. In 2001 however, no fish from the 1995 year-class were observed.

The low smallmouth bass abundance during the late-1980s and early 1990s may have been due to high competitor abundance (i.e., walleye). The increase in smallmouth bass abundance in the mid-1990s was expected given lower walleye abundance and favorable weather conditions (warm summers) but the most recent decline was not anticipated. As appears to be the case in eastern Lake Ontario, another factor, such as cormorant predation, may now be of increased importance in regulating smallmouth bass abundance. Cormorant abundance and feeding activity have increased during late-summer and early fall in the Bay of Quinte in recent years (Chapter 10 in this report).

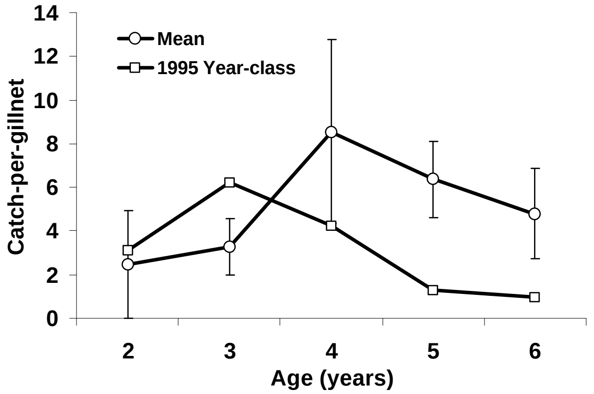


*FIG. 5. Smallmouth bass catch-per-gillnet (Outlet Basin, Lake Ontario), at successive ages for the 1995 year-class and the mean (+- 2*SE) for four other strong year-classes (1980, 1983, 1987 and 1988) for comparison.*

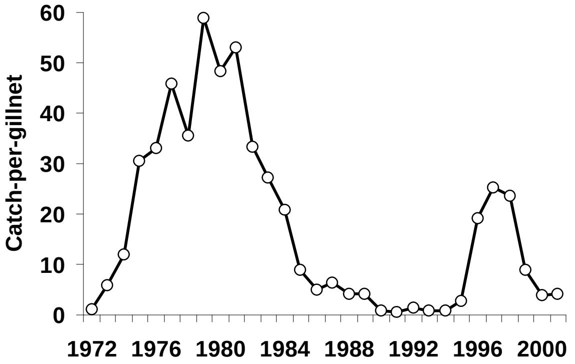


FIG. 6. Smallmouth bass abundance (3-yr running average) in Bay of Quinte index gillnets (Big Bay site) during mid-summer, 1972 to 2001.

Yellow Perch

Yellow perch are the most common species caught in our index netting surveys, and are an important commercial species (see Chapter 5 in this report). Their distribution is wide ranging throughout northeastern Lake Ontario and the Bay of Quinte. Several abundance indices, corresponding to areas of major commercial harvest interests, are presented below.

Bay of Quinte

Yellow perch have increased dramatically in the mid-1990s in the Bay of Quinte (Big Bay, Fig. 7). A broader range of age-classes was observed in 2001 compared with previous years (Fig. 8). The mean age was 2.6 yrs-old. The increase in yellow perch abundance is due to increased year-class strength beginning as early as 1993 but especially by 1995 (Fig. 9).

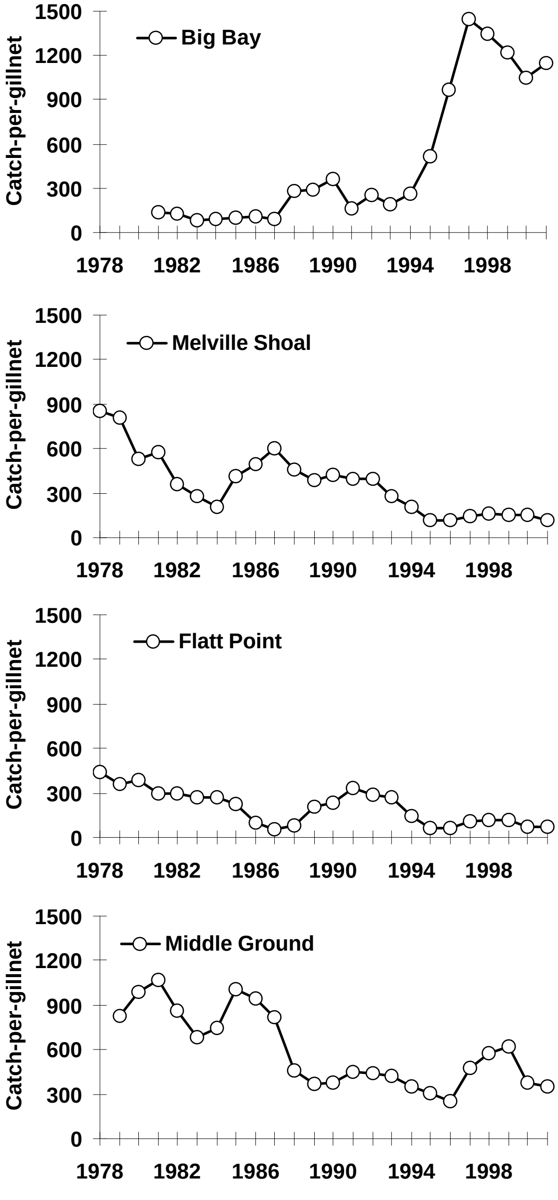


FIG. 7. Yellow perch abundance (catch-per-gillnet, 3-yr running average) in the Bay of Quinte (Big Bay, 1981 to 2001) and eastern Lake Ontario (Melville Shoal, 1978 to 2001; Flatt Point, 1978 to 2001), and Middle Ground (1979 to 2001).

Lake Ontario

Yellow perch catches in the Outlet Basin (Melville Shoal and Flatt Point, Fig. 7) declined slightly in 2001 but have been more of less stable since about 1995. The mean ages of the 2001 catches were 3.0 and 3.3 yrs-old at Melville Shoal and Flatt Point, respectively (Fig. 8). Yellow perch catches at Middle Ground also declined slightly in 2001 (Fig. 7). The mean age of the 2001 catch was 2.4 yrs-old (Fig. 8).

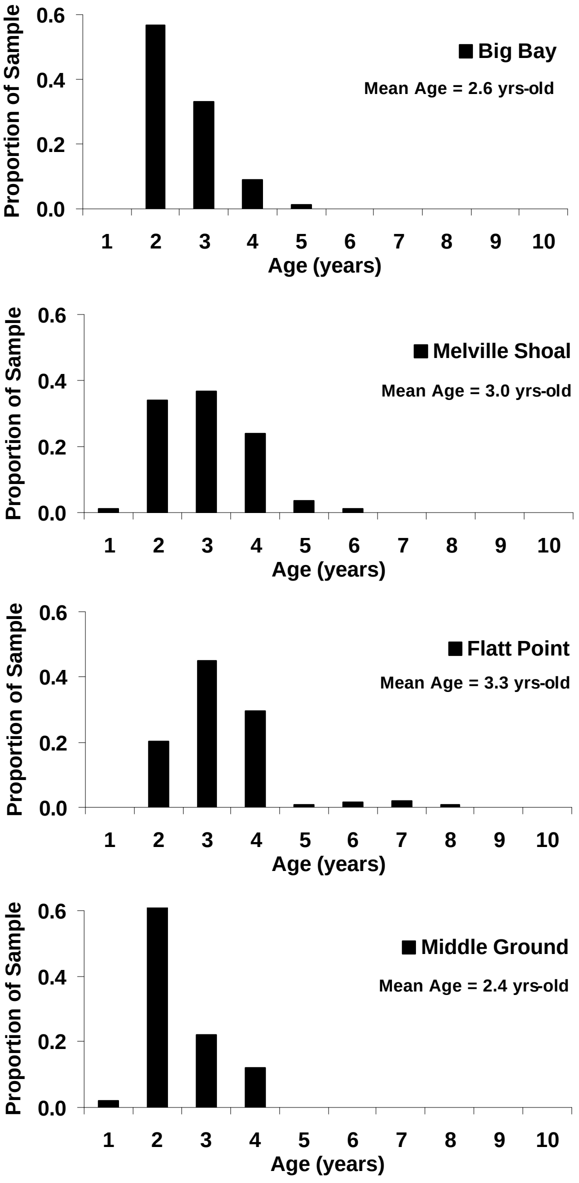


FIG. 8. Yellow perch age distributions in gillnet catches in the Bay of Quinte (Big Bay) and eastern Lake Ontario (Melville Shoal, Flatt Point, and Middle Ground), summer 2001.

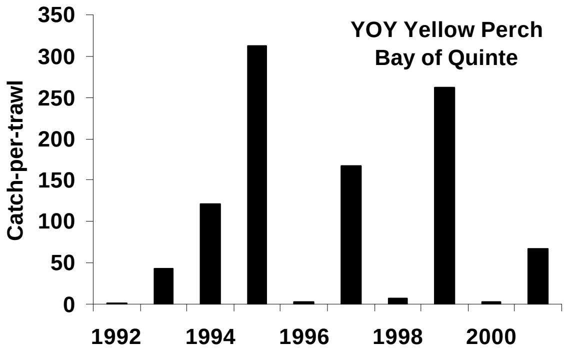


FIG. 9. Yellow perch year-class strength in the Bay of Quinte as represented by YOY catch-per-trawl (6 min duration; six sites: Trenton, Belleville, Big Bay, Deseronto, Hay Bay and Conway), 1985 to 2001.

Walleye

Walleye are the target of an important recreational fishery in the Bay of Quinte (see Chapter 7 in this report). A relatively small walleye quota is also allocated to the Lake Ontario commercial fishery which is otherwise mainly supported by lake whitefish, yellow perch and eel (see Chapter 5 in this report). Walleye also provide a spring aboriginal spear fishery and an unregulated aboriginal gillnet fishery in the Bay of Quinte.

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. Juvenile walleye remain in the Bay of Quinte year-round.

Abundance Trends

Walleye abundance was monitored at Big Bay (Bay of Quinte) and Melville Shoal (Outlet Basin of Lake Ontario, Fig. 1). Walleye abundance increased, beginning in the early 1980s at Big Bay and in the mid-to latter 1980s at Melville Shoal (Fig. 10), following production of the 1978 year-class. Walleye abundance peaked in the early 1990s and then declined. Abundance declined steadily and markedly in Big Bay; by 2001 abundance had declined by about 80% compared to the 1980s and early 1990s, and to its lowest level since the 1970s. At Melville Shoal abundance declined only slightly until the last two years when it declined by about 50% compared with early and mid-1990s levels.

Walleye age-class composition at the two sites reflected the age-specific distribution pattern of walleye during mid-summer (Fig. 11); young fish at Big Bay (e.g., mainly 1 to 5 yrs-old) and older, mature fish at Melville Shoal (e.g., mainly greater than 5 yrs-old).

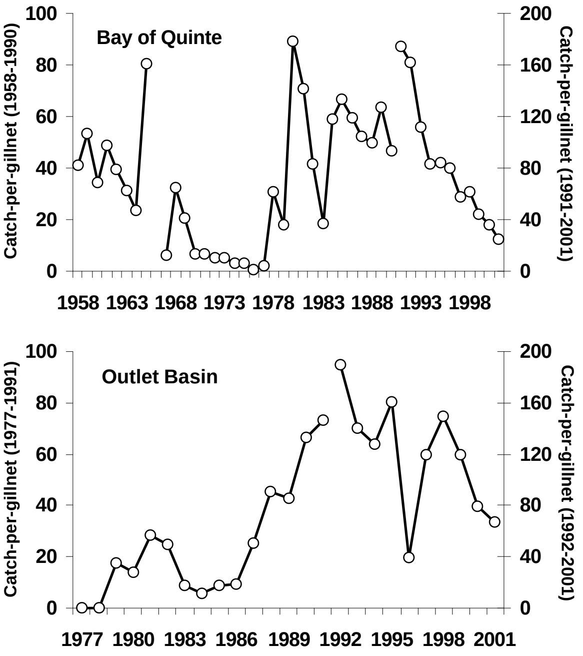
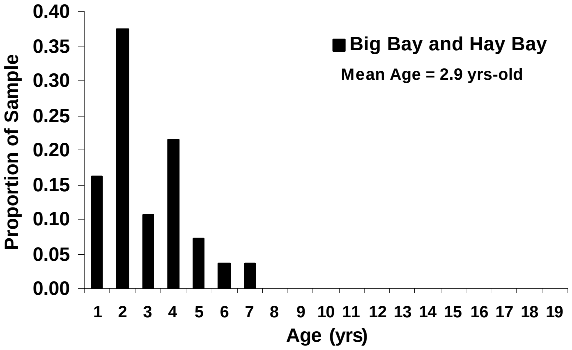


FIG. 10. Walleye abundance (least-square mean) in gillnets in the Bay of Quinte (Big Bay and Hay Bay), 1958 to 2001 (no gillnetting in 1966) and the Outlet Basin (Melville Shoal), 1977 to 2001, during summer. Multifilament gillnets (x-axis) were replaced with monofilament (y-axis) in 1991 in the Bay of Quinte and in 1992 in eastern Lake Ontario. The secondary y-axis is scaled by a factor of two relative to the primary y-axis because mono/multifilament gear comparisons showed that monofilament gillnets caught about twice as many walleye.

Year-class Strength

Young-of-the-year walleye abundance was measured in August bottom trawls at several Bay of Quinte sites (Fig. 12). The YOY catches represent a "first look" at walleye year-class strength but should be interpreted with caution when predicting future recruitment to older age-classes. 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, the 2000 year-class was low, and finally the 2001 year-class was similar to 1999 (Fig. 12).



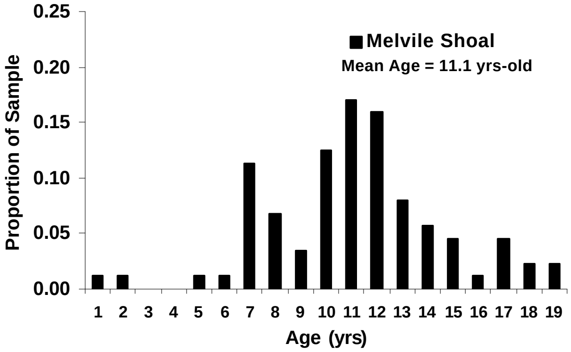


FIG. 11. Walleye age distributions in gillnets in the Bay of Quinte (Big Bay) and the Outlet Basin (Melville Shoal), Lake Ontario, 2001.

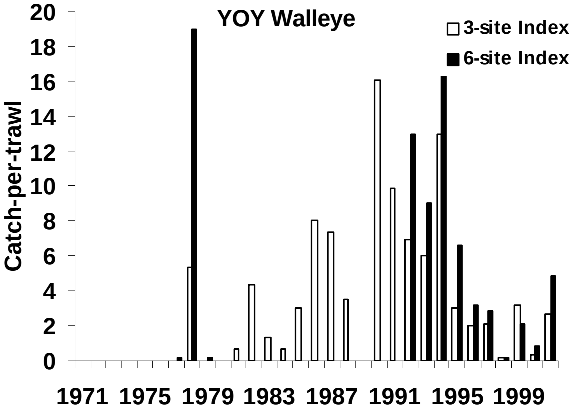


FIG. 12. Young-of-the-year walleye catch-per-trawl in the Bay of Quinte, 1972 to 2001 (no trawling in 1989) at 3 sites (Big Bay, Hay Bay and Conway), and 1972 to 1980, 1992 to 2001 (no trawling in 1989) at six sites (3 above plus Trenton, Belleville, and Deseronto).

Lake sturgeon

Eastern Lake Ontario commercial fishermen have reported moderate numbers of small lake sturgeon annually since 1996 (e.g., 49 fish in 1998, 35 in 1999, 24 in 2000, and 14 in 2001). Most of these fish are 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 except for 2000. One sturgeon was captured in 2001 (Table 1).

Table 1. Statistics for single lake sturgeon caught during index gillnetting in eastern Lake Ontario and the Bay of Quinte, 2001.

Site	Date	Depth (m)	Water Temp (^oC)	Mesh Size (mm)	Total Length (mm)	Weight (g)
GI13	July 10	12.5	15.5	140	738	2278

Round Goby

Round goby was accidentally introduced into Lake St. Clair around 1990, and has since spread throughout the Great Lakes. In Lake Ontario it was first seen near St. Catherines in 1998, and a number of sightings in the following summer suggests that gobies became established in the Niagara-Hamilton area. In 1999 round gobies were also observed, for the first time, in the Bay of Quinte area of eastern Lake Ontario. Their sudden jump from the western end of the lake to the Bay of Quinte, and that they were first detected near docks used by large shipping vessels, suggests that they were introduced to the Bay of Quinte through ballast water.

All of 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. A number of sightings in the following year (2000) suggested that the gobies became established throughout the lower Bay of Quinte. The sightings in 2001 (Fig. 13) suggest that the gobies have not progressed much further up the Bay, although their abundance in the established area is increasing. Reports to the east of the Bay were few in 2001, but show that gobies are now present as far as Kingston.

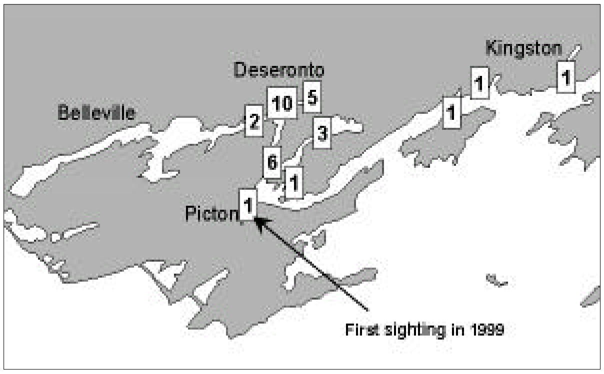


FIG. 13. Sightings of round gobies in Eastern Lake Ontario in 2001. Numbers of angler reports are shown; each report may contain more than one goby.

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4

St. Lawrence River Fish Community

P. A. Edwards, T. J. Stewart, A. Mathers

Introduction

The St. Lawrence River fish community is dominated by a rich assemblage of warm-water species; over 85 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, lake sturgeon and muskellunge. Yellow perch, smallmouth bass, and northern pike provide an important recreational fishery in the Thousand Islands area (Bendig 1995). In addition, the yellow perch and eel support an important commercial fishery (Chapter 6 in this report).

The waters of the St. Lawrence River, and in 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 in response to both environmental change and fishing pressures. Fish population levels declined throughout the early 1990s, but in many cases have reached a new equilibrium, one that is consistently lower than that experienced in the 1980s. The abundance of bass in fall gillnetting programs in the Thousand Islands area has declined throughout most of the 1990s. In eastern Lake Ontario, where a very similar trend has been observed, the decline was attributed to poor year-class strength related to cool summer water temperatures during the early 1990s (Hoyle and Schaner 2002) and increasing predation by cormorants (Schneider et al. 1999).

Populations of pike have declined throughout the 1990s. A variety of factors including cool spring weather, low spring water levels, and changes in the aquatic vegetation have been suggested as contributing to poor pike reproduction during this time period (Casselman 1996).

American eel spawn in the Sargasso Sea (Scott and Crossman 1973). A portion of the juvenile population migrates up the St. Lawrence River and into Lake Ontario. The eels reside in Lake Ontario for several years before migrating back to sea. While in Lake Ontario, eels provide 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). 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 for all fish species in 2001 and updates trends in abundance for yellow perch, smallmouth bass, northern pike and American eels.

Information Sources

Fisheries assessment activities on the St. Lawrence River have included standardized fall gillnetting, creel surveys, and monitoring the eels migrating over the ladder at the R.H. Saunders Hydroelectric Dam in Cornwall. The fall gillnetting program is designed to detect long-term changes in the fish communities and has been established in four distinct sections of the river; Thousand Islands, Middle Corridor, Lake St. Lawrence, and Lake St. Francis. These programs have been coordinated with the New York State Department of Environmental Conservation (NYDEC) assessment programs to provide ‘river-wide’ coverage of fisheries resources.

The 2001 netting program differed from previous years in that a new gillnet standard was introduced. Due to insufficient stock from the supplier, monofilament nets were used during the 2001 field program in addition to the multifilament nets used in previous years. A complete description of net construction details is provided in Table 1. In order to compare the catches of the new and old net designs, half of the gillnet sets were made with multifilament nets and the other half of the sets were made with monofilament nets. The 2001 netting in the Thousands Islands was conducted between September 10 and October 5, 2001, using methods described by Mathers and Stewart (2001). This program maintained the database established in 1987 and represented the eighth netting program in the Thousand Islands 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. 1997). In this report, we provide estimates for the total number of eels ascending the ladder and update the recruitment index for 2001.

Fish Species Update

The overall catch from 48 gillnet sets in the 2001 Thousand Islands project was 1,764 fish comprising 20 species (a complete summary of standardized gillnet catch-per-unit-effort is listed in Appendix C). The average number of fish captured per net set during 2001 (23.9 fish per net, both netting types combined) was lower than was observed in the 1999 survey, and the numbers of fish remain lower than those observed during the late 1980s (Fig. 1).

Preliminary examination of the data indicated that for most species the monofilament gillnet catches were higher (Fig. 2). The limited amount of data precludes assigning species specific conversions at this time. For all species combined the distribution of catches in monofilament and multifilament gillnet were not significantly different from normal ($p<0.2$, Kolmogorov-Smirnov test, Zar 1984), so simple parametric statistical tests were applied. There was no significant difference between the mean catch in deep and shallow strata. A comparison of mean catch of all species, depth strata combined, indicated that the mean monofilament catch (45.04 fish/set) was significantly higher ($p<0.01$) than the multifilament catch (28.46 fish/net). Therefore we applied a correction factor of 1.58 to convert the historical multifilament catch rates to the new monofilament standard.

Table 1. Description of new St. Lawrence River standard gillnet, 2001.

Stretched Mesh Size (inches)	Panel Length (feet)	Gear Height (feet)	Twine Diameter (mm)	# Meshes Deep	# Meshes Long	# Ties	Tie Length (inches)	Meshes per Tie
1.5	25	8	0.2	72	400	26.6	11.25	15
2	25	8	0.28	54	300	27.25	11	11
2.5	25	8	0.33	44	240	26.6	11.25	9
3	25	8	0.28	36	200	25	12	8
3.5	25	8	0.33	32	171	24.5	12.25	7
4	25	8	0.33	27	150	25	12	6
5	25	8	0.4	21	120	24	12.5	5
6	25	8	0.4	18	100	25	12	4
Total	200							

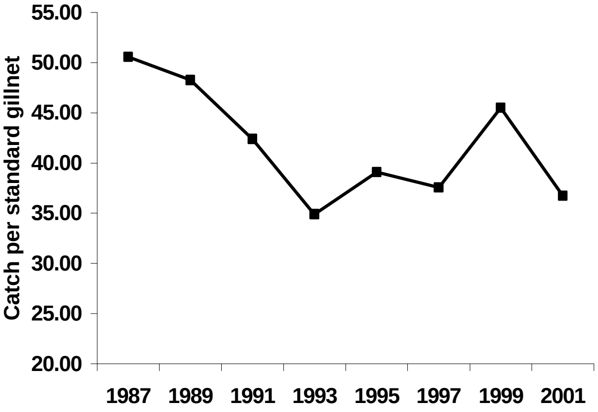

FIG. 1. Total number of fish captured in standard gillnets in the Thousand Islands area, St. Lawrence River, 1987-2001.

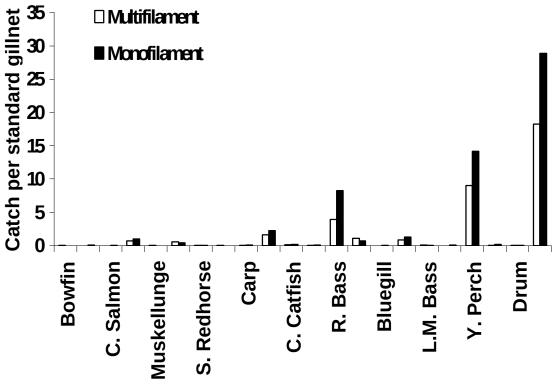

Fig. 2. Catch per standard mutlifilament and monofilament gillnets (depth strata combined) in the Thousand Islands area, 2001.

Yellow Perch

Although yellow perch continued to be the most abundant fish captured in the Thousand Islands gillnet program, the total catch in 2001 declined from that in 1999. The catches of yellow perch since 1995 however remain good relative to the period between 1989 and 1993 (Fig. 3). Catches of yellow perch in the Eastern Basin of Lake Ontario, Melville Shoal in particular, also declined slightly in 2001 (Chapter 3 in this report).

Smallmouth Bass

The recovery of smallmouth bass suggested by 1999 observations was not supported in 2001. Smallmouth bass abundance in 2001 resembled the low catches reported during 1993 to 1997 (Fig. 4). A similar pattern of declining catch was observed in 2001 in the Eastern Basin of Lake Ontario (Chapter 3 in this report).

Northern Pike

The decline in northern pike catches observed throughout the 1990's continued to be evident in the 2001 catch (Fig. 5). A similar decline in northern pike catches has been reported over the same time period in the New York waters of the Thousand Islands (McCullough 2002).

Other Species

Pumpkinseed and rock bass are also monitored by this program and are commercially harvested on the St. Lawrence River. Pumpkinseed populations appear to have followed a trend similar to the smallmouth bass, peaking in 1989 and then gradually declining over the next 10 years (Appendix C). Although catches of pumpkinseed increased during 1999, they resumed their declining trend in 2001. Rock bass abundance increased dramatically during 1999, a trend that continued in 2001, and remains the second most abundant species captured (Appendix C).

American Eel

The eel ladder was opened on June 3 and closed on November 8 (159 days). During this time period, the New York Power Authority trapped and transported eel at the base of the dam and released them above the dam to evaluate the effect of the release site on upstream migration. Some eels did migrate over the ladder, were captured in a net at the top of the ladder, and counted as was the practice in previous years. The estimated total number of eels, which would have exited the ladder in 2001 if there were no trap and transfer program, was 944; the lowest number

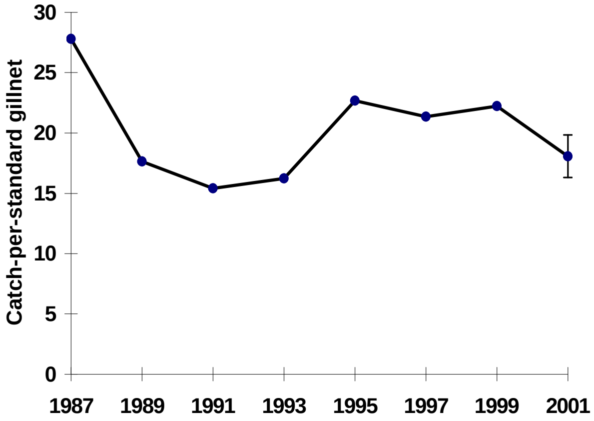

FIG. 3. Yellow perch catch in standard gillnets set in the Thousand Islands area 1987-2001. 95% confidence intervals were not applied to corrected historical data.

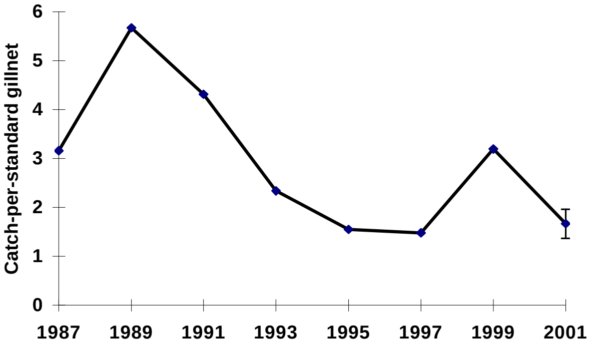

FIG. 4. Smallmouth bass catch in standard gillnets set in the Thousand Islands area, St. Lawrence River, 1987-2001. 95% confidence limits were not applied to corrected historical data.

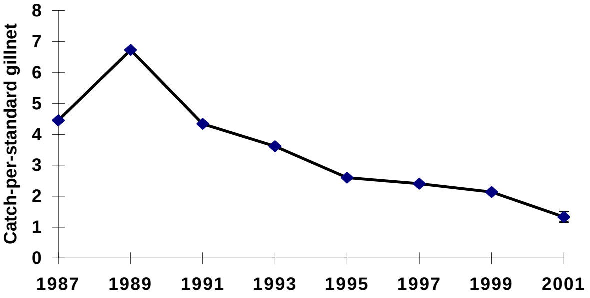

FIG. 5. Northern pike catch in standard gillnets set in the Thousand Islands area, St. Lawrence River, 1987-2001. 95% confidence limits were not applied to corrected historical data.

recorded since the installation of the ladder in 1974. The recruitment index (Casselman et al. 1997) was calculated to be 21 eels/day, based on the 31-day peak migration period occurring from June 19 to July 19, and was also the lowest value estimated in the operation of the ladder (Fig. 6). The recruitment index is correlated with commercial catches of eel 8 years later in Lake Ontario (Casselman et al. 1997).

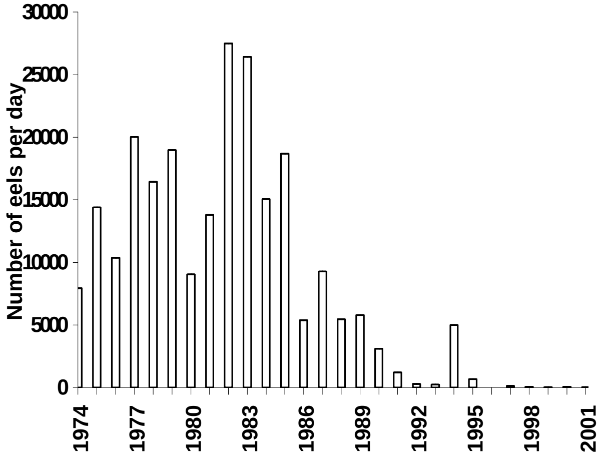

FIG. 6. Mean number of eels ascending the eel ladder per day at the R.H. Saunders Hydroelectric Dam, Cornwall, Ontario, during a 31-day peak migration period for 1974 to 2001. Vertical bars indicate the 95% confidence intervals. No counts were available for 1996. (Data from 1974-1995 re-drawn from data provided in Casselman et al. 1997).

Discussion

Although age distribution information for the 2001 program was unavailable for inclusion at the time of this report, yellow perch, bass and pike samples will indeed be aged to determine relative year class strength for 2001. The gear related conversion factor for the difference in catch-per-standard-gillnet (multifilament versus monofilament net) indicated in this report is preliminary and comparisons will be repeated once more in 2003. The two nets will also be compared in a similar study occurring on Lake St. Francis in 2002 and 2004. The low indices of recruitment of eel for the last decade do not bode well for the future of the commercial eel fishery in Lake Ontario and the upper St. Lawrence River. Continued declines in the number of eels ascending that ladder to almost negligible levels may be an early indication of stress in the global eel population.

Information and Research Needs

Additional work to verify the influence of temperature and evaluate the impacts of double-crested cormorant feeding on the abundance of both game and forage fish. This is particularly important with respect to estimating survival and the subsequent management of the smallmouth bass fishery. Our ability to effectively manage eels in the upper St. Lawrence River and Lake Ontario would be improved by a better understanding of the status of American eel throughout their range. In addition, the importance of eels that mature in the upper St. Lawrence River and Lake Ontario to the global eel stock requires clarification.

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5

Lake Ontario Commercial Fishery

J. A. Hoyle and A. Mathers

Introduction

Lake Ontario supports a relatively small but locally important commercial fish industry. The commercial harvest comes primarily from the Canadian waters of eastern Lake Ontario and the Bay of Quinte. Here, the most important species in the harvest include yellow perch, lake whitefish, walleye, eel and brown bullhead. About one million lbs (wholesale value of $1 million) are harvested annually from Canadian waters. This chapter updates the 2001 commercial harvest statistics for the Canadian waters of Lake Ontario.

Quota Management

The overall direction of commercial fish management is to support and assist the commercial fishing industry and while remaining consistent with the conservation and rehabilitation of fish stocks. In addition to conservation of fish stocks, license conditions attempt to reduce problems of incidental catch, manage the harvest and sale of fish that exceed human consumption guidelines for contaminants, 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). Managed species include 'premium' commercial species (e.g., lake whitefish, eel, black crappie, yellow perch), species with large allocations to other users (e.g., walleye), and species at low levels of abundance or requiring rehabilitation (e.g., lake herring). Changes to commercial fish licensing conditions in 2001 included minor

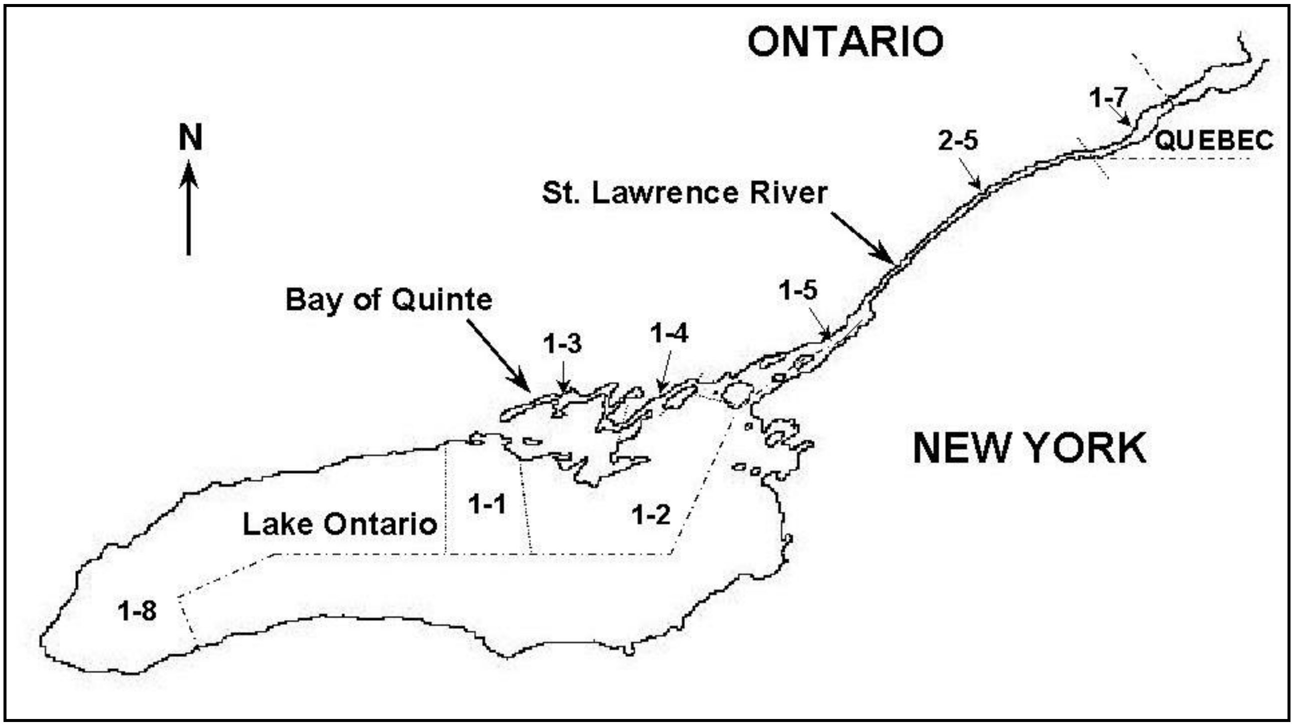

FIG. 1. Commercial fish quota zones on the Canadian waters of Lake Ontario (including the Bay of Quinte) and the St. Lawrence River.

TABLE 1. Commercial harvest quotas (lb) for the Canadian waters of Lake Ontario, 2001. See Fig. 1 for a map of the quota zones.

Species	Quota (lb) by Quota Zone					
	1-1	1-2	1-3	1-4	1-8	Total
American eel	20,565	108,195	33,065	14,388	4,680	180,893
Black crappie	3,940	2,500	15,810	800	2,800	25,850
Lake herring	15,690	15,300	7,250	7,337	-	45,577
Lake whitefish	25,159	291,460	61,728	79,324	1,280	458,951
Round whitefish	10,000	0	0	0	0	10,000
Walleye	4,876	42,892	-	12,796	800	61,364
Yellow perch	35,585	185,026	96,128	126,520	13,000	456,259

adjustments to quota; compare Table 1 in this report to Table 1 in Hoyle et al. (2001).

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, in collaboration with the Ontario Commercial Fisheries Association (OCFA), 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.

Commercial Harvest Summary

Commercial harvest statistics for 2001 are shown in Table 2. In 2001, there were 117 commercial fishing licenses on Lake Ontario. The total harvest of all species was 840,557 lb ($861,977.51) in 2001.

Lake whitefish

Lake whitefish harvest was 224,898 lb, 49% of the quota (Table 3), in 2001. The annual lake whitefish harvest has declined since 1996.

Eel

Eel harvest was 24,815 lb, 30% of the quota, in 2001. Eel harvest had been in decline since 1992 but doubled between 1999 and 2000. Harvest declined slightly in 2001.

Yellow perch

Yellow perch harvest was 199,036 lb, 44% of the quota, in 2001. Yellow perch harvest had increased significantly from 1996 to 1999 but declined slightly in 2000 and declined further by over 20% in 2001.

Walleye

Walleye harvest was 18,302 lb, 30% of the quota, in 2001. Walleye harvest had declined significantly in 1999 and 2000 but increased in 2001.

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.

Mean length and age in Quota Zone 1-2, representing the Lake Ontario whitefish stock, were 477 mm and 9.3 yrs-old, respectively (Fig. 2). The 1991 and 1992 lake whitefish year-classes contributed over 50% of the harvest.

In the Bay of Quinte (Quota Zone 1-3), the mean length and age were 480 mm and 9.0 yrs-old, respectively (Fig. 3). For the eighth year in succession, the 1991 year-class dominated the harvest, accounting for 45%.

Discussion

Although commercial fishing gear has remained

TABLE 2. Commercial fish harvest (lb) and value ($) for fish species in the Canadian waters of Lake Ontario, 2001.

	Harvest by Quota Zone (lb)						Price-	
Species	1-1	1-2	1-3	1-4	1-8	Total	per-lb	Value
American eel	1.494	11.718	6.195	1.457	3.951	24.815	$ 2.13	$ 52.855.95
Black crappie	110	110	8,411	6	509	9,146	$ 2.16	$ 19,755.36
Bowfin	2,032	92	4,949			7,073	$ 0.28	$ 1,980.44
Brown bullhead	14,004	1,032	101,930	3,659	28,620	149,245	$ 0.32	$ 47,758.40
Channel catfish		6	317	3	8,387	8,713	$ 0.30	$ 2,613.90
Common carp	12	12,516	1,117	1,695	9,153	24,493	$ 0.23	$ 5,633.39
Freshwater drum	195	6,905	33,268	6,205	17,685	64,258	$ 0.15	$ 9,638.70
Lake herring	8	267	669	497		1,441	$ 0.28	$ 403.48
Lake whitefish	7,195	177,601	26,835	13,254	13	224,898	$ 0.73	$ 164,175.54
Sunfish	3,345	1,767	77,786	151	319	83,368	$ 1.00	$ 83,368.00
Rock bass	1,502	3,458	3,307	208	3,003	11,478	$ 0.57	$ 6,542.46
Suckers	44	44	4,836		4,197	9,121	$ 0.13	$ 1,185.73
Walleye	1,061	11,730		5,112	399	18,302	$ 2.01	$ 36,787.02
White bass		1		57	32	90	$ 1.01	$ 90.90
White perch	99	80	2,268	1,252	1,381	5,080	$ 0.64	$ 3,251.20
Yellow perch	2,458	83,892	45,904	64,209	2,573	199,036	$ 2.14	$ 425,937.04
Total	33,559	311,219	317,792	97,765	80,222	840,557		$ 861,977.51

similar, the age distribution of lake whitefish in the harvest has changed significantly in recent years. Lake whitefish formerly recruited to the fishery as early as age-3 for males and age-4 for females. For example, the 1991 year-class was the largest year-class in the Bay of Quinte lake whitefish fishery in 1994 at age-3. Age of recruitment to the fishery has subsequently increased. In 2001, fish recruited to both Lake Ontario and Bay of Quinte fisheries at age-6. Initial interpretation of the lack of new recruitment to the fisheries included poor survival of young fish. It now appears that delayed age-at-maturity and reduced growth rates (see Chapter 2 in this report) can account for the change in the pattern of recruitment to the fisheries. The 1994 and 1995 year-classes of whitefish, which appeared to be strong as young-of-the-year in index trawling surveys, are just now recruiting to the fisheries. These two year-classes along with previous strong year-classes (e.g., 1992, 1991 and 1987) could sustain lake whitefish commercial harvest for several more years. However, more recent year-classes have been weak or failed (see Chapter 2 in this report). This will negatively impact the future commercial harvest.

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 relative abundance increases. Given that poor year-class strength in recent years will negatively impact commercial harvest, a more rigorous approach is needed. Estimation of a recommended allowable harvest (RAH) using an age-structured population model fitted to the heterogeneous mix of fishery and index fishing should provide better information on which to base a total allowable catch (TAC). The challenge for such a model will be to account for changes in catchability and selectivity due to on-going and dramatic changes in lake whitefish growth characteristics. Further, it may be appropriate to determine a “critical stock size” or “minimum spawning stock biomass”, below which no further harvest should occur.

The low numbers of new eel recruits passing the eel ladder at the Cornwall dam (see Chapter 4 of this report) can account for the 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. The complex global nature of the eel life-cycle, uncertainty regarding the cause of their decline, and economic interest in eels among numerous international management jurisdictions poses a significant challenge to effective management to sustain the population. As such, a

TABLE 3. Commercial harvest (% of quota) for the Canadian waters of Lake Ontario, 2001.

	Harvest (% of Quota)					
Species	1-1	1-2	1-3	1-4	1-8	Total
American eel	7%	11%	19%	10%	84%	14%
Black crappie	3%	4%	53%	1%	18%	35%
Lake herring	0%	2%	9%	7%		3%
Lake whitefish	29%	61%	43%	17%	1%	49%
Round whitefish	1%					1%
Walleye	22%	27%		40%	50%	30%
Yellow perch	7%	45%	48%	51%	20%	44%

management plan to sustain this species throughout its range should be coordinated and implemented by Canadian and U.S. federal agencies.

The yellow perch is a valuable commercial species that showed widespread increases in abundance in the late-1990s but appears to have declined somewhat in the last two years (see Chapter 3 in this report). Pressures to maximize harvest, and therefore commercial benefits, are high—especially with other commercial species in decline. The relatively low risk consequences of yellow perch over-harvest suggests that current harvest levels are appropriate.

Heterosporis sp. (Microsporidea: Pleistophoridae), a previously unknown parasite that severely degrades yellow perch flesh, has recently been detected in the eastern Lake Ontario region. The infection has the appearance of "freezer-burn" in the flesh of the fish. The rate of infection is currently low (see Chapter 17 in this report). Local commercial fishers and fish buyers have observed that up to a maximum of about 10% of some catches were infected in 2001. An increased infection rate could lead to reduced marketability of yellow perch.

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.

References

HOYLE, J.A., R. HARVEY, AND S. ORSATTI. 2001. Lake Ontario Commercial Fishery. 6 p. Part

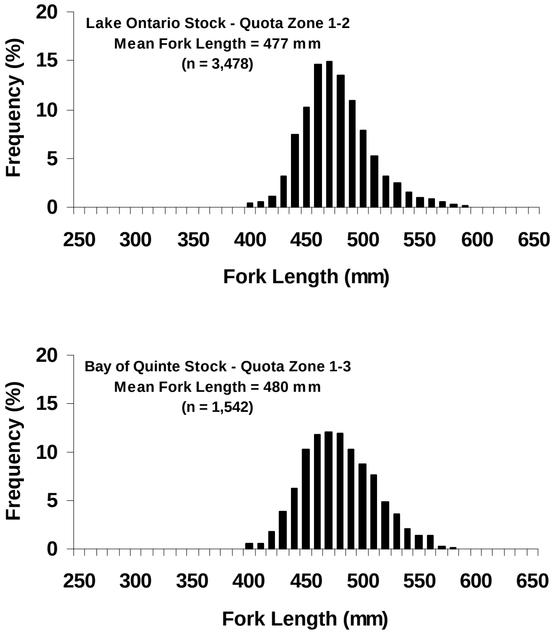

FIG. 2. Fork length (mm) distribution of lake whitefish in Quota Zone 1-2 (upper panel) and 1-3 (lower panel) in the 2001 commercial harvest.

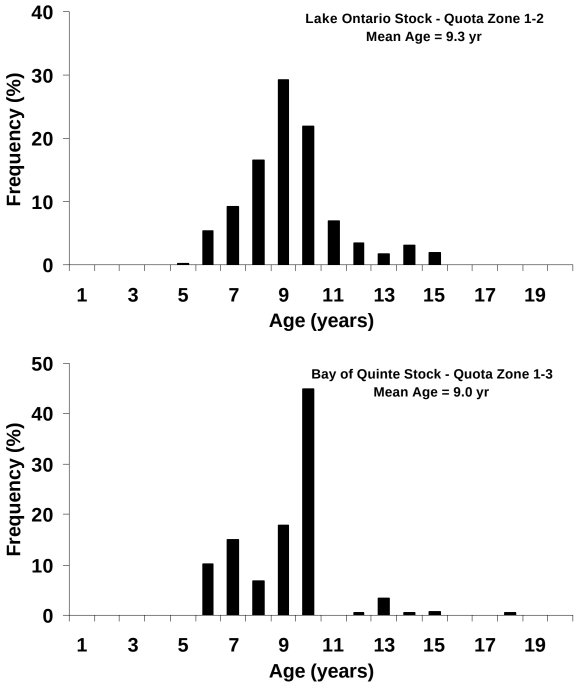

FIG. 3. Age distribution of lake whitefish in Quota Zone 1-2 (upper panel) and 1-3 (lower panel) in the 2001 commercial harvest.

6

St. Lawrence River Commercial Fishery

J. A. Hoyle

Introduction

The St. Lawrence River supports a commercial fishery with an annual harvest of about 350,000 lb and a landed value of about $400,000. The most important species in the harvest are yellow perch, sunfish, brown bullhead and eel. This chapter updates 2001 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 while being consistent with the conservation and rehabilitation of fish stocks. In addition to conservation 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).

Changes to commercial fish licensing conditions in 2001 included minor adjustments to quota; compare Table 1 in this report to Table 1 in Hoyle et al. (2001).

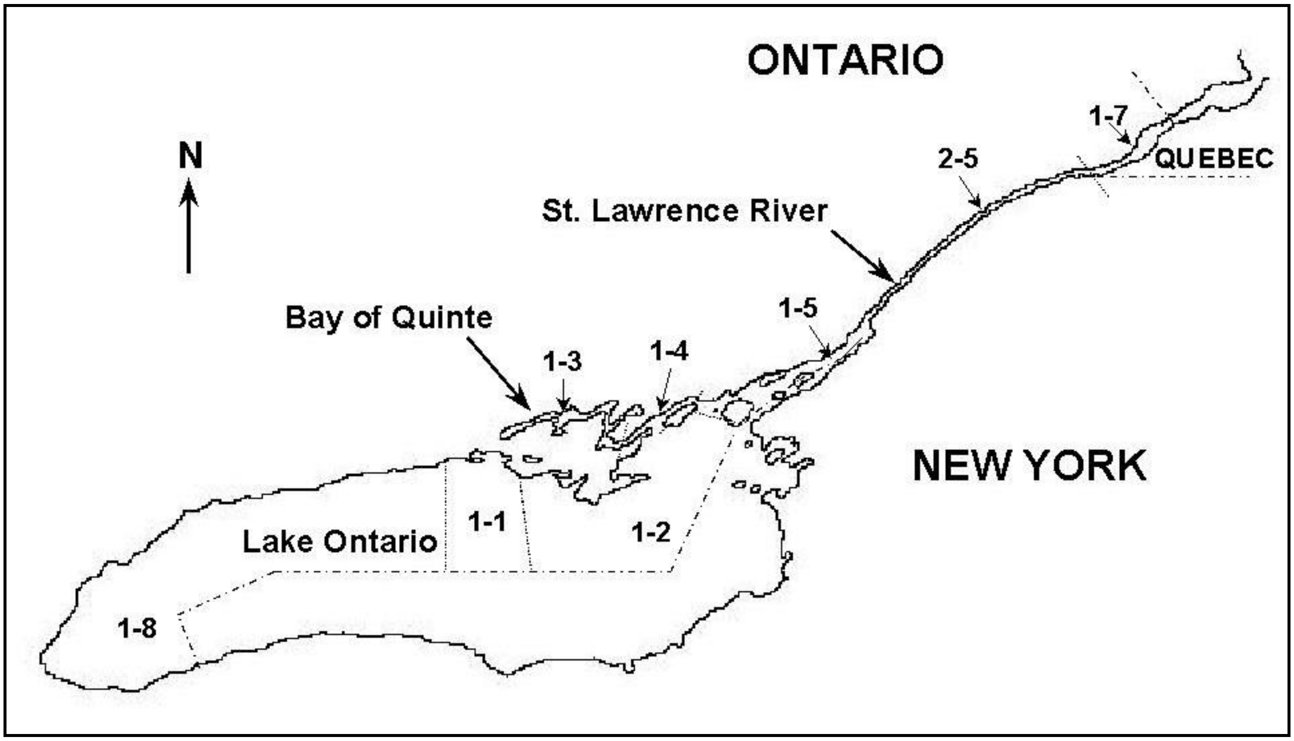

FIG. 1. Commercial fish quota zones on the Canadian waters of Lake Ontario and the St. Lawrence River.

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 2001 are shown in Tables 2 and 3. In 2001, there were 32 commercial fishing licenses on the St. Lawrence River. The total harvest of all species was 272,523 lb ($352,521.14) in 2001.

Eel

Eel harvest was 37,988 lb in 2001, up slightly from 36,080 lb in 2000. The majority of the eel harvest came from below the dam at Cornwall (Quota Zone 1-7) where the majority of the quota is harvested (94%).

Yellow perch

Yellow perch harvest was 58,390 lb in 2001, down 20% from the 2000 harvest. As was the case in 2000, the 2001 harvest declined in all three quota zones. The harvest represented 38% of the total quota (Table 3).

Other species

The commercial harvest of black crappie has declined dramatically, after peaking in 1999 at over 22,000 lb, to 7,934 lb in 2001. Most of the black crappie harvest comes from quota zone 1-5.

Discussion

Low indices of eel recruitment for the last decade do not bode well for the future of the commercial eel fishery in the upper St. Lawrence River and Lake

TABLE 1. Commercial harvest quotas (lb) for the Canadian waters of the St. Lawrence River, 2001. See Fig. 1 for a map of the quota zones.

	Quota (lb) by Quota Zone			
Species	Napanee (1-5)	Brockville (2-5)	Cornwall (1-7)	Total
Eel	13,360	10,825	32,822	57,007
Black crappie	25,590	18,065	4,840	48,495
Yellow perch	66,675	83,173	5,760	155,608

Table 2. Commercial fish harvest (lb) and value ($) for fish species in the Canadian waters of the St. Lawrence River, 2001.

	Harvest by Quota Zone (lb)					
Species	Napanee (1-5)	Brockville (2-5)	Cornwall (1-7)	Total	Price-per-lb	Value
American eel	4,661	2,448	30,879	37,988	$ 3.07	$ 116,623.16
Black crappie	6,881	387	666	7,934	$ 2.08	$ 16,502.72
Bowfin	3,518			3,518	$ 0.32	$ 1,125.76
Brown bullhead	32,718	9,884	67,863	110,465	$ 0.41	$ 45,290.65
Channel catfish	21			21	$ 0.27	$ 5.67
Common carp	222			222	$ 0.12	$ 26.64
Freshwater drum	66			66	$ 0.13	$ 8.58
Sunfish	21,754	14,056	13,926	49,736	$ 0.92	$ 45,757.12
Rock bass	473	1,024		1,497	$ 0.42	$ 628.74
Suckers	15		1,421	1,436	$ 0.10	$ 143.60
White perch	1,250			1,250	$ 0.72	$ 900.00
Yellow perch	30,726	25,582	2,082	58,390	$ 2.15	$ 125,538.50
Total	102,305	53,381	116,837	272,523		$ 352,551.14

Table 3. Commercial harvest (% of quota) for the Canadian waters of the St. Lawrence River, 2001.

Species	Harvest (% of Quota)			Total
	Napanee (1-5)	Brockville (2-5)	Cornwall (1-7)	
American eel	35%	23%	94%	67%
Black crappie	27%	2%	14%	16%
Yellow perch	46%	31%	36%	38%

Ontario (Chapter 4 in this report). Local eel management could potentially be improved by a better understanding of American eel status throughout their range (see Chapter 5 in this report).

The decline in yellow perch harvest over the past two years is consistent with slight declines in index gillnetting catches (Chapter 4 in this report, McCullough 2002). Yellow perch commercial harvest and abundance in index netting surveys in eastern Lake Ontario and the Bay of Quinte (Chapters 3 and 5 in this report) also declined somewhat from 1999 to 2001. These recent declines in perch abundance come after a period of generally increasing abundance in the mid-1990s.

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7

Bay of Quinte Recreational Fishery

J. A. Hoyle

Introduction

The Bay of Quinte supports a large and economically important recreational fishery. Walleye have been the dominant species sought and harvested in the fishery since the early 1980s. This recreational fishery grew when 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 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 from the Bay to Lake Ontario after spawning each spring to spend the summer months (see Chapter 3, Fig. 11 in this report). 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 seasonally for harvest in the Bay of Quinte recreational fishery.

There are two major components to the walleye angling fishery, the winter ice fishery and the open-water fishery. The ice fishery occurs primarily in January and February and has less angling effort and harvest than the open-water fishery. High annual variation in fishing pressure and success during the ice fishery is largely due to unpredictable ice conditions. Walleye of all sizes are harvested in the winter fishery. The open-water fishery occurs from the first Saturday in May to about the end of November. The harvest consists mainly of young immature fish except in the late fall when large fish are much more common. 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 which have favored fish species such as yellow perch and centrarchids (bass and sunfish). These changes have resulted in a decline in the abundance of young walleye—those residing year-round in the Bay of Quinte; as a result there has been a large impact on the open-water recreational fishery.

This chapter updates the results of ice and open-water recreational angling surveys conducted in 2001.

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 (2000, 2001) reports detailed survey designs for ice and open-water surveys, respectively.

Fisheries Update

Ice Fishery

Ice angling effort in 2001 was estimated to be 77,074 angler-hours (Table 1). Effort was down 45% from the previous year and down 62% from the previous 5-yr average to its lowest level since winter ice angling surveys began in 1982 (Fig. 2). An estimated 982 walleye were caught of which 938 were harvested. The number of walleye harvested was down 90% compared with the previous year (Fig. 2). Fishing success rate was also down 82% compared to that of the previous year (Fig. 2), accounting for the low walleye catches and possibly for the dramatic

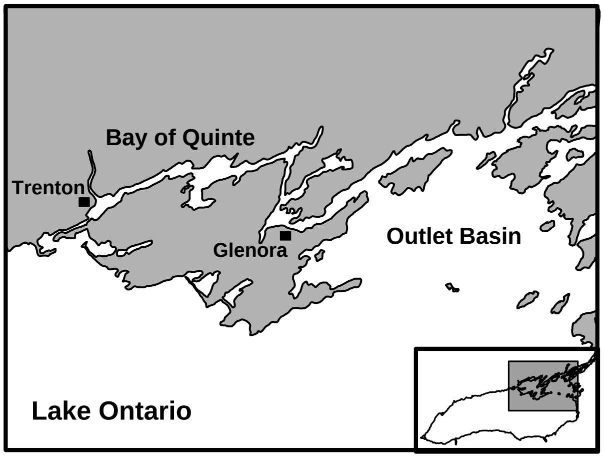

FIG. 1. Map of the Bay of Quinte showing the extent of recreational angling surveys from Trenton in the west to Glenora in the east.

TABLE 1. Bay of Quinte walleye recreational angling effort (angler hours), catch and harvest, 2001.

Season	Effort	Catch	Harvest
Ice Fishery:			
Ice-fishing total	77,074	982	938
Open-water fishery:			
Opening weekend	40,574	1,617	1,132
May	77,540	16,497	13,161
June	19,169	2,736	1,698
July	25,568	8,288	4,552
August	30,151	8,578	6,230
Fall	29,050	2,797	1,264
Open-water total	222,052	40,512	28,037
Annual total	299,126	41,494	28,975

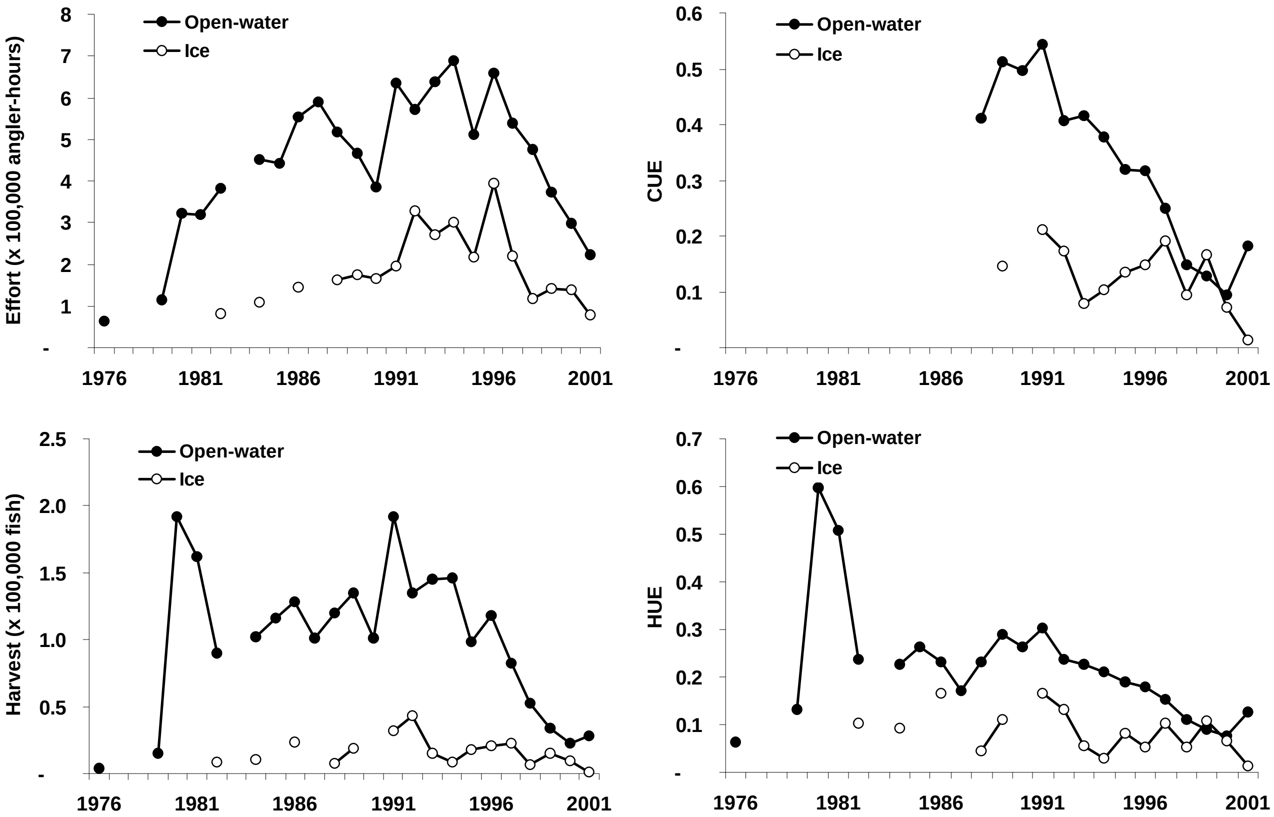

FIG. 2. Walleye angler effort, harvest, catch-per-unit-effort (CUE) and harvest-per-unit-effort (HUE) during the Bay of Quinte ice and open-water recreational fisheries, 1976 to 2001.

Table 2. Angling statistics for the Bay of Quinte open-water fishery, May 5 to November 30, 2001. 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	10,835	1,658	0.268	0.111
Sunfish	32,205	1,030	1.466	0.546
Smallmouth bass	6,116	803	0.495	0.070
Largemouth bass	19,740	4,597	0.762	0.160
Yellow perch	143,530	7,768	1.213	0.482
Walleye	40,734	28,078	0.182	0.126
Total	253,159	43,934		

decline in fishing effort. The average walleye harvested during the ice fishery was 579 mm fork length and weighed 2.5 kg.

Open-water Fishery

Open-water angling effort was estimated to be 222,052 angler-hours (Table 1, Fig. 2). Angling effort has declined for five consecutive years to its lowest level since 1979. Walleye catch was estimated at 40,512 fish of which 28,037 were harvested. The number of walleye harvested was up 23% from last year despite the decline in fishing effort (Fig. 2). This was because walleye angling success (0.182 and 0.126 walleye caught and harvested-per-rod-hour, respectively) improved in 2001 (Fig. 2). The increased fishing success can be accounted for by the recruitment of the 1999 walleye year-class to the open-water fishery as 2-yr-olds. This year-class made up about 50% of the walleye harvest in 2001. Walleye release rate increased this year (31% released in 2001 compared to 19% in 2000), possibly indicating that significant numbers of fish from this year-class were also being released. The average walleye harvested during the open-water fishery was 424 mm fork length, weighed 0.916 kg and was 3.3 yrs-old.

Although total angling effort remains largely focused toward walleye (90%), other species, particularly largemouth bass, are beginning to receive some targeted fishing pressure. Other species in the fishery (Table 2) are, for the most part, caught incidentally by walleye anglers. However, catch rates for other species have generally 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 favored these other species.

Discussion

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. Changes in the Bay of Quinte ecosystem have reduced the potential sustainable yield of walleye. On-going 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 ice and open-water recreational fisheries.

Although alternative species appear to be increasing in abundance, most 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.

Largemouth bass, which increased dramatically in anglers' catches in the last few years, had not previously been adequately assessed in index netting programs. A nearshore trapnet program, designed to address this short-coming was conducted in 2001 (upper Bay of Quinte only, Chapter 9 in this report).

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.

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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 began stocking coho the following year. Over the years, the addition of chinook salmon, rainbow trout, brown trout and lake trout to the stocking mix has enhanced various components of this fishery. We have monitored components of the salmon and trout fishery of Lake Ontario since the 1970s. Stocked salmon and trout formed the foundation of the fishery, although, in recent years natural reproduction of salmon and trout has increased. The shore, stream and boat fisheries for salmon and trout encompass more than three-quarters of the angling fisheries on the Ontario side of Lake Ontario (Savoie and Bowlby 1991). Accordingly, salmon and trout are the principal 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 relied on the boat fishery survey in western Lake Ontario to index salmon and trout populations and the entire salmon and trout fishery, since 1982. 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 and 2 of this report.

Information Sources

The portion of the salmon and trout fishery that launches boats from ramps in western Lake Ontario was monitored in 2001. This survey design was consistent with our surveys from 1985 to 2000 (Bowlby 2001).

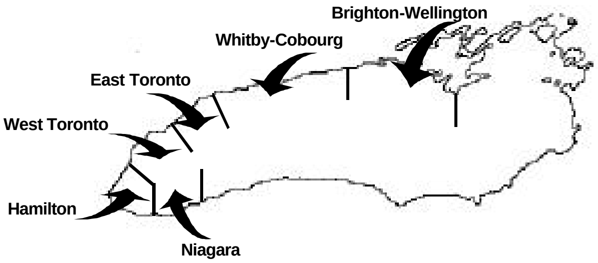

FIG. 1. The location of sectors used for stratifying the survey of western Lake Ontario boat anglers.

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 several launch ramp locations: St. Catharines Game and Fish, Fisherman's Wharf, Port Credit, Bluffers Park, Whitby, Port Darlington, Port Hope Harbour, Cobourg Yacht Club, Ontario Street, and Wellington. 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 the 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). Trailer and angler surveys were not conducted during

TABLE 1. Average daily trailer count on weekend days in 2001 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****. Trailer and angler surveys were not conducted during April in the Toronto sectors.*

Sector	Ramp	Apr	May	Jun	Jul	Aug	Sep	Total
Niagara	Queenston Sand Docks	10.0	4.5	1.8	3.0	4.3	2.0	25.5
	Welland Canal	12.0	7.5	9.8	5.5	9.8	15.0	59.5
	St.Catharines Game and Fish	***15.3***	***11.3***	***10.0***	***7.8***	***7.3***	***13.8***	***65.3***
	Beacon Motor Inn	5.0	2.8	3.5	4.3	3.5	2.0	21.0
	Sector total	42.3	26.0	25.0	20.5	24.8	32.8	171.3
Hamilton	Grimsby Municipal Ramp	0.5	0.0	0.8	0.8	0.0	0.0	2.0
	Foran's Marine	2.8	1.0	3.5	3.0	3.0	2.0	15.3
	Lakecourt Marina	0.3	0.3	0.0	0.5	0.3	0.0	1.3
	HRCA 50 Pt. Ramp	10.0	6.8	12.8	11.0	12.3	9.0	61.8
	Fisherman's Wharf	***13.3***	***11.0***	***15.0***	***24.5***	***30.3***	***19.0***	***113.0***
	Bronte Beach	4.5	4.0	8.5	28.8	34.5	19.5	99.8
	Shipyard Park	0.3	3.0	4.0	7.8	9.3	3.8	28.0
	Busby Park	0.0	0.5	0.5	0.8	1.0	0.5	3.3
	Sector total	31.5	26.5	45.0	77.0	90.5	53.8	324.3
West Toronto	***Port Credit Ramp***	N/A	***2.0***	***8.0***	***25.3***	***40.8***	***24.5***	***100.5***
	Lakefront Promenade Park	N/A	2.8	15.0	20.3	37.5	14.3	89.8
	Marie-Curtis Park	N/A	0.5	1.0	5.0	6.5	0.8	13.8
	Humber Bay West	N/A	2.5	11.5	16.8	14.3	8.8	53.8
	Sector total	N/A	7.8	35.5	67.3	99.0	48.3	257.8
East Toronto	Ashbridges Bay	N/A	2.0	3.5	19.5	14.8	2.3	42.0
	Bluffers Park	N/A	***3.0***	***7.5***	***38.3***	***39.3***	***7.5***	***95.5***
	Frenchman's Bay West	N/A	0.3	1.8	1.3	3.5	2.0	8.8
	Frenchman's Bay East	N/A	0.8	2.8	3.0	4.3	2.8	13.5
	Duffin Creek	N/A	0.0	0.3	0.3	0.5	0.0	1.0
	Sector total	N/A	6.0	15.8	62.3	62.3	14.5	160.8
Whitby-Cobourg	Port Whitby Marina	1.5	1.5	3.0	6.5	5.0	0.8	18.3
	Whitby Ramp	0.0	***0.8***	***1.5***	5.0	8.5	4.8	20.5
	Port Oshawa Marina	0.3	0.3	0.8	4.3	5.5	3.3	14.3
	CLOCA P. Darlington Ramp	0.3	0.0	***3.3***	***16.8***	***18.5***	5.8	44.5
	Port Newcastle	0.0	0.3	2.8	2.8	2.5	0.0	8.3
	Port Hope Harbour	***0.3***	***0.8***	***1.8***	13.0	17.0	***7.8***	40.5
	Cobourg Yacht Club	***1.0***	***1.0***	***1.0***	2.3	2.3	1.5	9.0
	Sector total	3.3	4.5	14.0	50.5	59.3	23.8	155.3

TABLE 1 (continued).

Sector	Ramp	Apr	May	Jun	Jul	Aug	Sep	Total
Brighton-Wellington	***Ontario Street Ramp***	0.8	***4.5***	***4.3***	7.5	7.0	***3.0***	27.0
	Brighton Marina	0.5	0.3	0.0	0.3	0.0	0.0	1.0
	Gosport Gov't Ramp	0.5	3.5	0.3	1.0	1.0	0.3	6.5
	Camp Barcovan	0.0	1.3	0.0	0.0	0.8	0.8	2.8
	McSaddens Marina	0.0	0.0	0.5	0.5	0.5	1.0	2.5
	Wellers Bay Marina	0.0	0.3	0.3	4.5	4.0	2.3	11.3
	North Shore Park	0.0	0.0	1.0	0.8	0.3	1.3	3.3
	Wellington Harbour Ramps	***2.3***	***6.0***	***7.0***	***28.3***	***17.3***	***3.3***	***64.0***
	Sector total	5.3	36.0	29.5	82.8	41.0	11.3	205.8
Total		82.3	106.8	164.8	360.3	376.8	184.3	1275.0

April in the Toronto sectors. Effort, catch, and harvest estimates for these missing strata were based on the 2000 values, adjusted by the ratio of effort between the years during the same period in other sectors.

Fisheries Update

Effort

During 2001, the effort of launch daily anglers and all boat anglers was estimated at 247,148 and 404,368 angler-hours, respectively. Effort declined by 17% since 2000. Prior to 2001, effort in the western Lake Ontario boat fishery had been relatively stable since 1994 (Fig. 2). The reasons for this decline are unclear, as catch and harvest rates for chinook salmon improved since 2000 (Schaner et al. 2002). Changes in some of the salmon and trout derbies in 2001 may have accounted for this decline. The largest decline in effort since 1985 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 after reinstatement of the Great Salmon Hunt and stocking increases. More than half of this effort occurred in July and August (Table 1) during the Great Ontario Salmon Derby.

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, 29% in 2000, and 37% in 2001. The relationship between catch rate with one rod or two rods is not straightforward. Rather, this relationship differs with the number of anglers onboard to the extent that increasing the number of rods results in no increase in catch/angler-hr for larger parties with more rods (Bowlby and Stewart 2000). Accordingly, we have chosen to continue reporting effort in angler-hr.

Catch and Harvest

Chinook salmon and rainbow trout accounted for 91% of the salmon and trout 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 2001 were similar to 1999 (Fig. 2). Catch and harvest rates of chinook salmon have varied less over the last 5 years than prior to 1996 (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), because of the higher fishing effort (Table 1). These minor changes in the seasonal and spatial patterns of catch are thought to be related 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 increased in 2001 despite a decline in effort (Fig. 2). Catch and harvest rates of rainbow trout were typical of the last decade (Fig. 3). Rainbow trout catch rates tend to be

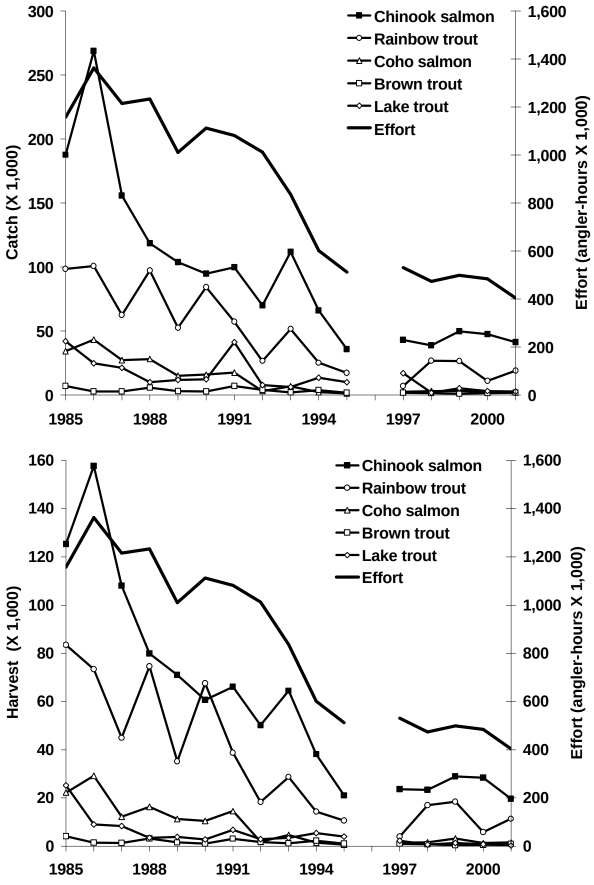

FIG. 2. Catch, harvest and effort in the boat fishery for salmon and trout in western Lake Ontario (Ontario portion), from 1985 to 2001. In 1996 the survey was incomplete.

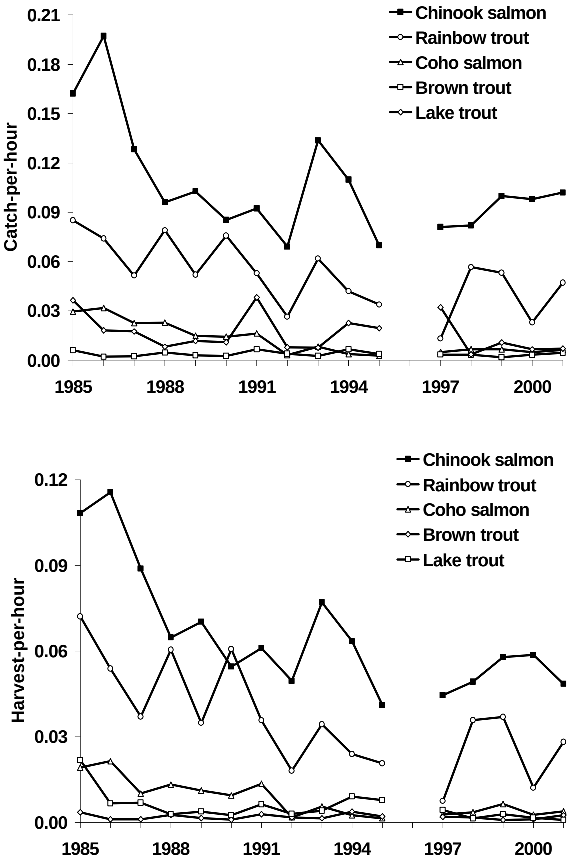

FIG. 3. Catch and harvest rates is the boat fishery for salmon and trout in western Lake Ontario (Ontario portion), from 1985 to 2001.

TABLE 2. Angling statistics for salmonid boat fisheries in western Lake Ontario (Ontario portion) during April to September 2001.

	Launch Daily Anglers					All Boat Anglers				
Species	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	25,985	11,097	0.0865	0.0369	57	41,227	19,624	0.0851	0.0405	52
Rainbow trout	8,887	4,372	0.0296	0.0145	51	19,095	11,393	0.0394	0.0235	40
Coho salmon	2,028	1,078	0.0067	0.0036	47	2,506	1,582	0.0052	0.0033	37
Brown trout	1,300	646	0.0043	0.0021	50	1,840	1,002	0.0038	0.0021	46
Lake trout	2,027	330	0.0067	0.0011	84	2,874	357	0.0059	0.0007	88
Atlantic salmon	60	-	0.0002	0.0000	100	112	-	0.0002	0.0000	100
Unidentified salmonine	1,368	37	0.0046	0.0001	97	2,728	53	0.0056	0.0001	98
Total salmonines	41,655	17,561	0.1386	0.0584	58	70,382	34,011	0.1452	0.0702	52

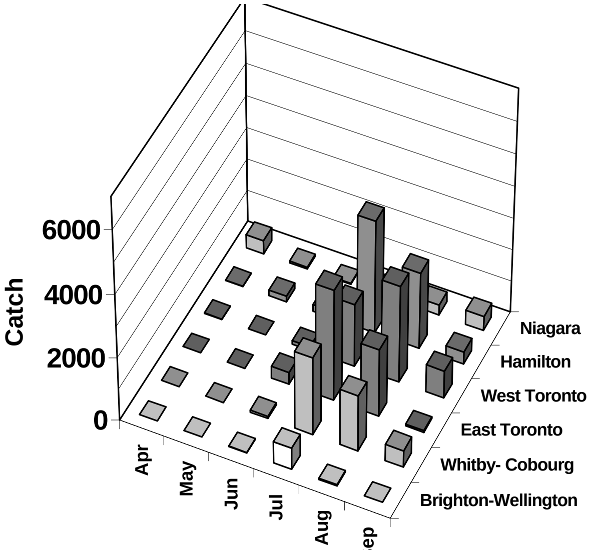

FIG. 4. The seasonal and spatial pattern of catch of chinook salmon by launch daily anglers in western Lake Ontario during 2001.

lower in Ontario waters of Lake Ontario during years with cooler springs (Schaner et al. 2001). During 2001, the low rainbow trout catches in Ontario waters were consistent with a moderate spring temperature.

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 stocking levels are focused on research rather than creating a fishery at this time. The reported catch may also be low due to misidentification. Anglers and survey technicians have difficulty with Atlantic salmon identification, and tend to report them as unidentified. A vast majority of tag returns of stocked adult Atlantic salmon from anglers in since 1998 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).

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9

Bay of Quinte Nearshore Fish Community

J. A. Hoyle

Introduction

The Bay of Quinte littoral area and residing fish community have expanded since the arrival of dreissenid mussels in the mid-1990s. The long-term fish community index netting programs on the Bay–that employed gillnet and bottom trawling gear in offshore areas–were not adequately assessing the expanding fish community in nearshore waters. Therefore, in 2001, the provincially standardized nearshore community index netting (NSCIN, Stirling 1999) program was initiated on the upper Bay of Quinte (Trenton to Deseronto). The standardized program ensures that results are comparable across years and with other lakes in Ontario.

The NSCIN program utilized 6-foot trapnets and was designed to evaluate the abundance and other biological attributes of fish species that inhabit the littoral area. Suitable trapnet sites were chosen from randomly selected UTM grids containing shoreline in the upper Bay of Quinte (Hoyle 2001).

Results

Thirty six trapnet sites were sampled from September 6 to 27 in a variety of habitat types and with water temperatures ranging from 16.7 to 22.0 °C (Table 1).

Over 16,000 fish comprising 24 species were captured (Table 2). The top five species by number were bluegill (37%), brown bullhead (36%), pumpkinseed (19%), black crappie (2%), and freshwater drum (1%), and by weight were brown bullhead (51%), bluegill (13%), freshwater drum (7%), pumpkinseed (7%), and channel catfish (6%). The centrarchid family of fish (bluegill, pumpkinseed, black crappie, largemouth bass, smallmouth bass and rock bass) comprised a total of 59% by number and 23% by weight of the catch (Table 2).

TABLE 1. Survey information for the 2001 NSCIN trapnet

Survey date	Sep 6 to Sep 27
Water temperature (°C)	Mean = 20.0 (range = 16.7 to 22.0)
No. of trapnet lifts	36
No. sites by depth (m):	
Target (2-2.5 m)	13
> Target (max)	22 (4.0 m)
< Target (min)	1 (1.9 m)
No. sites by substrate:	
Hard	17 (47%)
Soft	16 (44%)
Combination	3 (8%)
No. sites by cover:	
None	2 (6%)
1-25%	19 (53%)
25-75%	10 (28%)
>75%	5 (14%)

Mean length and weight statistics for selected species are reported in Table 3. Length distributions of 8 common species are found in Figure 1.

Discussion

The NSCIN trapnet program was initiated in 2001 to assess the expanding fish community in nearshore waters of the upper Bay of Quinte. The relative standard errors of mean trapnet catches (see Table 2) indicate that the intensity of this program is adequate to detect abundance changes of a wide variety of nearshore species with reasonable precision (e.g., RSE <20%). Species that are traditionally thought of as nearshore species and that are favoured in the

*TABLE 2. Total catch and catch-per-trapnet for the 24 species caught in the 2001 NSCIN trapnet program on the upper Bay of Quinte. Statistics shown include total catch, arithmetic mean catch-per-trapnet (number and weight), and percent relative standard error of the mean log_{10}(catch + 1). %RSE = 100*SE/Mean.*

	Catch		Catch-per-trapnet			
Species	Total	%	Number	RSE (%)	Weight (kg)	%
Bluegill	6,105	36.57	169.58	8	11.62	12.62
Brown bullhead	6,036	36.16	167.67	5	46.91	50.93
Pumpkinseed	3,218	19.28	89.39	5	6.08	6.60
Black crappie	353	2.11	9.81	8	2.32	2.52
Freshwater drum	229	1.37	6.36	17	6.56	7.12
Yellow perch	135	0.81	3.75	17	0.24	0.26
Walleye	114	0.68	3.17	14	4.76	5.17
Largemouth bass	89	0.53	2.47	16	0.49	0.53
White perch	79	0.47	2.19	26	0.26	0.28
Channel catfish	78	0.47	2.17	16	5.78	6.27
Gizzard shad	40	0.24	1.11	32	0.46	0.50
Northern pike	37	0.22	1.03	20	1.47	1.60
White sucker	37	0.22	1.03	15	1.13	1.22
Smallmouth bass	34	0.20	0.94	26	0.51	0.55
Rock bass	33	0.20	0.92	23	0.08	0.08
Moxostoma sp.	28	0.17	0.78	26	1.20	1.30
American eel	16	0.10	0.44	38	0.72	0.79
Bowfin	13	0.08	0.36	31	0.94	1.02
Longnose gar	9	0.05	0.25	45	0.25	0.27
Common carp	3	0.02	0.08	72	0.22	0.24
River redhorse	2	0.01	0.06	100	0.08	0.09
White bass	2	0.01	0.06	70	0.02	0.02
Mooneye	1	0.01	0.03	100	0.02	0.02
Golden shiner	1	0.01	0.03	100	0.00	0.00
No. species	24					

changing Bay of Quinte ecosystem (e.g., bluegill, pumpkinseed, black crappie, largemouth bass, and northern pike) had the lowest relative standard errors (RSE ranged from 5 to 20% for these species, Table 2).

The NSCIN program also captured some species of fish, including channel catfish, bowfin, river redhorse, golden shiner and mooneye, not observed in other assessment gear in 2001 (Table 4 and see Appendix B in this report). Centrachids were much more numerous in NSCIN trapnets (59% of total catch) compared with index gillnets (9%) and trawls (20%). Yellow perch made up less than 1% of the catch in NSCIN trapnets but dominated catches in other gear types (69% in gillnets and 36% in trawls). Yellow perch may not be abundant in nearshore areas during the time in which the NSCIN program was conducted.

Bay of Quinte angler survey information (see Chapter 7 in this report) indicated that largemouth bass catches had increased significantly over the last number of years. Largemouth bass catches in the Bay of Quinte NSCIN trapnets were not high relative to other Ontario lakes where the standardized NSCIN program has been conducted (Willox et al. 1997). According to these authors, Bay of Quinte largemouth bass would be classified as being of medium abundance and small average size compared to other Ontario lakes sampled. This result was not anticipated given angling survey results and anecdotal reports of

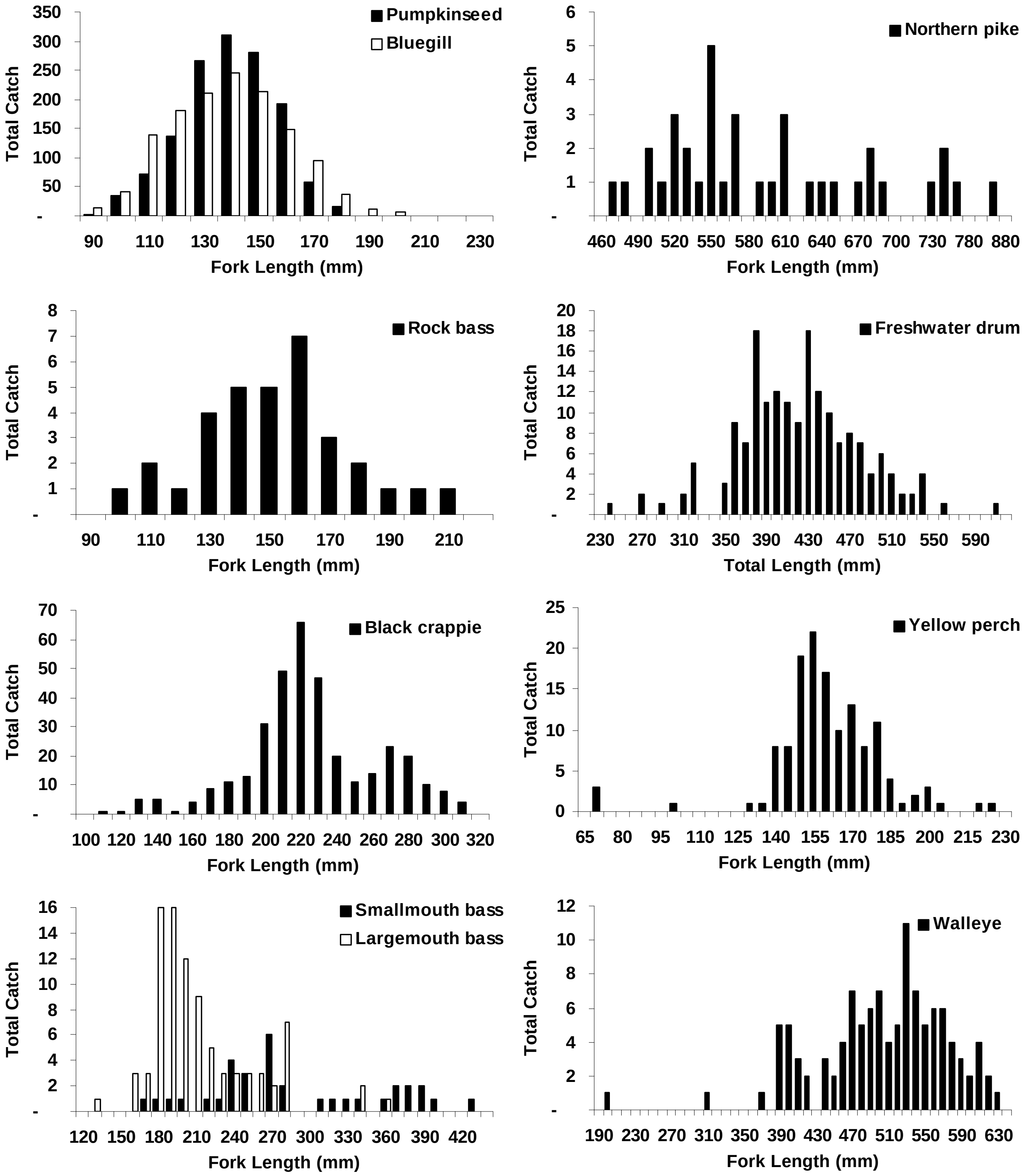

FIG. 1. Length distribution of selected fish species caught during the 2001 NSCIN trapnet survey on the upper Bay of Quinte.

TABLE 3. Mean length and weight statistics for selected species caught in the 2001 NSCIN trapnet program on the upper Bay of Quinte. All lengths are fork lengths except for freshwater drum which is total length. Mean weights were based on either actual sampled weights or length-weight regressions.

Species	Mean length (mm)	N	Mean weight (kg)
Bluegill	139	1,346	0.069
Brown bullhead	262	750	0.280
Pumpkinseed	140	1,369	0.068
Black crappie	226	353	0.239
Freshwater drum	422	177	1.034
Yellow perch	160	97	0.064
Walleye	504	112	1.544
Largemouth bass	212	89	0.184
White perch	190	77	0.117
Channel catfish	527	78	2.530
Northern pike	597	37	1.555
White sucker	412	35	1.089
Smallmouth bass	290	34	0.554
Rock bass	152	33	0.085

excellent largemouth bass angling. On a similar note, black crappie in the Bay of Quinte were classified as being of medium abundance and large average size.

Overall the 2001 NSCIN trapnet program on the upper Bay of Quinte appears to be a excellent program to assess the fish community in nearshore waters. Plans have been made to sample the entire Bay of Quinte in 2002. As the time-series for this program grows, it will provide invaluable fisheries-independent information for the management of a variety of nearshore species.

TABLE 4. Comparison of species-specific catches (% by number) in three gear types, NSCIN trapnets, gillnets (Big Bay) and trawls (mean at Trenton, Belleville, Big Bay and Deseronto) in the upper Bay of Quinte, 2001.

	Percent of catch (by number)		
Species	Trapnet	Gillnet	Trawl
Bluegill	36.574	2.573	4.462
Brown bullhead	36.161	2.438	4.513
Pumpkinseed	19.279	6.140	10.854
Black crappie	2.115	0.090	0.044
Freshwater drum	1.372	7.675	7.346
Yellow perch	0.809	68.849	36.339
Walleye	0.683	1.625	1.232
Largemouth bass	0.533	0.000	0.088
White perch	0.473	7.946	3.145
Channel catfish	0.467	0.000	0.000
Gizzard shad	0.240	0.767	4.762
White sucker	0.222	1.264	0.079
Northern pike	0.222	0.045	0.000
Smallmouth bass	0.204	0.181	0.040
Rock bass	0.198	0.000	0.026
Moxostoma sp.	0.168	0.045	0.000
American eel	0.096	0.000	0.004
Bowfin	0.078	0.000	0.000
Longnose gar	0.054	0.361	0.000
Common carp	0.018	0.000	0.013
White bass	0.012	0.000	0.004
River redhorse	0.012	0.000	0.000
Golden shiner	0.006	0.000	0.000
Mooneye	0.006	0.000	0.000
Alewife	0.000	0.000	11.600
Spottail shiner	0.000	0.000	9.341
Sunfish Family	0.000	0.000	4.637
Trout-perch	0.000	0.000	0.691
Johnny darter	0.000	0.000	0.594
Logperch	0.000	0.000	0.119
Round goby	0.000	0.000	0.044
Ictalurus sp.	0.000	0.000	0.013
Number of species	24	14	25

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10

Cormorants in the vicinity of Presqu’ile Provincial Park and the Bay of Quinte

P. A. Edwards, and T. J. Stewart

Introduction

Since the 1970's, population numbers of double-crested cormorants have increased significantly in many regions of North America (Wires et al. 2001). The dramatic increase in cormorant abundance in the Great Lakes region, including the Presqu’ile, Brighton and Bay of Quinte areas, has led to a variety of concerns including: perceived competition with sport and commercial fishermen, alteration and destruction of natural vegetation and nest trees, and impacts on other colonial waterbird populations (Hatch and Wesloh 1999; Wires et al. 2001).

Within the Great Lakes science community, opinions vary as to the impact of cormorants on fish communities and fisheries. Cormorants are generalists and eat abundant numbers of slow moving or schooling fishes in the size range 3-40 cm, but commonly prefer those <15 cm (Wires et al. 2001). Conclusions by Wesloh and Casselman (1992) and Jones et al. (1993) have indicated that although cormorants are indeed piscivorous, they do not have a significant impact on the fish community or fisheries of Lake Ontario on a lake-wide scale. Knowledge of the foraging patterns of cormorants however suggests that they could potentially deplete fish in the immediate vicinity of a nesting colony.

The cormorant program for 2000 and 2001 was initiated to examine the impact of double-crested cormorant feeding on small fish in the vicinity of Presqu’ile Provincial Park and the Bay of Quinte area. The working hypothesis was that cormorant feeding activity and related impacts on the fish community would diminish as a function of the distance from the nesting colony. Sites were selected to cover what was anticipated to be a range of cormorant feeding intensities, and fish attributes were to be examined to determine any differences in abundance or fish community structure that could be attributed to cormorant feeding activity.

Methods

Fish Trawls

This study took advantage of earlier outboard trawling carried out by the Lake Ontario Management Unit from 1988-1991. This program was initiated in 1988 (Bowlby 1989), and was designed to index the abundance of ‘small’ fish in the Bay of Quinte and the nearshore habitats of eastern Lake Ontario. Fish captured in the program included young of the year (YOY) and older fish of species such as walleye, gizzard shad, trout-perch, and spottail shiner. The indices of abundance proved useful for predicting year-class strength and yearly indicators of fish population response to stress from environmental or fish community changes (Hoyle 1992). Previous programs have established suitable index trawling sites, examined the influence of season and site depth, and determined the optimal number of replicate trawls at each site.

Study areas were selected in 2000 based on their distance from the major cormorant nesting colony located at Presqu'ile Bay (Fig. 1). It was assumed that the use of distance as a selection criterion would incorporate a potential gradient in cormorant feeding intensity from negligible (beyond the likely feeding range of cormorants) to extremely high (in the immediate vicinity of a colony) into the study design. Three offshore areas, located off the southwestern shore of Prince Edward County, were initially included in the study, but were excluded from the 2001-sampling plan due to the inability of the trawls to capture fish in the offshore areas.

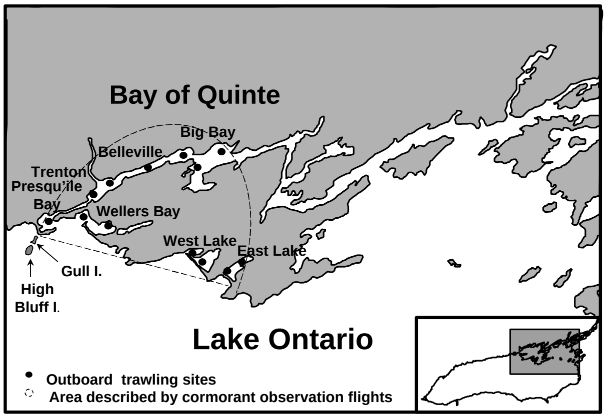

Fig. 1. Depiction of the geographic extent of the 2000 and 2001 Bay of Quinte cormorant program.

Outboard trawling for the cormorant study in 2000 and 2001, using apparatus as described in Bowlby (1989), occurred during three time periods: spring (June), summer (August), and autumn (September). Trawls were conducted between 08:00 and 16:00 daily. Each trawl lasted 6 minutes at a speed of 4.3 km/h (2.3 knots or 2.7 mph), with a trawling distance of approximately 430-460 m. A few tows were cut short due to unsuitable bottom conditions. Three replicate tows were performed at each trawling site at depths ranging from 3.0-8.0 m. Where possible, each subsequent tow was 1.0 m deeper than the initial tow. Each tow at a site was made in the same direction. Temperature and dissolved oxygen profiles and secchi disk depths were recorded at each site.

Fish Sampling

Total count and total catch weight by species groups were documented for all fish caught. In the case of white perch, white bass, smallmouth bass, largemouth bass, yellow perch, and walleye, YOY and older fish were considered as separate groups. For all other species no distinction was made between YOY and older fish.

Length tallies (using 5 mm size categories) were made for each species. Where excessive numbers of fish were captured, at least 30 representative individuals of each species group were length tallied. All walleye captured were sampled. All sampling procedures were the same as those used in the LOMU fish community-indexing program (Hoyle 2001).

Cormorant Observations

Cormorants were observed and counted from a Cessna 172 at an altitude of 300 feet and at a maximum ground speed of 100 knots. The flight route circumnavigated the study area. An in-flight observer counted the number of birds and marked the location and number of birds on a map according to their activity: on the water (including feeding and diving), flying, or resting (on land and in trees). The direction of any flying birds was indicated on the map.

Aerial surveys in 2000 consisted of weekly flights (34 total) beginning May 2 and ending October 23. In 2001, aerial surveys were reduced to biweekly flights (15 total) beginning April 19 and ending October 30. The duration of each survey flight was approximately 2 hours and included counts in seven areas: East Lake, West Lake, Wellers Bay, Presqu'ile Bay, Trenton, Belleville and Big Bay (Fig. 1).

Wind speed, wind direction, visibility, and approximate wave height were recorded for all flights. If wind speeds exceeded 20 knots or poor visibility interfered with counting, the flight was rescheduled for the next available day.

Probability Model

We hypothesized that during the nesting period, cormorant density would be negatively correlated with distance from the colony. To test this hypothesis we further sub-divided the counting areas into 14 separate zones ranging in area from 0.7- 28.6 km^2. Within each zone, the density of cormorants was calculated from the total counts of cormorants and the area of each zone. We also determined the approximate distance of each zone from the colony, to be the distance from the estimated center of the zone to the center of High Bluff Island.

We defined the cormorant nesting period as mid-April to August 31st and calculated a combined mean density over the two years of the study period. Due to the contagious distribution of the count data, we used a square-root transformation, took the arithmetic mean, and then back transformed (Zar 1984). Finally, a log-linear relationship was determined between the distance from the colony and mean density of cormorants.

To allow us to estimate historical cormorant densities from colony nest counts, we derived a general probability function that would describe the probability of observing a cormorant as a function of distance from the colony. We envisioned a series of discrete rings or halo’s as described by Ashmole (1963) and Birt et al. (1987), of constant width expanding out from the colony at regular intervals of increasing distance. As the distance from the colony increased the area bounded by the halo also increased. If foraging cormorants distribute themselves randomly in our study area, then they have the potential to disperse over a wider area as they fly further from the colony. To estimate probability from an observed density vs. distance relationship as described above; it was necessary to account for the increased area of dispersal, as represented by an increasing area available for dispersal by birds moving further from the colony. We determined that the probability of observing a cormorant under this scenario was equal to the observed density x p x distance. Using the function describing the relationship between observed density and distance, we estimated the probability over discrete distances from 5 to 100 km and scaled the probabilities to unity over this range. Using this function we were able to determine an index of cormorant density for any specified distance from the colony and known colony size. Using historical nest count information and the distance of our study sites from the colony, we estimated a cormorant abundance index for each of our study sites in each year.

Analytical Methods

Previous outboard trawls, conducted from 1988 to 1991 were limited to August sampling, therefore we only included data from the August sampling in 2000 and 2001 to examine variation in the trawl catches over the entire period from 1988 to 2001. Sub-sampling of some species in the earlier data sets required additional data manipulation to derive total catch weight so current analysis was restricted to numerical catch statistics only. In 2000 and 2001, sampling was conducted over three seasons and total catch weights were recorded for all species. For this time period we examined both numerical and weight-based (biomass) catch statistics.

A sub-set of catch statistics were selected for examination: total catch, total catch of commonly abundant species (centrarchids, white perch, and yellow perch), total centrarchid catch, total white perch catch, total catch of yellow perch (excluding YOY), total catch of all yellow perch, total catch of bullhead, and total catch of walleye.

Replicate sampling allowed us to examine the relationship between the mean and the variance of each catch attribute using Taylor's Power Law to derive a specific transformation for each catch attribute examined (Elliott 1977). Correlation analysis was used to examine the relationship between catch statistics and both the cormorant abundance index and the observed mean cormorant densities. Analysis of Variance (ANOVA) was first used to examine the variation in the 2000 and 2001 catch statistics due to season before running the correlation analysis.

Results

Trawl catches

A total of 18 species were caught in the 2000 trawls, and 27 species in the 2001 trawls. Three-spine stickleback and brook silverside comprised 55.5% of the total catch in 2000, with yellow perch representing 18.1% and sunfish (both bluegill and pumpkinseed) representing 15.7% of the trawl. In 2001, yellow perch comprised 42.5% of the total catch, with sunfish representing 28.9% of the trawl. Although the trawls caught fish between 20–568 mm in total length, 86.3% of the fish were between 35–130 mm (Fig. 2). See Appendix 1 for a complete list of fish species collected in both the 2000 and 2001 outboard trawl programs.

Cormorant Counts

In both 2000 and 2001, fewer cormorants were observed during the nesting period (April – August) than during the post-nesting period (August – October) (Fig. 3). Cormorant densities in the Bay of Quinte were lower in 2001 than in 2000. High numbers of cormorants were observed earlier in 2001 than in 2000.

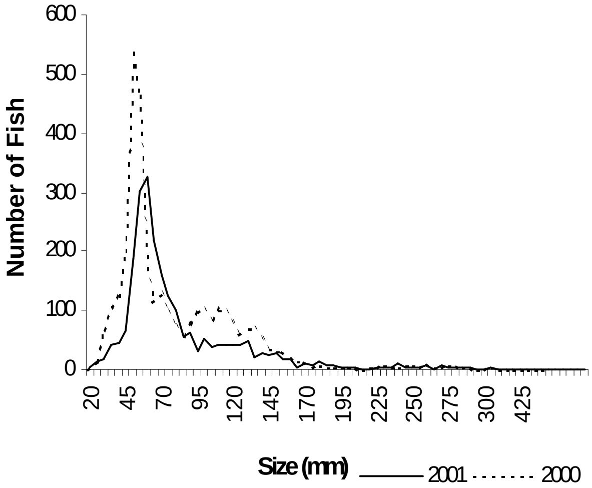

Fig. 2. Plot illustrating the size distribution of all fish caught in both the 2000 and 2001 trawls.

Probability Function

We found a significant ($p<0.05$) negative correlation between the logarithm of distance from the colony and logarithm of the mean back-transformed cormorant density (Fig. 4). From the fitted equation we derived the corresponding probability distribution describing the probability of observing a cormorant during nesting period over the range of 5 to 100 km away from the colony (Fig. 5).

Correlation analysis

The sensitivity of the correlation coefficients to the addition or removal of the East Lake and Presqu'ile sites was examined. For both the longer data series analysis (1988-2001) and the more recent sub-set (2000 & 2001), neither the inclusion of East Lake nor the exclusion of the low catches at Presqu'ile Bay in 2001 altered the overall trends and significance levels of the analysis. Therefore trawl data from East Lake (all years) were eliminated from the analysis as excessive weed growth had interfered with effectiveness of the trawls. Presqu'ile data were included in the analysis, despite several seasonal samples missing, as it represented the site directly adjacent to the cormorant colony.

August catch samples (1988-2001)

The correlation between the cormorant abundance index and all fish catch statistics were negative and significant (Table 1). A scatter plot of the data (Fig. 6) indicated some clustering of the observations, and a high degree of variance despite the use of normalizing transformations. The three data clusters represent the earlier trawl series (1988-1991) during a period of high catch and low cormorant abundance, a more recent period (2000-2001) of lower catches and higher cormorant abundance, and a small cluster of very high cormorant abundance and low catches at the Presqu'ile Bay site in 2001.

Seasonal catch samples (2000-2001)

An ANOVA indicated that variations in trawl catches due to season and year were not significant ($p>0.05$) thus all data was combined. The correlation between the cormorant abundance index and fish numerical catch statistics was, for the most part, negative and significant (Table 2). The scatter plot of the seasonal catch versus cormorant abundance index closely resembles the plot of interannual August catch samples (Fig. 7). Two distinct clusters are observed, within the main cluster, the points displaying lower catches and higher cormorant abundance represent

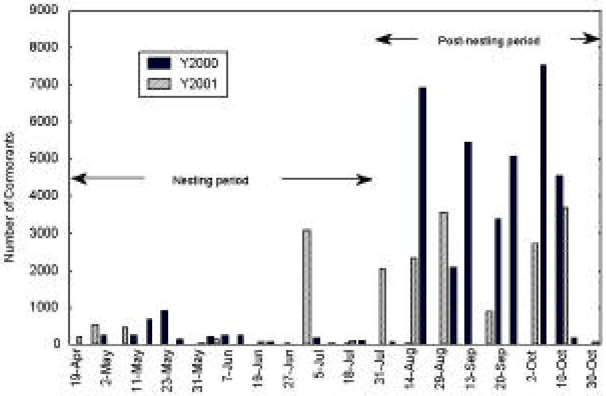

Fig. 3. Number of cormorants observed during flights over the study area in 2000 and 2001.

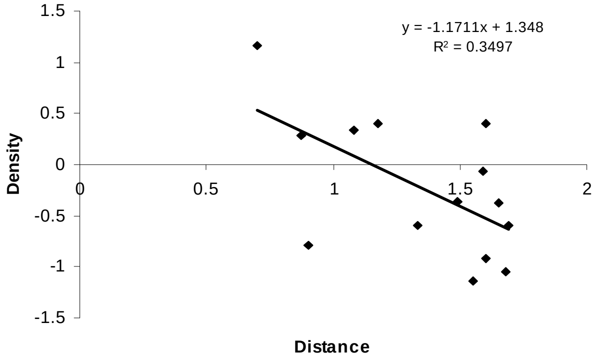

Fig. 4. Plot of density as a function of distance from the colony, also shown is the significant ($p<0.05$) negative correlation between the two. The data presented represents spring and summer data (2000 & 2001).

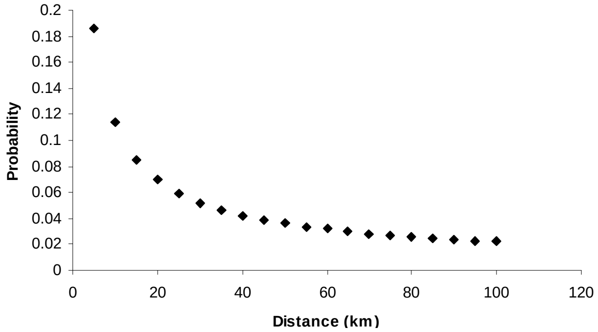

Fig. 5. Plot of the probability function describing the probability of observing a cormorant at a given distance from the nesting colony. The line is derived from the equation shown in Fig. 4.

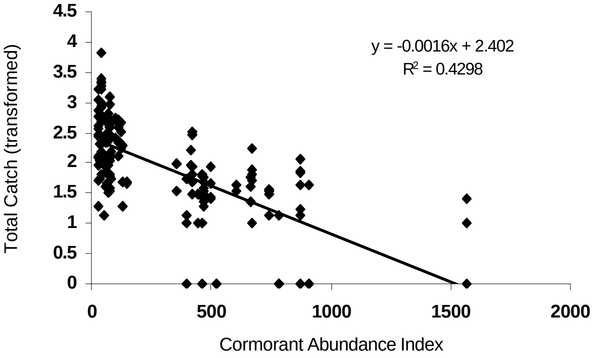

Fig. 6. Plot of the correlation between the cormorant abundance index and the transformed 'total fish catch' data. The left-most cluster represents August trawls from 1988-1991; the central cluster represents August trawl data from 2000 and 2001; the cluster to the right represents Presqu'ile Bay trawl data (2000 & 2001). The 2000 and 2001 data includes all trawl sites except East Lake.

Table 1. Inter-annual correlation between the index of cormorant abundance and select fish metrics. Each fish metric was first transformed using Taylor's transformation and derived from August trawl catch numbers (1988-1991, 2000-2001).

Fish Metric	**N**	**r**	**p**
All Fish	171	-0.6556	< 0.05
Selected Fish	171	-0.6308	< 0.05
Walleye	171	-0.4579	< 0.05
Yellow Perch	171	-0.3148	< 0.05
Centrarchids	171	-0.1788	< 0.05
White Perch	171	-0.6406	< 0.05
Bullhead	171	-0.2018	< 0.05

those sites closest to the cormorant colony; while sites furthest away from the colony are represented by higher catches and lower cormorant abundance. As in the previous analysis, the small cluster of points with very high cormorant densities and low catch represent the Presqu'ile Bay samples sites.

Discussion

Cormorants like many other seabirds are colonial nesters. The size of their colonies is regulated, and the population stabilized by density dependent factors, particularly food supply during the breeding season (Ashmole 1963). Ashmole further suggested that feeding activity during the breeding season has the potential to create prey-depleted halos around colonies (Birt et al. 1987). Birt et al. (1987) demonstrated this 'central foraging theory' with results indicating that two large breeding colonies of double-crested cormorants first depleted prey in nearby bays, then were subsequently forced to forage in bays up to 16 km away.

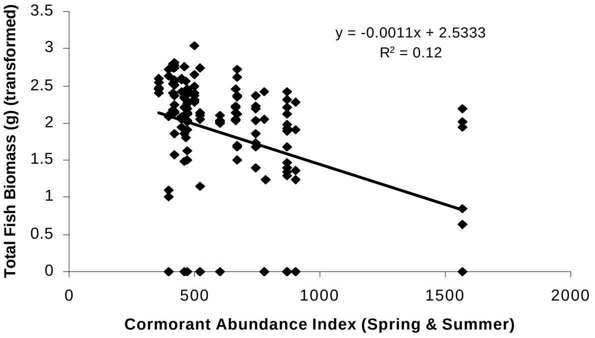

Fig. 7. Plot of the correlation between the cormorant abundance index and the transformed 'total fish biomass' data. Data shown represent 2000 and 2001 spring and summer trawls at al sites except East Lake. The points furthest to the right in the graph represent trawl data from Presqu'ile Bay.

Table 2. Seasonal Correlation between the index of cormorant abundance and select fish metrics. Each fish metric was first transformed using Taylor's transformation. Data represents spring and summer trawl data from 2000 & 2001. East Lake was not included in this analysis.

		Biomass		**Catch**	
Fish Metric	**N**	**r**	**p**	**r**	**p**
All Fish	146	-0.35	< 0.05	-0.46	< 0.05
Selected Fish	146	-0.43	< 0.05	-0.41	< 0.05
Walleye	146	-0.41	NS	-0.15	NS
Yellow Perch	146	-0.34	< 0.05	-0.33	< 0.05
Centrarchids	146	-0.34	< 0.05	-0.29	< 0.05
White Perch	146	0.54	< 0.05	-0.27	< 0.05
Bullhead	146	-0.14	NS	-0.12	< 0.05

The probability function we developed could be extrapolated and applied to other years and colonies to derive time and site-specific indices of cormorant abundance. However, further examination of cormorant foraging distribution data is required to determine the robustness of this function. Other studies of sea-bird colonies have observed that foraging birds may change foraging patterns and fly further to seek food once nearby fish stocks have been depleted (Lewis et al. 2001). This may be less likely to occur with the Presqu'ile area colony as long as stocks of offshore alewife remain readily available. This assumption is supported by conclusions from Palmer (1962) which suggested that a requirement for nesting cormorants is an adequate food supply within approximately 16 km of the colony.

An interesting conclusion from both recent Lake Erie studies, and previous studies elsewhere, is that marine birds may not always forage in the patches that contain the highest concentrations of prey (Stapanian et al. 2002). Cormorants and other marine birds likely forage in habitats with prey densities sufficient for their needs, and that require the least expenditure of energy due to flight distance from the colony. This observation has obvious management implications for the Bay of Quinte, Eastern Lake Ontario, and other Great Lakes. If prey fish densities, such as alewife, in the immediate vicinity of a colony are high enough to support the colony, then the most significant foraging pressure of cormorants may be restricted to a halo of ≤ 16-20 km around the colony.

The impact of cormorants in the Bay of Quinte area may be an issue to fisheries stakeholders, but it remains, at present, an issue on a localized scale. Those areas closest to the High Bluff Island colony in Presqu'ile Bay are most likely to have reduced fish populations as a result of cormorant foraging. However, whether localized reductions will be manifested as a noticeable lake-wide decline is still in question in Lake Ontario and the other Great Lakes. Stapanian (2002) commented that "while numbers of fish consumed by cormorants in Lake Erie seem impressive,…accurate estimates of lake-wide fish stocks are needed in order to understand the proportion of the fishery that the cormorants consume." According to Stapanian et al. (2002), "predation by cormorants on fish in Lake Erie accounted for only 1.7% of the biomass that supports walleye for 1 year." At present it has been concluded that the impact of cormorants on the fishery of western Lake Erie appears to be localized and minimal on a lake-wide scale. In the Bay of Quinte (including West Lake) and in Lake Ontario, the observed localized impact cormorants are having on fish communities in close proximity to the Presqu'ile colony is not currently reflected in sites over 25 km from the colony (e.g. Belleville, Big Bay).

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Appendices

Appendix 1. Catches of fish in the 2000 and 2001 outboard trawl programs.

	Annual Totals	
Species	**2000**	**2001**
Longnose gar	.	1
Alewife	49	32
Gizzard shad	.	6
Lake whitefish	.	1
Rainbow smelt	.	1
Northern pike	2	7
White sucker	.	3
Spottail shiner	61	143
Mimic shiner	.	34
Bluntnose minnow	.	4
Brown bullhead	.	58
Brook stickleback	.	1
Threespine stickleback	380	181
Trout perch	.	18
White perch	20	92
Sunfish	11	2
Rock bass	14	19
Pumpkinseed	118	373
Bluegill	134	293
Largemouth bass	4	11
Black crappie	4	11
Lepomis sp.	.	2
Yellow perch	290	978
Walleye	1	19
Johnny darter	1	1
Log perch	.	2
Brook silverside	476	.
Freshwater drum	1	5
Mottled sculpin	1	.
Total Fish	1567	2298
Total Number of Species	18	27

11

Resurgence and Decline of Lake Whitefish (*Coregonus clupeaformis*) Stocks in Eastern Lake Ontario, 1972 to 1999

J. A. Hoyle, J. M. Casselman, R. Dermott[1], and T. Schaner

Preface

The symposium on Salmonid Communities in Oliogotrophic Lakes (SCOL-I, Loftus and Regier 1972) provided insights on stresses acting on Great Lakes' ecosystems. In 2001, the Great Lakes Fishery Commission (GLFC) initiated a second SCOL symposium (SCOL-II) to synthesize new knowledge. As part of the synthesis, Great Lakes' investigators submitted various working papers covering a variety of topics for use at a workshop. The following manuscript was one of the contributions and can also be found on the internet at <http://www.glfc.org/bote/upload/lakewhitefishhoyle.doc>. The publication of the complete Lake Ontario SCOL-II synthesis is expected in 2002.

Introduction

Lake whitefish (*Coregonus clupeaformis*) is an abundant species in the cold-water fish community of eastern Lake Ontario. It is also the most important commercial species in Lake Ontario (Christie 1973, Hoyle et al. 2000). The majority of the commercial harvest is taken from the northeastern part of the lake. Here, there are two major spawning stocks, a "bay" stock that spawns in the Bay of Quinte and a "lake shore" or "lake" stock that spawns along the south shore of Prince Edward County.

By the mid-1960s these two stocks and the fishery they supported had collapsed (Christie 1968); only a remnant population persisted through the late 1960s and 1970s. During the 1980s, both stocks showed a dramatic resurgence. By the early 1990s, the stocks had recovered to historically high levels of abundance, and had accumulated a large spawning stock biomass comprised of several strong year-classes (Casselman et al. 1996). Lake whitefish abundance most recently peaked in the early 1990s, and has shown a significant decline in the years since. The decline in abundance, a change in diet, and a significant decline in body condition was related to a decline in *Diporeia hoyi*, an important item in the lake whitefish diet, following the appearance and proliferation of dreissenid mussels in eastern Lake Ontario (Hoyle et al. 1999).

In this paper we review the historical and present status of the species by: (1) describing the long-term commercial harvest statistics (1870 to 1999), (2) updating indices of adult and young-of-year abundance and thereby describing stock resurgence and decline over the past three decades, (3) reviewing factors influencing stock abundance, and (4) examining the synchrony of dreissenid mussel invasion, the decline in *Diporeia* abundance, and the decline in lake whitefish abundance, recruitment, body condition, and growth in the 1990s. We also comment on the future outlook for lake whitefish stocks in Lake Ontario.

Historical Perspective

Historically, the lake whitefish was an important component of the Lake Ontario commercial fishery. Long-term commercial harvest trends show that lake whitefish harvest was high in the mid-1800s, low at the turn of the 20th century, historically high during the 1920s, very low in the late 1960s and 1970s, and again high by the mid-1990s (Fig. 1). Generally, the commercial harvest trends reflected lake whitefish abundance trends, with some exceptions. Harvest

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during the 1950s was maintained at high levels only due to increased fishing effort and efficiency with the advent of nylon gillnets (Christie 1973). Also, regulatory action was taken to protect spawning stocks in the 1970s and commercial harvest quota allocations were established in the early 1980s to limit harvest, and thereby protect the recovering stocks.

Until the mid-1940s, lake whitefish and other salmonids, including lake trout (*Salvelinus namaycush*), lake herring (*Coregonus artedii*), and deepwater ciscoes (*Coregonus reighardi*, *Coregonus hoyi* and *Coregonus kiyi*), made up the bulk of the commercial harvest (Fig. 1). By 1950, lake trout and the deepwater ciscoes were well on their way to becoming extirpated from Lake Ontario (Christie 1973). This left lake whitefish and lake herring as the only remaining salmonids in the fishery. But their abundance was also in decline at this time, and by the mid-1960s lake whitefish and lake herring had declined to the point where significant fisheries for these species could no longer be supported. The commercial fishery turned to a variety of other, primarily warm-water, species.

During the 1980s, lake whitefish stocks recovered but lake herring did not; this left lake whitefish as the only native salmonid that could support a significant commercial harvest. Harvest quota allocation was increased as the stocks recovered, and by the early 1990s lake whitefish were again the most important species in the commercial fishery with an annual harvest of about 400,000 lb.

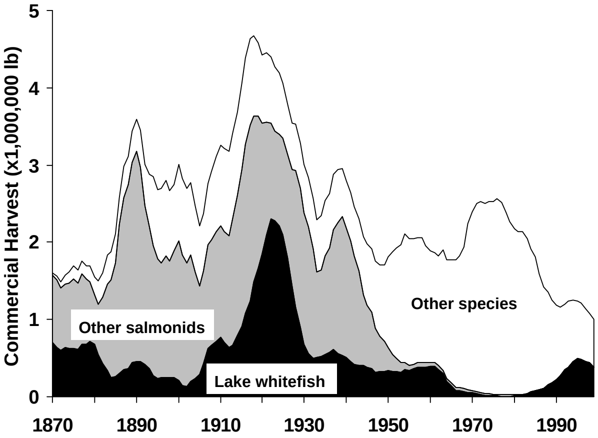

FIG. 1. Lake Ontario commercial harvest (millions of pounds from Canadian waters) from 1870 to 1999. Other salmonids include lake trout, deepwater ciscoes and lake herring.

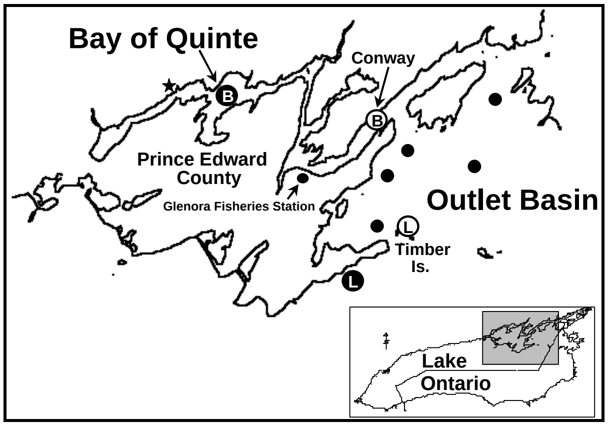

FIG. 2. Northeastern Lake Ontario showing lake whitefish index gillnetting (circles) and trawling (open circles, B—"bay" stock at Conway, L—"lake" stock at Timber Island) locations in the outlet basin of eastern Lake Ontario and the lower Bay of Quinte. Also shown are lake whitefish collection sites on the spawning areas of "lake" (L, south-shore Prince Edward County) and "bay" (B, Bay of Quinte) spawning stocks (closed circles). The Glenora Fisheries Station is located, as is the Belleville Water Treatment Plant (closed star).

Methods

Long-term trends in lake whitefish harvest (1870 to 1999) from the Canadian waters of Lake Ontario were obtained from Baldwin et al. (1979) and updated from records maintained at the Glenora Fisheries Station.

Indices of lake whitefish abundance (1972 to 1999) were developed from the long-term fish community index netting programs in the outlet basin of eastern Lake Ontario and the lower Bay of Quinte. Bottom trawling was used to assess young-of-year lake whitefish abundance for the bay and lake stocks in their respective nursery areas (Conway and Timber Island, respectively, Fig. 2). Bottom set gillnets with graded mesh sizes ranging from 1½ to 6 inch stretched mesh were used to assess juvenile (1 and 2 yr-old fish) and adult (3 yr-old and older) lake whitefish abundance for mixed stocks in the offshore waters of the outlet basin of eastern Lake Ontario (Fig. 2).

Lake whitefish collected during commercial fishing operations on the spawning areas (Fig. 2) of both major stocks (1988 and 1990 to 1999) were examined for biological attributes (i.e., fork length, weight, sex, maturity), and age was interpreted using otoliths (only for 1988, 1990 and 1994 to 1999).

Lake whitefish diet was examined in the summer of 1998 from fish collected during index gillnetting operations (Fig. 2) in the outlet basin of eastern Lake Ontario. All diet items were identified and counted, and a random sample of each diet item type was measured for size. Diet was expressed in terms of frequency of occurrence among lake whitefish stomachs containing food items.

Dreissenid mussel density was measured on and near lake whitefish spawning shoals in the years 1992 through 1997, and at a wide-variety of locations during 1994 and 1997 in eastern Lake Ontario and the Bay of Quinte.

Diporeia density (1987 and 1990 to 1998) was measured by the Department of Fisheries and Oceans at two long-term index sites in the lower Bay of Quinte (Conway) and the outlet basin of eastern Lake Ontario. Samples were collected using a 9 inch Ekman dredge (0.05 m^2).

Results

Indices of Abundance

Lake whitefish abundance was very low in the late 1960s and 1970s (Fig. 1) but a dramatic resurgence occurred during the 1980s. Bottom trawling surveys indicated that young-of-year lake whitefish production was extremely low in the 1970s, but began to increase in the late 1970s (lake stock) and early 1980s (bay stock, Fig. 3, upper panel). By 1986, significant young-of-year production was occurring on a more consistent basis. Especially large year-classes occurred in 1987, 1991, 1992, 1994 and 1995. Catches of juvenile (1 and 2 yr-old fish) and adult (3 yr-old and older) lake whitefish (mixed stocks) responded by increasing throughout the 1980s and early 1990s in the outlet basin of eastern Lake Ontario (Fig. 3, lower panel). For example, juvenile fish from the 1991 and 1992 year-classes contributed 58% of the catch in 1993, the year of peak lake whitefish catches. However, the large numbers of young-of-year fish produced in 1994 and 1995 did not contribute strongly to the juvenile/adult population (i.e., 29% of the catch in 1996). Survival of juvenile fish appeared to have declined.

In 1997, five lake whitefish carcasses were observed in bottom trawls and 3 dead or dying fish were caught in outlet basin gillnets. This was the first such occurrence in 40 years of index netting activity. In 1998, seven more carcasses were observed. The cause of death could not be determined. The fish ranged in size from 250 to 350 mm total length and represented young, immature fish 2 to 3 years of age. No carcasses were observed in 1999.

Biological Attributes of Spawning Stocks/ Commercial Harvest

Lake whitefish body condition declined significantly after 1993 in both spawning stocks (Fig. 4). Length-at-age declined significantly after 1996 for both stocks (Fig. 5). Lake whitefish were caught on spawning shoals by age 3 in early sampling years (i.e., up to 1994) but not until age 5 or 6 in later sampling years. Mean age of the harvest has increased from 5 and 6 yrs-old for bay and lake stocks respectively in 1994 to 8 and 9 yrs-old respectively in 1999. Lake whitefish year-classes for which there was sufficient data (1988, 1989 and 1990 year-classes) showed total annual mortality rates ranging from 40 to 50%.

Diet

Samples collected in the summer of 1998 from the outlet basin of eastern Lake Ontario indicated that dreissenid mussels dominated the juvenile and adult lake whitefish diet. Dreissenid mussels were present in 90% of the stomachs while other peleycypods (mainly *Pisidium* and *Sphaerium*) had been consumed by 24% of the fish (Table 1). The dreissenid mussels consumed by lake whitefish were small (95% of

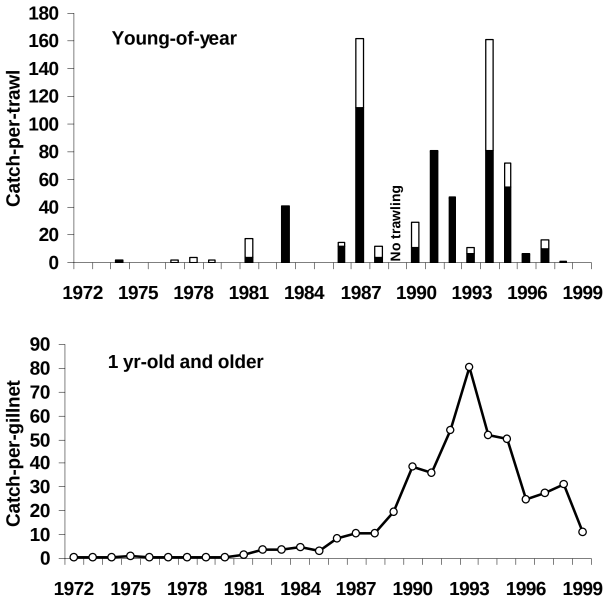

FIG. 3. Young-of-year lake whitefish catch-per-trawl (12 minute duration) for "lake" (Timber Island) and "bay" (Conway) stocks, 1972 to 1999 (no trawling in 1989, upper panel), and 1 yr-old and older lake whitefish (mixed stocks) catch-per-gillnet (sum of catch adjusted to 100 m of each mesh size, 1½ to 6 inch) in the outlet basin of eastern Lake Ontario, 1972 to 1999 (lower panel).

mussels measured 2 to 7 mm total length). Not a single *Diporeia* was observed among the nearly 6,000 food items identified.

Dreissenid Mussel Invasion

Dreissenids (settled mussels) were observed in eastern Lake Ontario at least by 1992, and in the Bay of Quinte by 1993 (Table 2). By 1994, dreissenid mussel had reached densities of thousands to hundreds of thousands per m^2 in most areas but were at lowest densities in the lower Bay of Quinte. By 1997, dreissenid densities were on the order of thousands to hundreds of thousands per m^2 in all areas.

Diporeia *Abundance*

Deepwater amphipod (*Diporeia hoyi*) density in eastern Lake Ontario and the lower Bay of Quinte was high (300 to 400 per 0.05 m^2) but declined dramatically in 1993 and further, to near zero, by 1994. No increase in *Diporeia* density occurred after 1994 (Fig. 6).

Discussion

Factors Regulating Abundance

Climate

Climatic conditions have been correlated with lake whitefish production. Cooler Novembers and warmer Aprils were both associated with higher subsequent catches (Christie 1963). Christie developed thermal indices that incorporated the effects of cold Novembers followed by warm Aprils and associated them with strong year-classes, with the opposite combination associated with weak ones (Christie 1963, Christie and Regier 1971). Lake whitefish studies over the years have shown broad variability in year-class strength, and many early studies have shown the importance of climatically driven environmental conditions (Miller 1952, Lawler 1959). Climatic temperatures play a very important role in whitefish production in eastern Lake Ontario. The resurgence in the 1980s of whitefish stocks in eastern

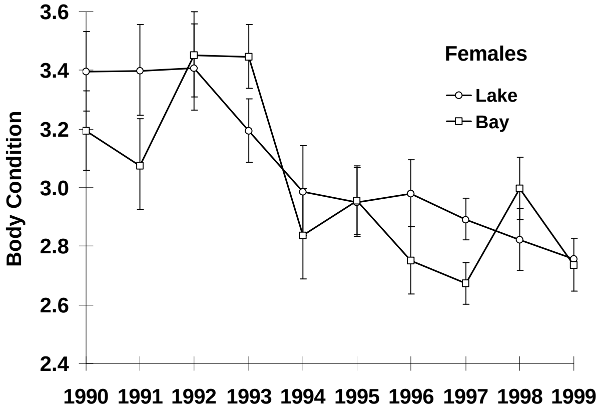

FIG. 4. Female lake whitefish body condition (least-squares mean weight adjusted for differences in length among years) in samples collected from spawning areas for "lake" and "bay" stocks, 1990 to 1999. Error bars are 95% C.I.

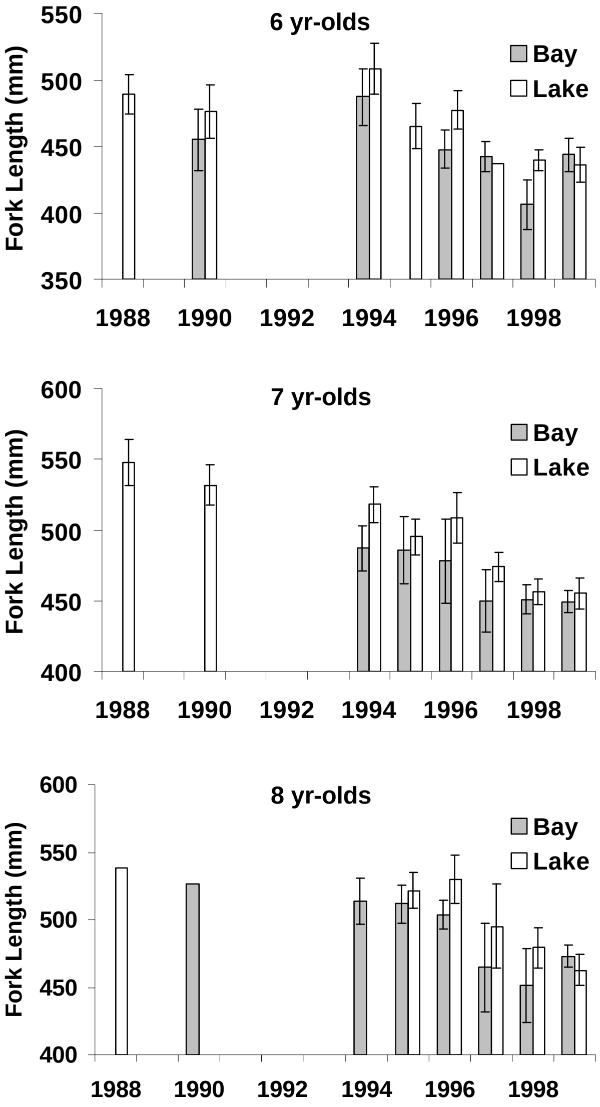

FIG. 5. Fork length-at-age for lake whitefish (6, 7 and 8 yr-olds) samples collected from spawning areas for "lake" and "bay" stocks, 1988 to 1999 (no data for 1989 and 1991 to 1993). Error bars are 95% C.I.

Lake Ontario and the Bay of Quinte is coincident with ideal thermal conditions described by Christie, particularly with the very cold falls and winters of 1976-77 and 1977-78. These conditions not only enhanced the survival and development of lake whitefish eggs and fry but reduced potential predators such as white perch and alewife (see below). Climate can play a role by producing ideal thermal conditions for the survival and development of eggs and fry and at the same time effecting selective mortality on their potential predators because of extreme environmental conditions. The cold falls and winters prior to the 1980s greatly enhanced lake whitefish recruitment and no doubt influenced the resurgence seen in the early 1980s (Casselman et al. 1996), and the warm falls and winters recently may have contributed to poor year-class strength since 1996.

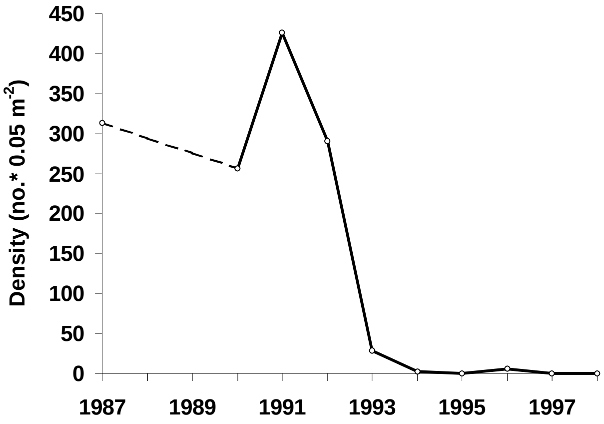

FIG. 6. Mean Diporeia *density (no. per m^2) at two sites located in the outlet basin of eastern Lake Ontario and the lower Bay of Quinte.*

TABLE 1. Frequency of occurrence of major taxa in the diet of lake whitefish during summer 1998 in the outlet basin of eastern Lake Ontario.

	Taxon		Frequency of Occurrence
Crustacea	Decapoda		0.7
	Copepoda		
	Amphipoda		
	Mysidacea		
Insecta	Diptera		9.9
	Trichoptera		4.9
Mollusca	Gastropoda		4.9
	Pelecypoda	*Dreissena*	90.1
	Pelecypoda	Other[1]	23.9
Number food items			5,814
Number of non-empty stomachs			142
Number of fish examined			169

[1] includes mainly *Pisidium* and *Sphaerium* (fingernail clams).

Exploitation

Although exploitation rates alone (as high as 50 to 65%) could account for the decline in lake whitefish abundance in the 1950s and 1960s (Christie 1968), a relaxation of fishing pressure, after the stocks collapsed, was not immediately followed by an increase in lake whitefish abundance. Other factors (see discussion below) were also operating to limit abundance during the late 1960s and 1970s. More recently, lake whitefish harvest levels were closely managed; harvest levels were increased in the 1980s and 1990s as stock abundance increased. Mark-recapture population estimates for the Bay of Quinte lake whitefish stock in 1991 indicate that exploitation rate by the commercial fishery was less than 5% that year. In more recent years exploitation was thought to be low to moderate on each spawning stock (unpublished data).

It appears that recent levels of exploitation have allowed sufficient escapement for the spawning stocks. Based on age composition on spawning shoals, lake whitefish mature at age 3 or 4 yrs-old, at least until 1994, while mean age of the harvest has ranged from 5 to 9 yrs-old, with the oldest mean ages being observed in the most recent years. Lake whitefish year-classes produced in the late 1980s showed moderate total annual mortality rates ranging from 40 to 50%.

Exotic Species

Non-native fish species, known to feed on larval fish, were hyper-abundant during the 1960s and 1970s when lake whitefish were at very low levels of abundance. Predation pressure by large rainbow smelt (*Osmerus mordax*), white perch (*Morone americana*), and alewife (*Alosa pseudoharengus*) may have been strong enough to keep the lake whitefish stocks depressed (Christie 1973, Loftus and Hulsman 1986, Casselman et al. 1996). The abundance of rainbow smelt, especially large smelt, declined during the 1980s, and can be directly attributed to predation by stocked lake trout (Casselman and Scott 1992). White perch and alewife numbers were greatly reduced as a result of selective winterkills during the cold winters of 1976-77 and 1977-78 (Hurley 1986). Their

TABLE 2. Dreissena *mussel density (no. per m^2) on lake whitefish spawning shoals (Petticoat Pt., Makatewis Is., and Trident Pt.) and at multiple sites in eastern Lake Ontario and the Bay of Quinte, 1992 to 1995 and 1997.*

	Dreissena mussel density (no. per m^2)				
	1992	1993	1994	1995	1997
Eastern Lake Ontario		214 - 9,218			
Petticoat Pt. (eastern Lake Ontario)	50 (a)	950 (a)	3,672		
Upper Bay of Quinte			445 - 389,448		26,312 - 82,580
Makatewis Is. only (upper Bay)	0 (a)	2,580 (a)	389,448	40,477	82,580
Trident Pt. only (upper Bay)	0 (a)	0 (a)	141,980	121,728	39,750
Middle Bay of Quinte			967 - 46,552		28,032 - 31,684
Lower Bay of Quinte			9 - 2,086		8,270 - 120,615

(a) estimates based on divers' visual estimates (all other estimates are based on counts of collected *Dreissena*)

numbers did not subsequently build up to previous levels, due in part to predation pressure by a recovering native walleye (*Stizostedion vitreum vitreum*) population and by stocked trout and salmon. Therefore, predation pressure on larval lake whitefish was greatly reduced in the late 1970s and 1980s.

The parasitic sea lamprey (*Petromyzon marinus*) may have been a factor causing increased mortality of lake whitefish in the 1950s. At this time lake whitefish was the only prey remaining after lake trout and burbot (*Lota lota*) stocks collapsed (Christie 1973). Lamprey control measures initiated in the early 1970s have alleviated the potential for lamprey to control lake whitefish numbers.

More recently, the invasion and proliferation of dreissenid mussels have dramatically altered eastern Lake Ontario and Bay of Quinte ecosystems during the 1990s. This has impacted lake whitefish stocks (see discussion on changes in the benthic food web below).

Cultural Eutrophication

Cultural eutrophication, along with over-exploitation, may have been a factor limiting lake whitefish abundance in the late 1960 and 1970s, at least for the Bay of Quinte stock (Hurley and Christie 1977). This factor may have operated directly by impairing over-winter egg survival on spawning shoals, as well as indirectly by influencing fish community structure. The highly eutrophic conditions in the Bay of Quinte during the 1960s and 1970s time-period were not suitable for top piscivores but favoured intermediate predators, some of which were known larval fish predators, including white perch, yellow perch (*Perca flavescens*) and alewife.

Point-source phosphorus control in the Bay of Quinte, initiated in the late 1970s, began to reverse the process of eutrophication (Minns et al. 1986). Water quality gradually improved through the 1980s, thereby lessening the influence of cultural eutrophication on lake whitefish reproduction and fish community structure. More recently, in the mid-1990s, the gradual movement away from highly eutrophic conditions has been greatly accelerated by dreissenid mussel impacts.

Recent Changes in the Benthic Food Web

Dreissena invaded eastern Lake Ontario as early as 1991 (veligers, Schaner 1998), and settled mussels were observed by 1992. Measurable effects on water quality were produced by 1993 (e.g., water clarity, Johannsson et al. 1998). *Dreissena* invaded the Bay of Quinte in 1993, were fully established by 1994 (Schaner 1998), and significant changes in Bay of Quinte water quality (e.g., phosphorus, chl a, water clarity, E.S. Millard, Department of Fisheries and Oceans, personal communication) and phytoplankton communities (K.H. Nicholls, Ontario Ministry of Environment and Energy, personal communication) were observed by 1995.

The benthic invertebrate community has also changed markedly in eastern Lake Ontario since the arrival of dreissenid mussels. The changes have included a marked decline in *Diporeia* abundance, a formerly important food item in the lake whitefish diet (Ihssen et al. 1981). *Diporeia* declined by 90% in 1993 compared with the 1990 to 1992 average, and further declined to negligible numbers thereafter. By 1998, dreissenid mussels dominated the diet of eastern Lake Ontario lake whitefish. At this time, native sphaerid and pisidium clams were a much less common part of the diet while not a single *Diporeia* was found. Lake whitefish body condition declined significantly after 1993, in both spawning stocks. The decline in body condition is likely related to the decline in abundance of *Diporeia* and possibly other native benthic macroinvertebrates.

The decline in *Diporeia* abundance is likely directly related to dreissenid mussel impacts (e.g., direct competition for phytoplankton) but predation by lake whitefish may also be a potential factor. Lake whitefish abundance peaked in 1993 at historically high levels (see above), the same year that impacts on amphipod abundance was first observed. Sly and Christie (1992) suggested that the resurgence of lake whitefish in Lake Ontario would decrease the density of *Diporeia*. Predation by white perch, was previously hypothesized to be responsible for maintaining low *Diporeia* abundance in the lower Bay of Quinte during the mid-1970s (Johnson and McNeil 1986). *Diporeia* density increased following the collapse of the white perch population in 1978 (Johnson and McNeil 1986). However, the most recent decline in *Diporeia* abundance did not occur gradually, as lake whitefish numbers built up, but rather abruptly, to virtual extirpation, following the appearance of dreissenid mussels. *Diporeia* has also declined in other areas of Lake Ontario (Randy Owens, U.S. Geological Survey, personal communication; Ron Dermott, Department of Fisheries and Oceans, personal communication) where lake whitefish are absent or rare. Also, in the lower Bay of Quinte and the outlet basin of eastern Lake Ontario, *Diporeia* density has not increased even though lake whitefish numbers declined at least by one-half between 1993 and 1998. Therefore lake whitefish predation is likely not a significant factor suppressing *Diporeia*.

Dermott and Munawar (1993) indicated *Diporeia* abundance in the profundal zone of Lake Erie was limited by competition for space and food with *Dreissena*. Our data on *Dreissena* and *Diporeia* distribution and density do not allow precise examination of their potential interaction. Nonetheless, it appears that, in eastern Lake Ontario, impacts on *Diporeia* occurred very soon after dreissenid mussel invasion and were profound.

Future Outlook

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 were once again the most important commercial species in Lake Ontario. But dramatic changes to Lake Ontario and Bay of Quinte ecosystems generally and to the offshore benthic food web particularly, following dreissenid mussel invasion, 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 and growth are poor and indicate that food resources are limiting. Most recently there has also been poor production of young fish. These results are symptomatic of a stressed population and suggest that lake whitefish populations will continue to decline.

In light of declining abundance, poor recruitment, and continued poor body condition and growth, along with the uncertain future because of ecosystem change, it would be prudent to manage whitefish populations conservatively. Recent harvest levels have allowed for sufficient escapement of the spawning stocks that, in unstressed populations, would not threaten their sustainability. It is not clear what level of exploitation, if any, is appropriate for stocks experiencing such extreme food web disruption.

Recent changes in Lake Ontario's offshore benthic food web have implications for other benthivores. Slimy sculpin (*Cottus cognatus*), and juvenile lake trout, along with the lake whitefish, are likely candidates to be impacted.

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Lake Ontario Salmonid Introductions 1970 to 1999: Stocking, Fishery and Fish Community Influences

T. J. Stewart and T. Schaner

Introduction

The symposium on Salmonid Communities in Oligotrophic Lakes (SCOL-I) (Loftus and Regier 1972) provided insights on the stressors acting on Great Lakes ecosystem. In 2001, the Great Lakes Fishery Commission (GLFC) initiated a second SCOL symposium (SCOL-II) to synthesize new knowledge. As part of the synthesis, Great Lakes investigators submitted various working papers covering a variety of topics for use at a workshop. This is paper is one such contribution and can also be found on the internet at <http://www.glfc.org/bote/upload/salmonid introductionsstewart.doc>. The publication of the complete Lake Ontario SCOL-II synthesis is expected in 2002.

The initial introduction of salmonids into the Great Lakes was an attempt to control nuisance levels of alewife but quickly became focused on developing a multi-million dollar recreational fishing industry (O'Gorman and Stewart 1999). In early 1970s, New York State and the Province of Ontario began to establish recreational fisheries and rehabilitate lake trout by accelerating the introductions of lake trout (*Salvelinus namaycush*), brown trout (*Salmo trutta*) , rainbow trout *(Oncorhynchus mykiss*), chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*Oncorhynchus kisutch*) and Atlantic salmon (*Salmo salar*). Limited stocking of kokanee salmon (*Oncorhynchus nerka*), was discontinued in 1973. The introductions initially failed to establish significant fisheries due to high parasitic sea lamprey induced mortality (Pearce et al. 1980). In the early 1980s, sea lamprey were effectively controlled (Christie and Kolenosky 1980) and the survival of all stocked trout and salmon improved. Hatchery programs in both New York and Ontario were expanded and stocking levels were increased. In the following years, activity in the recreational fishery greatly expanded. Total annual expenditures by anglers participating in Lake Ontario's recreational fisheries were $53 million (Canadian) for Ontario in 1995 (Department of Fisheries and Oceans 1997) and $71 million (U.S.) for New York in 1996 (Connelly et al. 1997). In this paper we describe the recent history (post 1970) of salmonid introductions and the offshore boat fishery. We also review and summarize information regarding major fish community influences of introduced salmonids in Lake Ontario.

Management of salmonid stocking levels

The number of salmonids stocked rapidly increased during the 1970s and 1980s (Fig. 1). In the mid-1980s, the state of New York and the province of Ontario agreed to limit stocking to 8 million salmonids annually (Kerr and LeTendre 1991) in response to concerns about the sustainability of the high predator levels, declining alewife, record fishery yields and perceived risks to the burgeoning recreational fishery (Kocik and Jones 1999; O'Gorman and Stewart 1999).

In 1992, and again in 1996, joint New York and Ontario technical syntheses and stakeholder consultations resulted in changes to stocking policy (O'Gorman and Stewart 1999; Stewart et al. 1999). Stocking levels were reduced to 4.5 million salmonids in 1996, and have been maintained at between 4 and 5.5 million annually. In 1999, the percentage of the total salmonid stocked by species was 39.2% chinook salmon, 18.8% lake trout, 17.2% rainbow trout, 12.2% brown trout, 7.2% coho salmon, and 5.5% Atlantic salmon.

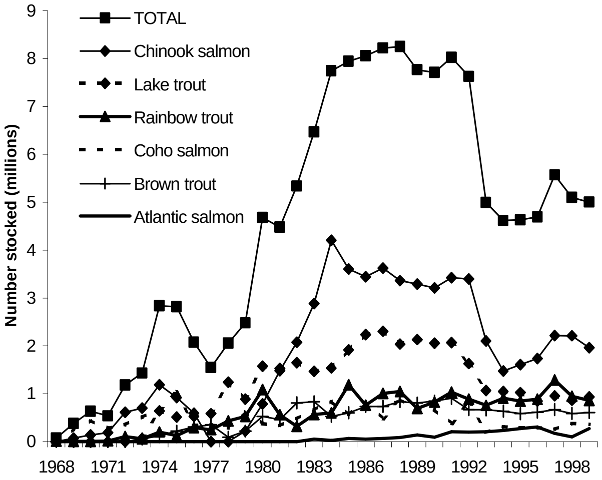

FIG. 1. Number of salmonids stocked in Lake Ontario, 1968-1999 (excludes fish stocked at a weight < 1 g).

Species stocking history

Chinook salmon

The resumption of chinook salmon stocking into Lake Ontario by New York state in 1969, and by Ontario in 1971, followed a 35-year hiatus (Parsons 1973; Kocik and Jones 1999). Despite early failed introductions in Lake Ontario, significant angling returns from Lake Michigan following introductions of Pacific salmon caused renewed interest in the other Great Lakes (Kocik and Jones 1999). Chinook salmon was initially not the dominant species stocked (Fig. 1). However, angler preference for the large fast growing chinook along with lower hatchery production costs compared to other species, resulted in an increased predominance of chinook salmon. By 1982, chinook salmon dominated the stocking of Lake Ontario salmonids. From 1982 to 1999, they represented between 32 to 54% of the annual stocking.

Stocking levels of chinook were influenced by fisheries management efforts to regulate the level of predation on alewife. Alewife is the primary prey of Lake Ontario chinook salmon (Jones et al. 1993). As a result of their high abundance and fast growth, chinook salmon account for an estimated two-thirds of the lakewide predator demand for alewives (Jones et al. 1993). Consequently, management of predator demand required management of chinook salmon stocking levels. As the mainstay of the recreational fishery and the associated tourism economies, changes to chinook salmon stocking levels were controversial. Chinook salmon stocking numbers received considerable bi-national management attention and public scrutiny (Kocik and Jones 1999; O'Gorman and Stewart 1999; Stewart et al. 1999). Stocking numbers peaked in 1984 at 4.2 million fish and ranged from between 3.2 and 3.6 million fish from 1985 to 1992. Chinook salmon stocking was reduced substantially in 1994, based on a management review in 1992 (O'Gorman and Stewart 1999), and ranged from 1.5 to 1.7 million fish annually from 1994 to 1996. Due to stakeholder demand, and a second management review (Stewart et al. 1999), stocking was increased slightly in 1997 and has ranged from 2.0 to 2.2 million fish annually from 1997 to 1999.

Lake trout

The history of Lake Ontario lake trout stocking, rehabilitation, management, and research is well documented (Schneider et al. 1983; Elrod et al. 1995; Schneider et al. 1998). Initial efforts at rehabilitation between 1953 and 1964 were abandoned, but renewed after initiation of sea lamprey control in 1971 (Schneider et al. 1983). Lake trout stocking policy has been directed at meeting management objectives for rehabilitation described in joint New York and Ontario rehabilitation plans (Schneider et al. 1983; Schneider et al. 1998). Lake trout of nine genetic strains have been stocked into Lake Ontario since 1972. The strain composition is dominated by non-Great Lake strains (6 strains), two Lake Superior strains, and a brood stock developed from mixed strains of hatchery fish that survived to maturity in Lake Ontario (Elrod et al. 1995). Lake trout stocking increased to 1.9 million fish in 1985, and was maintained above 2.0 million fish annually until 1992. Changes to stocking policy to regulate predation on alewife resulted in reductions in lake trout stocking in 1993. From 1993 to 1999 stocking of lake trout has ranged from 0.9 to 1.1 million fish annually. Management efforts have maintained lamprey mortality at low levels, restricted excessive angler or incidental commercial harvests, improved survival by increasing the proportion of Seneca genetic strain, and varied stocking practices to improve survival (Elrod et al. 1995; Schneider et al. 1998).

Rainbow trout

The rainbow trout is unique among the introduced salmonids as it represents the earliest to naturalize and has the longest history of successful introduction. Naturalized populations were established in all five Great Lakes by the early 1900s (MacCrimmon and Gotts 1972, referenced in Kocik and Jones 1999). In

Lake Ontario, there were established spawning runs in several tributaries by the 1960s (Christie 1973). Despite the presence of wild runs, rainbow trout stocking accelerated from 107,000 in 1972 to 1.1 million by 1980. From 1981 to 1999 annual stocking has ranged from 570,000 to 1.3 million fish annually representing from 6 to 23% of the total salmonids stocked. Compared to other introduced salmonids, rainbow trout stocking numbers have received less scrutiny. Encouragement of wild rainbow trout production has recently been established as a management goal (Stewart et al. 1999), however no specific stocking policies to support this goal have been developed. Much of the annual variation is due to the stocking of a diversity of life-stage (spring fingerlings, fall fingerlings, and yearlings) and the vagaries of the management of hatchery space in a multi-species fish culture program.

Brown trout

Brown trout are native to Europe but have been introduced throughout the world (MacCrimmon and Marshall 1968). Self-sustaining stream resident stocks occur in the Lake Ontario watershed but few wild brown trout exist in the main-body of Lake Ontario (Bowlby 1991). The stocking of brown trout accelerated along with other salmonids during the 1970s and 1980s and reached a peak of 0.9 million fish in 1991. From 1992 to 1999 stocking has been relatively unchanged, ranging from 585,000 to 672,000 fish annually.

Coho salmon

Much of the initial excitement and development of salmon fishing can be attributed to introductions of coho salmon (Scott and Crossman 1999; Kocik and Jones 1999). Both New York and Ontario’s renewed interest in salmonid introductions began with an initial stocking of coho salmon in 1968 (New York) and 1969 (Ontario). Coho salmon continued to dominate the province of Ontario’s stocking program until 1979. Total stocking of coho reached its peak in 1988 with the stocking of 879,000 fish. The next largest stocking of coho was in 1992 at 829,000 fish. Cost considerations resulted in the discontinuation of coho stocking by the province of Ontario from 1992 to 1996. However, because of strong public sentiment the province of Ontario resumed coho stocking in 1997. From 1993 to 1999, the number of coho stocked in New York and Ontario combined, has ranged from 196,000 to 360,000 fish annually.

Atlantic salmon

Differing and changing management objectives and policies among state, provincial, and U.S. Federal agencies has influenced the history of Lake Ontario Atlantic salmon stocking. In the recent past (post 1970), in the province of Ontario, management and stocking practices have been directed at investigating the feasibility of establishing Atlantic salmon. Stocking began in Ontario with the stocking of 1,000 fall fingerling into Wilmot Creek in 1987. From 1988 to 1995 between 28,000 and 76,000 spring yearlings and fall fingerlings, were stocked into the Credit River, Wilmot Creek and the Ganaraska River (1995 only). From 1996-1999, Ontario began to emphasize fry stocking, and between 121,000 to 249,000 Atlantic salmon fry were stocked annually. In the early years, fish from both landlocked and anadromous strains were stocked. Beginning in 1991, all Atlantic salmon stocked by the province of Ontario have been from a genetic strain of anadromous fish from the LeHave River, Nova Scotia.

In New York, the Department of Environmental Conservation program evolved from an initial rehabilitation emphasis beginning in 1983, to an increased emphasis on the establishment of a trophy sport fishery (Abraham 1988). Beginning in 1996, the U.S. Fish and Wild Service initiated limited stocking to investigate the survival and growth of stocked Atlantic salmon in selected New York tributaries. The first stockings (post 1970) of Atlantic salmon by New York were in 1983, and from 1983 to 1990 annual stocking numbers ranged from 25-53,000 fish. From 1991 to 1999 stocking increased to between 98,000 and 302,000 Atlantic salmon yearlings and fingerlings annually. New York stocked Atlantic salmon originate from four distinct landlocked strains (Little Clear Lake, Grand Lake, Lake Memphremagog, and Sebago Lake) and one anadromous strain (Penobscot River, MN).

Salmonid fisheries

The salmonid fishery is comprised of several components: an offshore-boat fishery; a lakeshore fishery; and a tributary fishery. The only fishery that is consistently monitored is the offshore boat fishery, which is thought to represent one-third to one-half of the total recreational fishing effort and harvest (Savoie and Bowlby 1991; T. Eckert, personal communication, New York Department of Environmental Conservation, Cape Vincent, N.Y. 13601).

Total annual fishing effort in the offshore boat fishery ranged from 2.2 to 4.4 million angler-hours from 1985 to 1995 (Fig. 2), with 70% of the fishery effort occurring in New York waters (Stewart et al. 2002). Fishing effort increased over the period from 1985 to 1990, but declined to about half the 1990 peak level by 1995 (Fig. 2). Total annual harvest ranged from 153 to 548 thousand fish (Fig. 2) with 58% of the harvest being from New York waters and 42% from Ontario (Stewart et al. 2002). Harvest peaked in 1986 and declined thereafter (Fig. 2).

The species composition of the harvest, in order of dominance was chinook salmon, rainbow trout, lake trout, brown trout and coho salmon (Stewart et al. 2002). Atlantic salmon harvest has been limited to several hundred fish (less than 1% of the total harvest) and will not be considered further. Harvest generally declined from 1985 to 1995 by 2 to 4-fold for all species but trends varied somewhat in New York and Ontario (Fig. 3). Chinook salmon harvest declined from a high of 224,000 in 1986 to 53,000 by 1995. Rainbow trout harvest declined from a high of 120,000 in 1988 to 40,00 fish by 1995. Lake trout harvest declined from a high of 121,000 in 1985 to 28,000 by 1995. Brown trout harvest declined from a high of 79,000 in 1986 to 28,000 by 1995. Coho salmon harvest showed the largest decline from a high of 46,000 in 1986 to 6,000 fish by 1995.

Commercial versus recreational fishing yields

Historical commercial fisheries in the U. S. and in western and central Canada waters relied on stocks of ciscoe, lake whitefish, and lake trout. These stocks and their associated fisheries had collapsed or were greatly reduced by the mid-1940s. (Christie 1973). In eastern Lake Ontario commercial fisheries persisted. Their longevity can be attributed to lake whitefish stocks, that persisted through the 1950s and by increased reliance on warm-water species (Christie 1973). The modern commercial fishery continues to be concentrated in the nearshore waters of the northeastern part of Lake Ontario. Harvest is comprised of 15 to 20 species dominated by warm-water species (American eel, walleye, yellow perch, brown bullhead) and lake whitefish.

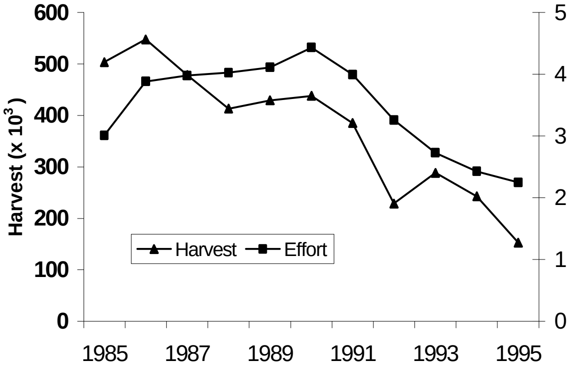

FIG. 2. Total annual fishing effort and harvest of salmonids in the offshore boat-fishery in Lake Ontario for the water of New York and Ontario combined, 1985-1995 (redrawn from table in Stewart et al. 2002).

The commercial fishery yielded 1,050 mt of fish in 1985, but by 1995 yields had declined to 600 mt (Fig. 4). By comparison, yields from the salmonid boat-fishery peaked at 2,600 mt in 1987 and declined to 824 mt in 1995 (Fig. 4). Recreational boat-fishing yields exceeded commercial fishing yields in all years.

Examination of long-term commercial catch statistics has provided much of our understanding of early fish community structure and function (Christie 1973). Fishery yields have been used to assess changes in system productivity and food-web dynamics (Matuszek 1978; Leach et al. 1987; Loftus et al. 1987). The combined recreational and commercial yields from 1985 to 1995, expressed on an area basis ranged from 0.7 to 1.8 kg/ha. Recreational fishing yields reported in this study do not include harvests from large unsurveyed shore and tributary fisheries. Including these fisheries would result in yields at least twice as high as those documented. Matuszek (1978) determined that the maximum sustained average annual yield from historical Lake Ontario commercial fisheries from 1915 to 1929 was 1.25 kg/ha. Clearly, current fish yields far exceed historical maximums. The extremely high yields in the last decade, derived primarily from hatchery supported recreational fisheries, has no historical precedent.

Influences of introduced salmonids on the fish community

An examination of the fish community influences of introduced salmonids in Lake Ontario must consider various temporal and spatial scales. Spatial scales of influences range from effects of migratory salmonids on individual stream ecology (Kocik and Jones 1999 and references therein), to impacts on unique eco-regions such as the outlet basin of eastern Lake Ontario (Christie et al. 1987a; Casselman and Scott 1992), to whole-lake food-web impacts (Jones et

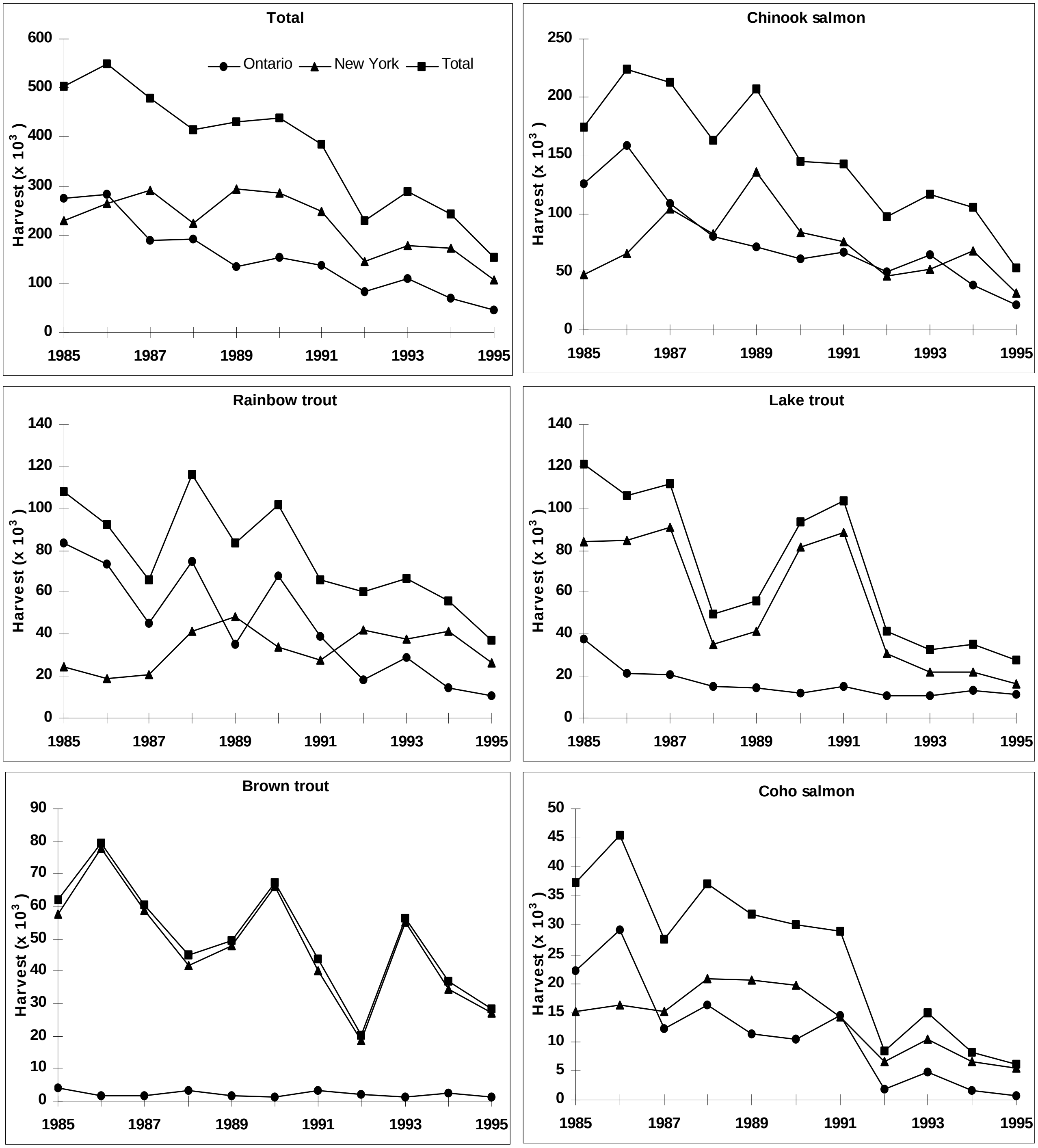

FIG. 3. Total annual Lake Ontario salmonid boat-fishery harvest and annual species-specific harvest for New York and Ontario, 1985-1995 (from Stewart et al. 2002).

al. 1993; Rand et al. 1994; Rand and Stewart 1998a; Rand and Stewart 1998b). Similarly, impacts of introduced salmonids have been investigated at the level of individual year-classes (Jones and Stanfield 1993), multi-species trend analysis (Christie et al. 1987a, O'Gorman et al. 1987) and longer-term impacts of ecosystem and food-web restructuring (Christie et al. 1987b; Eschenroder and Burnham-Curtis 1999).

Despite the diversity of investigations, we believe only two major biotic influences are evident: direct and indirect effects on fish communities through predation on alewife and smelt; both positive and negative influences on the persistence and restoration of native salmonids. A third influence, although not strictly biotic, but a consequence of the stocking of large numbers of hatchery exotics into a perturbed fish community, is the loss of an ecological paradigm on which to base fish community management.

Predation effects

Stocking of salmonids resulted in rapid build-up of predator levels through the 1970s and early 1980s (Fig. 1). Lake-wide harvest rates of chinook salmon, rainbow trout, lake trout, brown trout, and coho salmon in the offshore recreational fishery peaked in 1985 or 1986 and declined thereafter (Stewart et al. 2002). Index gillnet catches of lake trout in U.S. waters reached their highest level in 1986 and remained high (Elrod et al. 1995). In Canadian waters, the build-up of lake trout was 3-4 years later (Elrod et al. 1995) corresponding to a 3-year lag in the initiation lake trout stocking by Ontario.

Earliest available data suggest that prior to the build-up of predator levels (i.e. pre-1985), alewife and smelt were regulated by intraspecific and interspecific competitive interactions, cannibalism, and weather (Smith 1968; Christie 1973; Christie et al. 1987a; O'Gorman 1974; O'Gorman et al. 1987; Smith 1995; O'Gorman and Stewart 1999). The increasing importance of predation by introduced salmonids and other piscivores was recognized but it was not considered to be a dominant influence (Christie et al. 1987a; O'Gorman et al. 1987).

The diet of salmonids in Lake Ontario is comprised almost entirely of smelt and alewife (Brandt 1986; Rand and Stewart 1998a; Lantry 2001). By the late 1980s and through the 1990s the impact of predation on alewife and smelt became more evident (O'Gorman and Stewart 1999; Casselman and Scott 1992), although it was confounded with declines in nutrients and zooplankton production (Millard et al. 1996; Rudstam 1996). O'Gorman and Stewart (1999) observed that biomass of adult alewife caught in bottom trawls was 42% lower from 1990 to 1994 than from 1980 to 1984. In the outlet basin of eastern Lake Ontario, bottom trawls catches of alewife and smelt have been variable, but declined to extremely low levels beginning in 1993 (OMNR, unpublished data). Regional variation in the timing and extent of prey fish decline is to be expected and bottom trawling catches can be influenced by changed fish distribution. Less equivocal are whole-lake hydroacoustic estimates, which demonstrate a severe and persistent decline in offshore smelt and alewife numbers throughout the 1990s (Fig. 5). We contend that smelt and alewife numbers remained low throughout the 1990s due primarily to high levels of predation by introduced salmonids.

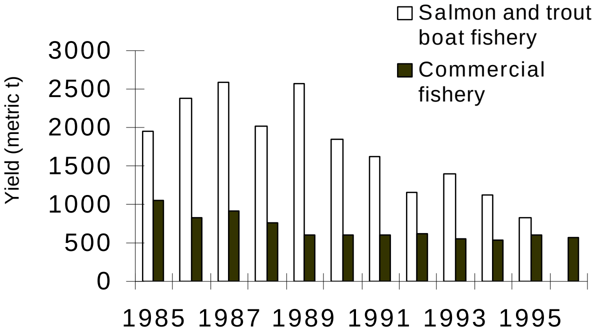

FIG. 4. Lakewide yields from Lake Ontario's New York and Ontario angling boat fishery for salmonids and from Ontario's commercial fishery, 1985-1996. The total boat-angling harvest was not measured in 1996.

The suppression of alewife and smelt in Lake Ontario during the late 1980s and 1990s was associated with a number of fish community changes. The alewife is considered the dominant biotic influence on Lake Ontario fish communities (O'Gorman and Stewart 1999; Stewart et al. 1999, and reference therein). However, many of the food-web interactions attributed to alewife (for example, predation on fish larvae, competition with other planktivores, and their importance in the diet of trout and salmon) also apply to rainbow smelt (Brooks 1968; Christie 1973; Nepszy 1977; Brandt 1986; Loftus and Hulsman 1986). Alewives are ubiquitous in their distribution while rainbow smelt tend to inhabit deeper and colder water. Both species exhibit large-scale seasonal re-distribution between the offshore and nearshore. The abundance, distribution and ecology of these two species result in important interactions with

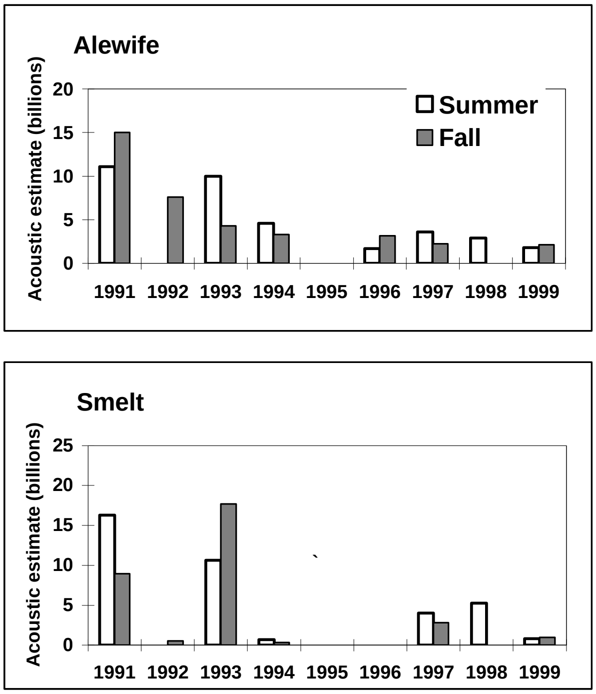

FIG. 5. Whole-lake acoustic estimates of abundance (number of fish) for alewives and smelt in Lake Ontario, 1991-1999.

virtually all offshore fish species and many inshore fish species. Coincident with the decline of alewife and smelt there was an increase in natural reproduction of lake trout, an increase in offshore abundance of native three-spine stickleback, a recovery of native lake whitefish stocks, and some improvements in native populations of yellow perch, emerald shiner, and lake herring (Stewart et al. 1999). Other factors have contributed to these changes, but they are consistent with the hypothesis of a relaxation of predation and competition from suppressed populations of alewife and smelt. More recently, the loss of *Diporeia* (deepwater amphipod) in large regions of Lake Ontario, coincident with colonization by dreissenids, has reversed whitefish recovery and may impact other species (Hoyle et al. 1999).

Effects on native salmonids

The introduction of hatchery salmonids may enhance restoration of native salmonids. Atlantic salmon and lake trout were native to Lake Ontario but all native gene pools were lost. Introductions of hatchery fish raised from available gene pools are the only way to re-establish these species. Evidence suggests that a diet high in alewives result in early mortality syndrome in the offspring of lake trout and Atlantic salmon due to an inducement of thiamine deficiency (Fisher et al. 1996; McDonald et al. 1998). The suppression of alewife by introduced salmonids may increase the diversity of Atlantic salmon and lake trout diets and mitigate the loss of thiamine.

Existing rare native brook trout and potentially future stocks of wild Atlantic salmon could be negatively impacted by continued introductions of hatchery salmonids. Kocik and Jones (1999) summarized studies on the potential interactions of introduced Pacific salmonids (rainbow trout, coho salmon, and chinook salmon) on native brook trout and on the potential for Atlantic salmon restoration. Studies and field observations indicate that it is possible for native and non-native salmonids to coexist (Kocik and Jones 1999; Scott and Crossman 1999). However, all of the introduced non-native salmonids potentially compete for spawning and nursery habitat and food with introduced Atlantic salmon and native brook trout. The high abundance of non-native salmonids, and increasing naturalization, may limit the production of native brook trout and the future extent of Atlantic salmon restoration.

Historically, four species of deepwater ciscoe, *Coregonus nigripinnis, C. reighardi, C. kiyi, and C. hoyi* inhabited Lake Ontario (Christie 1972). The loss of these species has been attributed to overfishing, increased abundance of alewives and smelt, and predation by sea lampreys (Christie 1973; Smith 1968). Fish management agencies have proposed the reintroduction of deepwater ciscoe into Lake Ontario. In Lake Michigan, although cause and effect are debated, bloaters (*C. hoyi*) increased coincident with a decline in alewife and high levels of introduced salmonid abundance (Eck and Wells 1987; Kitchell and Crowder 1986; Stewart and Ibarra 1991). These conditions exist in Lake Ontario, likely favour successful reintroduction of native deepwater ciscoes, and are dependent on maintaining a high abundance of introduced salmonids.

Loss of an ecological paradigm

The initial introduction of salmonids into the Great Lakes was an attempt to control nuisance levels of alewife but quickly became focused on developing multi-million dollar recreational fishing industry (O'Gorman and Stewart 1999). In Lake Ontario, efforts to rehabilitate lake trout where renewed with increased effort to control sea lamprey. The strategy for the rehabilitation of lake trout, and later Atlantic salmon, in Lake Ontario have had strong scientific and ecological underpinnings (Eschenroder et al. 2000; Elrod et al. 1995; Ontario Ministry of Natural Resources 1995; Schneider et al. 1983; Stanfield et al. 1995). On the other hand, science-based management of the recreational sport fishery has focused only on the potential for over-stocking (Jones et al. 1993; O'Gorman and Stewart 1999; Stewart et al. 1999).

The potential for a large controlling influence of piscivores on the structure and function of the Lake Ontario fish community was recognized (Christie et al. 1987a; Christie et al. 1987b), but this has yet to influence management decision making (Stewart et al. 1999). The Lake Ontario fish community is largely comprised of a mix of exotic species that have no evolutionary sympatry. Additionally, recruitment of the dominant predator, and the associated top-down influence on fish communities (Christie et al. 1987a; McQueen et al. 1989) is largely controlled through stocking levels. As a consequence, it is difficult to apply conventional ecological paradigms or descriptions of historical fish community structures to understand or predict species interrelationships or equilibrium states (Christie et al. 1987b; Eschenroder and Burnham-Curtis 1999). This is not only a challenge to fisheries managers but also requires researchers to develop new conceptual models of fish community structure and function to guide management.

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Eastern Lake Ontario Walleye: A Foreword

Starting in 2001 and throughout the winter of 2002, the Ministry of Natural Resources (MNR) presented information to the public outlining MNR's conservation concerns about walleye. Scientific information documented environmental change, a smaller walleye population and over-fishing. A significant reduction in walleye harvest, by as much as 75% from existing levels was required. The principle objective was to look for solutions to sustain the walleye fishery over the long term and to provide the associated benefits.

In recent years, the decline in the recruitment and abundance of walleye in eastern Lake Ontario has placed walleye at the center of attention within the Lake Ontario Management Unit (LOMU). There has been increased assessment effort aimed at estimation of the population size, describing the implications of possible total harvest amounts and discussions about management strategies. The following three chapters discuss aspects of the biology of the walleye population in the Bay of Quinte and eastern Lake Ontario.

Chapter 13 is a copy of a manuscript submitted for publication. This manuscript was reviewed and endorsed by a panel of experts from the Great Lakes Fishery Commission in the spring of 2001. It was an important component of the information that MNR provided to the public about walleye.

Chapter 13 provides three biological reference points that reflect analyses of recruitment, fishing mortality, abundance estimates and the forecasting of several outcomes based on a variety of possible exploitation/recruitment scenarios. The first biological reference point, a critical stock size of 160,000 fish, was defined as being the population of walleye from which the minimum stock size would be would reached after two years of failed recruitment. A minimum stock size was estimated to be 40,000 fish and represents a stock size from which walleye recovered in the late 1970's. The second biological reference point was a recommended exploitation rate and was based on the exploitation rate of 10%[1] that calculated from the time period in the 1980's and early 1990's when harvest rates supported the recovery of the walleye population from low levels. The third biological reference point was termed the precautionary limit and set at twice the critical stock size.

The management decision model based on these biological reference points recommended that if the abundance of walleye is less than 160,000 fish, then all fishing must stop. Between the critical stock size and the precautionary limit, exploitation rates must be conservative. Above the precautionary limit of 320,000 fish, the target exploitation level must not exceed 10%.

In Chapters 14 and 15, the status of walleye in 2001 and updated forecasting are presented, respectively. The walleye population in 2001 was about 400,000 fish, which is above the precautionary biological reference point. However, fish 3-years-old and older were exploited at almost twice the recommended exploitation rate. The forecasting based on 2001 information and analyses in Chapter 15 suggests that the population of walleye will remain relatively stable through to 2006. However, predicted abundance estimates will change dependent about the recruitment of young fish and other new information. There is the potential of a decrease in abundance below the 320,000 mark, if there is poor production of a year class in 2002 and in subsequent years.

The walleye population of Bay of Quinte and eastern Lake Ontario provides important cultural, social and economic benefits to the area. LOMU will continue to concentrate efforts on updating its information about walleye and applying the most appropriate and current analyses and modeling techniques to its data in order to provide the best available science to provide to the public and upon which to base management decisions.

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[1] In Chapter 13, there was a small error made in estimating the recommended exploitation rate. All other analyses in Chapter 13 were unaffected, and the error was corrected. The result was a change in the recommended exploitation rate from 8% to 10%.

13

Biological Reference Points for Management of a Declining Walleye (*Stizostedion vitreum*) Population in the Bay of Quinte and Eastern Lake Ontario [1]

T. J. Stewart, J. A. Hoyle, A. Mathers, and T. Schaner

Abstract

We synthesized long-term information on the walleye (*Stizostedion vitreum*) population and fisheries of the Bay of Quinte and eastern Lake Ontario from 1957-2000, derived biological reference points for the management of the declining walleye population, and forecasted the level of exploitation and walleye population size in 2001 and 2005. The forecasts indicate that walleye will be overexploited in 2001 and that the population may fall below the critical stock size by 2005. We examined index gillnet and trawl series (1958-2000), harvests from angling, commercial and aboriginal fisheries (1957-2000), and mark-recapture population estimates (1985-1999). Catch-age-analysis (CAGEAN) was performed using open-water angling effort and harvest and index trawl and catch information for the years 1974-1988 and 1984-1998. For the latter period, CAGEAN estimates were calibrated with mark-recapture population estimates. Information on the walleye population and fisheries was most complete for the years 1984-2000, and information from these years were represented in a time-step age-structured model that simulates recruitment, growth, mortality, and exploitation of a fish population. The model was calibrated to replicate population structure estimated through CAGEAN and mark-recapture. An exploitation reference point was derived empirically by defining a historical period of walleye population resurgence and fisheries development and using the model to calculate the average exploitation rate over that period. Minimum stock size and critical stock size reference points were derived empirically by determining the population size of walleye during a period of low but sustained abundance using several methods. The simulation model was used to evaluate whether reference points would be exceeded in the years 2001 and 2005 under varying assumptions of recruitment, population size, and fisheries harvest.

Introduction

The walleye (*Stizostedion vitreum*) population in the Bay of Quinte and eastern Lake Ontario is one of the Great Lakes' largest and more important walleye stocks. This population declined in the late-1960s, and then rebounded in the late-1970s subsequent to the control of cultural eutrophication and coincident with massive and selective winter-kill of white perch and alewife (Hurley and Christie 1977, Hurley 1986, Bowlby et al. 1991). During the 1980s and early 1990s, production of many good year classes, optimal trophic conditions, and conservative fishing practices resulted in a build-up of walleye to record high levels. A gradual decline in nutrients (Minns et al. 1986) and a rapid increase in water clarity and aquatic vegetation followed the colonization of Dreissenid mussels in 1994 (unpublished data, Bailey et al. 1999, Scott Millard, Great Lakes Laboratory for Fisheries and Aquatic Sciences, Bayfield Institute, Canada Centre for Inland Waters, Burlington, ON, L7R 4A6, personal communication). Coincidentally walleye recruitment, and soon after, the walleye population, declined.

A small commercial and angling fishery were maintained through the period of decline. Fisheries

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[1] An earlier draft of this paper was completed in March 2001 and submitted for technical review to the Aquatic Research and Development Section, Ontario Ministry of Natural Resources and to the Board of Technical Experts (BOTE) of the Great Lakes Fishery Commission.

further developed in response to the increasing walleye population. In the 1980s, an angling fishery grew rapidly in the Bay of Quinte. Initially, commercial walleye harvest was restricted to help promote continued walleye rehabilitation, however, a seasonally and spatially limited entrapment-gear commercial fishery was eventually established in 1989 (Bowlby et al. 1991). Increased aboriginal walleye harvest occurred following the 1990 Supreme Court of Canada decision (*Regina v. Sparrow 1990*) establishing the priority of food fishery rights of indigenous peoples over the rights of other users (Olver et al. 1995). During the most recent period of decline, continued fishing increased the risk of over-exploitation. There was need for an assessment of the level of exploitation and the development of management recommendations to conserve the walleye.

Biological reference points that describe the status of stocks have been used as management tools to support the decision-making process and to recommend the direction of required management changes (Smith et al. 1993, Caddy and Mahon 1995, FAO 1996). It has been recommended that uncertainties associated with biological reference points and management applications be considered (Smith et al. 1993, Rosenberg and Restrepo 1994, FAO 1996, Francis and Shotton 1997). In this paper, we take a pragmatic approach to develop biological reference points by examining long-term fisheries population and harvest data and incorporate them into a fisheries management simulation model. Reference points are derived empirically by analyzing historical periods of walleye population resurgence and fisheries development. We propose a management decision model formulated in terms of population size and exploitation rate. The management decision model defines a safe level of harvest appropriate to the declining walleye stock and the current mix of fisheries, and defines a minimum stock size and a critical stock size at which we recommend a cessation of fishing. We in turn explore the management consequences of uncertainty and the risks to the walleye stock by using the simulation model to forecast walleye population size and exploitation rate.

Methods

Walleye abundance indices

The abundance of walleye 1-yr-old and older was monitored during summer using bottom-set gillnets at two fixed sampling sites (Big Bay and Hay Bay) in the Bay of Quinte (1958 to 2000 excluding 1966) and at one site in eastern Lake Ontario (Simcoe Island 1977-1985, replaced with nearby Melville Shoal 1986 - 2000, Fig. 1). Gillnets were comprised of a graded series (1.3 cm intervals) of mesh sizes from 3.8-12.7 cm or 15.2 cm stretched mesh. Multifilament nets were replaced with monofilament nets in 1991 (Bay of Quinte) and 1992 (eastern Lake Ontario). Gillnets were set parallel to the contour in depths ranging from 5.0-17.5 m. Catches were adjusted to represent 100 m of each mesh size, summed across mesh sizes, and referred to as catch-per-gillnet. Abundance of young-of-the-year walleye was monitored annually using a bottom trawl at six fixed sampling sites (Trenton, Belleville, Big Bay, Deseronto, Hay Bay and Conway; Fig. 1) in the Bay of Quinte (1972-2000 excluding 1989). Sampling occurred in late summer (August and early September) and consisted of one to six replicates at each site. For both the trawl and gillnet time series, adjustments were made using linear regression techniques to estimate missing data for some strata in some years.

Walleye harvest

Walleye harvest was assessed with different methods and intensities from various fisheries. Angling surveys were conducted from 1957-1962, 1974, 1976, 1979 to 1982 and 1984 to 2000 for the open-water fishery and in 1982, 1984, 1986, 1988-2000 for the ice-angling fishery. Aerial and on-water counts of fishing boats and ice-huts were made to determine angling effort. Anglers were interviewed to determine catch/harvest rates and biological

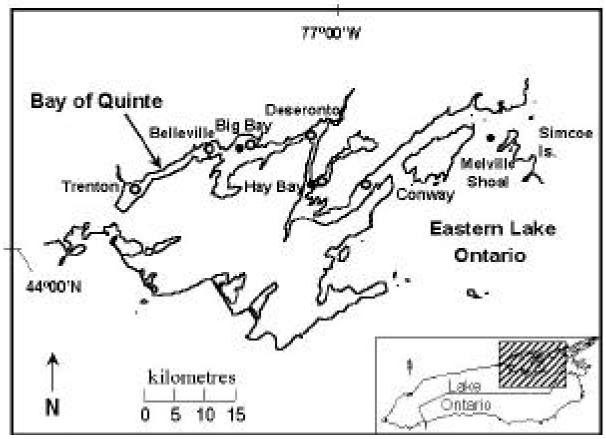

FIG. 1. Map of Bay of Quinte and eastern Lake Ontario showing index gillnetting and trawling sites.

characteristics of the angler's harvest. Commercial harvest was reported directly by fishers as part of licensing conditions. Aboriginal spear-fishing harvest was monitored on three Bay of Quinte rivers during the spring walleye spawning run. Spear-fishing effort on the Napanee and Moira Rivers was measured using random hourly counts of spear-fishing activity for the years 1994-2000. Interviews with spear-fishers provided information on harvest rates and biological characteristics of the harvest. Annual harvest on the Salmon River was censused directly by the aboriginal community and provided for the years 1982, 1988-1989, and 1991-1998. Harvest in 1999 and 2000 was assumed to be the average of the 1992-1998 harvests. The only major source of walleye harvest that was not formally surveyed was that of the aboriginal gillnet fishery.

Population estimates

Mark-recapture

Marking and recapture surveys were conducted during spring and fall from 1985-1987 and during fall in 1988, 1989, 1991, 1992, 1998, 1999 and 2000. Walleye were batch-marked with a punch on two dorsal fin rays. Various combinations of fin rays were used to provide a binary code that uniquely identified year and location. Marking and recapturing sessions were during spring (April) and fall (September-November) until 1987. Beginning in 1988, all marking and recapturing sessions were during fall. Age-specific population estimates were calculated for each year class using Jolly-Seber and Peterson methods (Ricker 1975). These data provided direct estimates of the number of walleye present in 1985-1989, 1991, and 1999. Analysis of covariance of the log-transformed population estimates was used to estimate a common, instantaneous mortality and survival among year-classes. For the years 1985 to 1991 survival did not differ significantly among year-classes. The mean survival was 68.4% (95% CI 63.3, 73.9). The population estimates of younger walleye were excluded from this analysis as the estimates suggested that marked and unmarked fish were not randomly distributed until age 3 or 4. We used the survival estimate to adjust the age-specific estimates of the population, particularly younger fish, to interpolate estimates for 1990 and to back-cast estimates for 1979-1984. Marking and recapture sessions in 1998-2000 were found to have concentrated effort earlier in the fall than in previous fall sessions, before older fish had completed their migration from Lake Ontario into the Bay of Quinte. To be consistent with previous years and to avoid non-random distribution of marked and unmarked fish we determined the pattern and timing of the migration and included only recapture observations made after the migrating fish had reached the Bay of Quinte.

Catch-age-analysis

Catch-age-analysis (CAGEAN, Deriso et al. 1985) was performed using open-water angling effort and harvest, and index trawl and gillnet catch information (see above) to estimate the walleye population for the years 1974-1998. Due to limitations of the CAGEAN software, estimates were obtained separately for the years 1974-1988 and 1984-1998. Initial estimates of natural mortality and catch and effort lambdas were iteratively varied to account for fishing mortality from other fisheries and to calibrate the CAGEAN estimates with direct estimates from mark-recapture from 1985-1991.

Population and fisheries simulation model

The Fisheries Management Support System (FMSS, Korver and Kuc 2000) was used to represent the observed walleye population and fisheries dynamics. This allowed us to determine a reference exploitation rate, to forecast population trends in the near future, and to explore the consequence of uncertainty to population and fishery dynamics. FMSS is a time-step, age-structured model that simulates recruitment, growth, mortality and exploitation of a fish population. We bypassed the recruitment submodel of the FMSS and used CAGEAN population estimates of 1-yr-old fish as input to describe the known history of the Bay of Quinte walleye population. Natural mortality was estimated based on the difference between walleye mark-recapture abundance and harvest by all fisheries during 1985-1991. Parameters describing growth and size-dependent gear vulnerability were estimated from index fishing and harvest data.

We represented only the years 1984-2000 in the FMSS simulation model as all fisheries were well established and the data describing the fisheries and walleye population was most complete. Some small components of the total harvest were not available in some years; measures of spear-fishing harvest prior to 1988 and in 1990, incomplete spear-fishing information in from 1996 and 1999; small angling fisheries in the open waters of Lake Ontario, and some small seasonally or regionally restricted fisheries. To complete the time-series, harvest was estimated for these missing years and regions by interpolation or by applying average harvest values from available surveys to non-surveyed years. The only major source of harvest that was not formally surveyed was the aboriginal gillnet fishery. Harvest for this fishery was determined based on surveillance by conservation officers (Ron Harvey, Lake Ontario Management Unit, Ontario Ministry of Natural Resources, R.R. #4, Picton, Ontario, K0K 2T0, personal communication) and applied in the simulation model. Aboriginal gillnet harvests were assumed to be negligible prior to 1992. From 1992-1996, the aboriginal gillnet harvest was specified at 12,800 kg annually. A constant annual rate of increase was applied thereafter to reach 163,000 kg by 1999 and then held constant.

Angling fisheries were modeled through fishing effort, such that yearling fishing effort (input) was translated through a catchability relationship, into fishing mortality and harvest. The parameters of this catchability relationship were adjusted to match model outputs with measured historical harvests. Commercial and aboriginal fisheries (spear and gillnet) were modeled as direct removals, and observed levels of harvest were specified directly as inputs in the model. The simulation model was calibrated to replicate population structure estimated through CAGEAN and mark-recapture estimates for the 1984-1998 period, with most weight given to agreement with the abundance of walleye 2-yrs-old and older.

Determination of biological reference points

Exploitation rate

We chose a historical reference period to define a safe level of harvest. From 1985-1994, the Bay of Quinte walleye population recovered, produced a succession of good year-classes, and supported the development of a diversity of fisheries. After 1994, coincident with Dreissenid colonization, walleye abundance and recruitment declined. During 1985-1994, walleye was the keystone predator in the Bay of Quinte having a major depressing effect on numbers of white perch and alewife (Hurley 1986, Ridgeway et al. 1990) and the resurgence of the walleye coincided with the winter-kills of these two species (Hurley 1986, Bowlby et al. 1991). Our contention was that the moderate exploitation rate of walleye contributed to higher walleye recruitment through fish community interactions with white perch and alewife. Given the changes occurring in the Bay of Quinte, the observed decline in walleye abundance and recruitment, and continuing uncertainty associated with the invasion by Dreissenid mussels, we do not believe walleye should be exploited beyond the historical levels observed during 1984-1995. The simulation model representation of the fish and population was used to determine the exploitation rate during this period.

Minimum stock size

During 1977-1979, the adult walleye population was at a very low level, nevertheless, it produced the strong year-classes (especially 1978) that led to a recovery of the population and development of fisheries (Hurley 1986, Bowlby et al. 1991). We reasoned that the size of the remnant populations of walleye during the years 1977-1979 represented a stock size sufficient to support recovery of fisheries, which from a management perspective, can be considered a minimum stock size.

We estimated the size of the population during the reference years using several methods. The population in 1979 was determined from back-cast estimates from mark-recapture. Alternative estimates were derived from CAGEAN for the period 1974-1988 (see above). We had less confidence in the CAGEAN population estimates prior to 1979. For comparison, we developed a power function regression model relating standardized index gillnet catch taken from Bowlby et al. (1991) to the mark-recapture population estimates for 1979-1990. Gillnet catch rates for 1977 and 1978 were substituted into the derived power function regression to estimate the population in those years.

Critical stock size

Allowing the current walleye population to decline to the minimum stock size observed during 1977-1979 is extremely risky and may not sustain the population. The size of the population during this period was estimated with error and the actual size of the stock maintaining the population may have been higher. The reasons for the resurgence of the Bay of Quinte walleye stock are difficult to attribute to one cause. Historically, at this stock size, the recovery of the walleye in 1977-1979 was associated with improved water quality and severe winter-kills of white perch and alewife with subsequent release of walleye from predation and competition (Hurley 1986, Bowlby et al. 1991). Recently, fish community and trophic changes may be similarly suppressing recruitment. Although current conditions have not resulted in persistent and complete recruitment failure, it is not likely that these conditions will be substantially mitigated, and they could get worse. The biological and ecological risk and uncertainty associated with the estimate of minimum stock size required us to implement a margin of safety. We assumed that complete recruitment failure for two consecutive years was realistic. We established a margin of safety by determining a depletion factor that would result in the population reaching the minimum stock size in two years assuming no recruitment and experiencing recently observed estimates of total mortality. We applied the reciprocal of the depletion factor to expand to the minimum stock size, and defined the resultant population as the critical stock size.

Management decision model

We incorporated the biological reference points into a simple management decision model of proportional threshold harvesting, similar to that described by Lande et al. (1997). In our framework, management activities adjust harvest to achieve the recommended rate of exploitation, such that harvest would decline in direct proportion to the walleye population decline. As the population approaches the critical stock size, exploitation rate would be further reduced. Below the critical stock size there is a complete cessation of all fishing.

Evaluating uncertainty

We used both the FMSS simulation model and the management decision model to explore major sources of uncertainty in the management of the walleye. Our assessment of the future status of the walleye population has two major areas of uncertainty: the magnitude of the aboriginal gillnet fishery, and future levels of walleye recruitment. Both sources of uncertainty have a large influence on the population, and neither is easy to predict. Surveillance by conservation officers suggested that the aboriginal gillnet harvest in the most recent years may have been the largest source of fishing mortality. We simulated ranges of recruitment and aboriginal gillnet harvest in the FMSS model to predict future walleye populations and assess the level of exploitation.

For this analysis, we consulted with conservation officers monitoring the aboriginal gillnet fishery and established a range of possible harvests in 1999 of 50,000 to 200,000 kg (Ron Harvey, Lake Ontario Management Unit, Ontario Ministry of Natural Resources, R.R. #4, Picton, Ontario, K0K 2T0, personal communication). As before, the 1992-1996 aboriginal gillnet harvest was specified at 12,800 kg annually. A constant annual rate of increase was applied thereafter to reach various target levels of harvest in 1999 and then held constant. We chose to simulate four levels of aboriginal gillnet harvest (50,000 kg, 100,000 kg, 150,000 kg and 200,000 kg).

For recruitment scenarios, we used the estimates of abundance of 1-yr-old walleye derived from the CAGEAN analysis for the low recruitment years of 1995 and 1997 and extrapolated from recent trawl and gillnet indices to determine comparable estimates for 1998-2000. We then determined the mean, upper and lower 95% confidence intervals on these estimates from 1995-2000 and simulated this range of recruitment in our model.

We chose a simple matrix approach to exploring uncertainty by simulating twelve combinations of recruitment and gillnet harvest comprised of three fixed levels of recruitment (mean, upper, and lower 95% confidence interval) and four fixed levels of aboriginal gillnet fishery harvest. Angling effort, commercial harvest and aboriginal spear fishing harvest were held constant at year 2000 levels. Our performance measures were the resulting size of the population and the exploitation rate of 3-yr-old and older walleye in years 2001 and 2005. We compared these estimates to our biological reference points to determine the risks to the walleye population and the management implications.

The implications of the 1999 mark-recapture population estimates were also investigated using the FMSS simulation model. The factors examined in these simulations were the uncertainty around the 1999 mark-recapture estimate, and the level of aboriginal gillnet harvest. The model was started in January 2000, using the fall 1999 mark-recapture estimates, as well as its upper and lower 95% confidence limits, as the starting population, and run for one year. The aboriginal gillnet fishery was simulated as described previously. Since we were only interested in 3-yr-old and older fish and the simulation was run for only one year, recruitment assumptions were not critical.

Results

Walleye abundance trends

When index gillnetting first began in the Bay of Quinte during the late-1950s, walleye were moderately abundant (Fig. 2). The population declined in the late-1960s, and remained extremely low until the late-1970s (Fig. 2). Young-of-the-year walleye catches in August bottom trawls indicated that very little recruitment occurred during the 1970s until 1978 when a large year-class was produced (Fig. 3). Large year-classes were regularly produced after 1980 (Fig.

3), and the walleye population expanded dramatically throughout the 1980s (Fig. 2). Summer gillnet catches peaked in the early-1990s then declined steadily to the year 2000. Young-of-the-year catches were low after 1994 (Fig. 3). In 1998, young-of-the-year walleye catch was the lowest observed since 1980.

Walleye harvest

Angling surveys in the Bay of Quinte during the late-1950s and early-1960s showed a walleye fishery in decline from a harvest of over 35,000 fish in 1957 to 2,500 by 1962 (Fig. 4). A moderate-sized commercial fishery was also in decline at that time (about 35,000 fish harvested per year), although it persisted at low levels until 1970. Walleye fisheries were very small during the late 1960s and most of the 1970s (Fig. 4).

A large open-water angling fishery for walleye developed in the Bay of Quinte within two years following production of the large 1978 year-class. This fishery averaged 130,000 fish harvested annually between the years 1980 and 1996. After 1996 the walleye harvest by this fishery declined dramatically to 30,000 by the year 2000. An ice-angling fishery also developed in the Bay of Quinte during the early 1980s with an average walleye harvest of about 17,000 fish from 1982-2000. Walleye harvest in the ice-angling fishery was less than 1,000 fish in 2001. Commercial harvest of the Bay of Quinte walleye stock also began to increase in 1979 and 1980 but the fishery was restricted through regulation changes in 1981 (Fig. 4). A 30,000 lb walleye quota and some incidental catch allowance maintained a relatively small commercial walleye harvest that averaged about 8,000 fish per year from 1989-1998 but this fishery also declined to less than 5,000 fish in 1999 and to just over 3,000 fish in 2000. The aboriginal spring spear fishery harvested 3,000 to 4,000 fish annually on the Bay of Quinte's Salmon River prior to 1992. This harvest increased when spearing activity expanded to include the Napanee and Moira Rivers. The spear fishery harvest, for the three rivers, was over 6,000 fish on average between 1992 and 1995, and over 13,000 fish on average between 1996 and 2000 (Fig. 4).

Population estimates

Population estimates of fish age 3-yrs-old and older from CAGEAN and mark-recapture (Fig. 5) were consistent with index fishing trends (Fig. 2). In the 1970s the population was very low. The 3-yr-old and older population expanded beginning in 1980 and reached a temporary peak of 1.3 million in 1981,

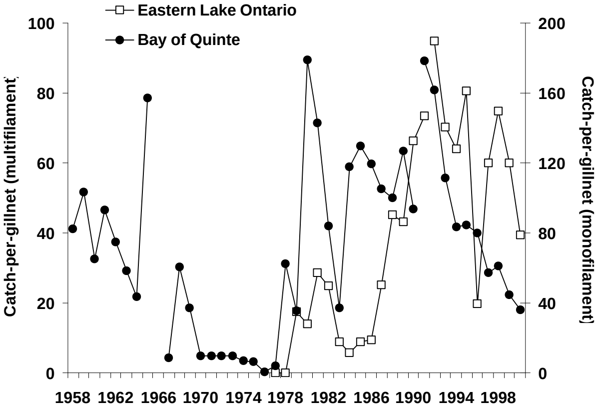

FIG. 2. Walleye abundance in gillnets in the Bay of Quinte, 1958-2000 (no gillnetting in 1966) and eastern Lake Ontario, 1977-2001, during summer. Multifilament gillnets were replaced with monofilament in 1991 in the Bay of Quinte and in 1992 in eastern Lake Ontario. The secondary y-axis is scaled by a factor of two relative to the primary y-axis because mono/multifilament gear comparisons showed that monofilament gillnets caught twice as many walleye.

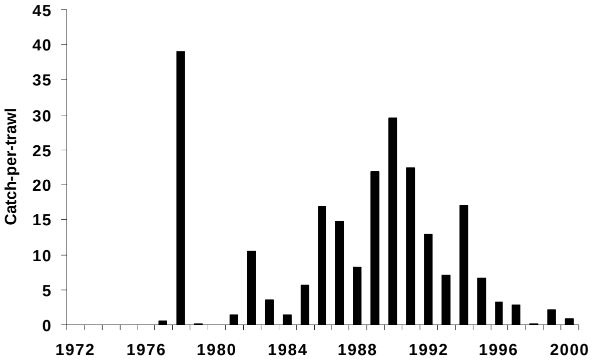

FIG. 3. Young-of-the-year walleye abundance in bottom trawls in the Bay of Quinte, during August and early September, 1972-2001 (no trawling in 1989).

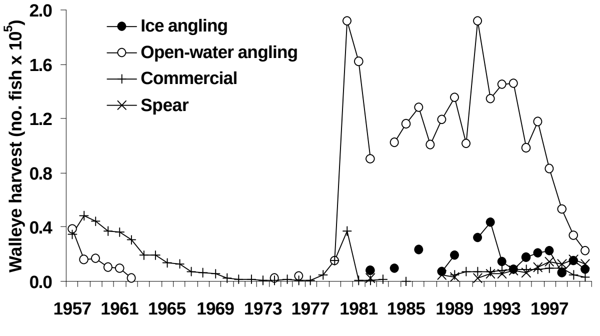

FIG. 4. Trends in walleye harvest by open-water angling (1957-1962, 1976, and 1979-2000), ice-angling (1982, 1984, 1986, 1988, 1989, and 1991-2001), commercial (1957-2000), and aboriginal spear fisheries (1982, 1988 and 1989, and 1991-2000).

followed by a decline and then a more gradual increase to between 1.1 and 1.2 million fish from 1991-1994. From 1995-1999, the population declined to approximately 0.4 million (Fig. 5).

There is generally good agreement between the CAGEAN estimates for 1984-1998 and the available mark-recapture estimates (Fig. 5). However, population estimates for walleye in 1999 (Table 1) were considerably lower than expected and represent a substantial departure from recent population trajectories (Fig. 5). The large decline in the mark-recapture estimates from 1998 to 1999 may indicate high mortality rates. Total mortality for fish 3-yrs-old and older total mortality ranged from 45 to 66 % (Table 2).

Model application and recommended exploitation rate

The FMSS simulation model was calibrated to CAGEAN population structure and trends and the population estimates were highly correlated with a regression slope near 1.0 (Table 3). CAGEAN estimates were highly correlated with adjusted mark-recapture estimates with a regression slope near 1.0. Harvest observations were also well represented in the model. Spear fishing and commercial fishing harvests (specified directly) as well as annual open-water angling-harvest (simulated through effort) were highly correlated with model representations with a regression slope near 1.0, but correlation with observed ice-angling harvest was poor. High variability in ice-angling effort and harvest rates due to ice conditions and weather are likely explanations. However, a regression slope near 1.0 in the ice-angling representation (Table 3) indicates that the simulation of this harvest was not biased. Also, the smaller size of the ice-angling fishery relative to the open-water angling (Fig. 4) means that errors in estimating ice-angling harvest in some years was of minor consequence to the adequacy of the model representation of harvests. Accordingly, The FMSS simulation model representation of the walleye population and fishery (Fig. 6) captured the major trends in the population and fisheries described above (Figs. 2 and 4). The population starts at about 0.80 million fish in 1984 and climbed to about 1.2 million fish during the early-1990s (Fig. 6). The model further predicts that the walleye population will decline to 0.66 million by 2000. Overall, total harvest declined as the population declined (Fig. 6). The spear and aboriginal gillnet harvests increased in the late-1990s

TABLE 1. Peterson population estimates and confidence limits for 3-yr-old and older walleye in the Bay of Quinte and eastern Lake Ontario for 1998 and 1999.

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

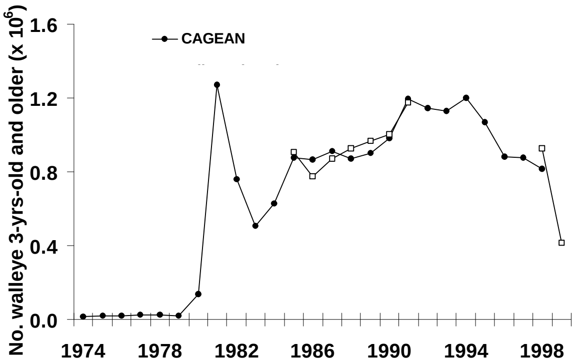

FIG. 5. Population of 3-yr-old and older walleye during fall in eastern Lake Ontario and the Bay of Quinte. For 1984-1988 only the later CAGEAN (1984-1998) results are shown.

TABLE 2. Walleye population size (no. of fish) and total annual mortality in the Bay of Quinte and eastern Lake Ontario for 1998 and 1999, by age.

Year	Age 1	2	3	4	5	6 & 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 mortality	-	32%	46%	61%	61%	66%	57%

TABLE 3. Relationship between mark-recapture abundance, CAGEAN abundance, FMSS simulation model predictions, and selected fishery statistics for Bay of Quinte and eastern Lake Ontario walleye. Correlation with spear fishing harvest and commercial harvest were not calculated, as annual measured values were specified directly in the model.

Variables (Y vs X)	Years	N	R-value	Slope Y=bX (95% C.I.)
Comparison of CAGEAN and mark-recapture estimates:				
CAGEAN 3-yr-old and older abundance vs mark-recapture estimates	1985-91	7	0.87	0.9 (0.94-1.05)
Comparisons of FMSS model estimates and observed fishery harvests:				
FMSS model population 2-yr-old and older vs CAGEAN	1984-98	15	0.97	1.01 (0.99-1.04)
FMSS model open-water angling harvest vs surveyed harvest	1991-00	10	0.98	1.02 (0.94-1.10)
FMSS model ice angling harvest vs surveyed harvest	1991-00	10	0.28	1.10 (0.65-1.54)

relative to the early-1990s while the opposite is true for the angling and commercial fisheries (Fig. 6). Applying the simulation model to the 1985-1994 reference period (see methods), the exploitation rate of fish 3-yrs-old and older ranged from 5 to 10%, with an average of 8%.

As argued above, 1985-1994 was prior to the invasion by Dreissenid mussels and was a period of good walleye recruitment and expanding fisheries. It is reasonable to assume that the moderate exploitation rate contributed to the higher walleye recruitment through suppression of potential predators. We recommend the average historical exploitation rate of 8% observed during this period as a safe level of harvest for the declining walleye population and changing conditions.

Minimum stock size

There was good agreement among CAGEAN, back-cast mark-recapture, and gillnet regression estimates of minimum stock size for the years 1977-1979 (Table 4). The power function regression of back-cast mark-recapture estimates and index gillnet catches for the years 1979-1990 was highly significant ($r=0.97$, $p<0.004$). Substituting observed gillnet catches into this regression gave estimates of 35,287 to 67,180 fish. The back-cast mark-recapture for 1979 was 31,381 and the CAGEAN estimates ranged from 35,251 to 40,794. Initial cursory examination of data presented in Bowlby et al. (1991) suggested a minimum stock size approximating 40,000 fish 3-yrs-old and older. Estimates from current analyses (Table 4) were consistent with this value, so it was retained.

Critical stock size

Critical stock size was defined as the population that would reach the minimum stock size in two years assuming no recruitment and experiencing recently observed estimates of mortality. Total annual mortality estimates based on otolith-aged fish from the index gillnets ranged from 40-50% (unpublished data) and 57% from a comparison of age-specific abundance in 1998 and 1999 (Table 2). We chose to use 50% total annual mortality as representative of observed values. At such mortality, along with recruitment failure, a population can be reduced to one quarter in two years, so we chose a depletion factor of four. Applying this to our minimum stock size of 40,000, we defined the critical stock size as 160,000 fish age 3-yrs-old and older.

TABLE 4. Estimates of the population of 3-yr-old and older walleye in the Bay of Quinte and eastern Lake Ontario for 1977-1979 from regression analysis (gillnet), CAGEAN, and mark-recapture.

Year	Gillnet	CAGEAN	Back-cast Mark-Recapture
1977	46,920	40,794	
1978	67,180	40,137	
1979	35,287	35,251	31,381

Management decision model

The management decision model specifies the total allowable catch (TAC) as a function of population size (Fig. 7). The exploitation rate and critical stock size reference points were used to define three management decision zones: status-quo management, reduced fishing, and no fishing (Fig. 7). We recommended that harvest of walleye age 3-yrs-old and older not exceed the historical reference exploitation rate of 8% when the population is above twice the critical stock size (i.e., higher than 320,000 fish). We recommend that harvest be further restricted

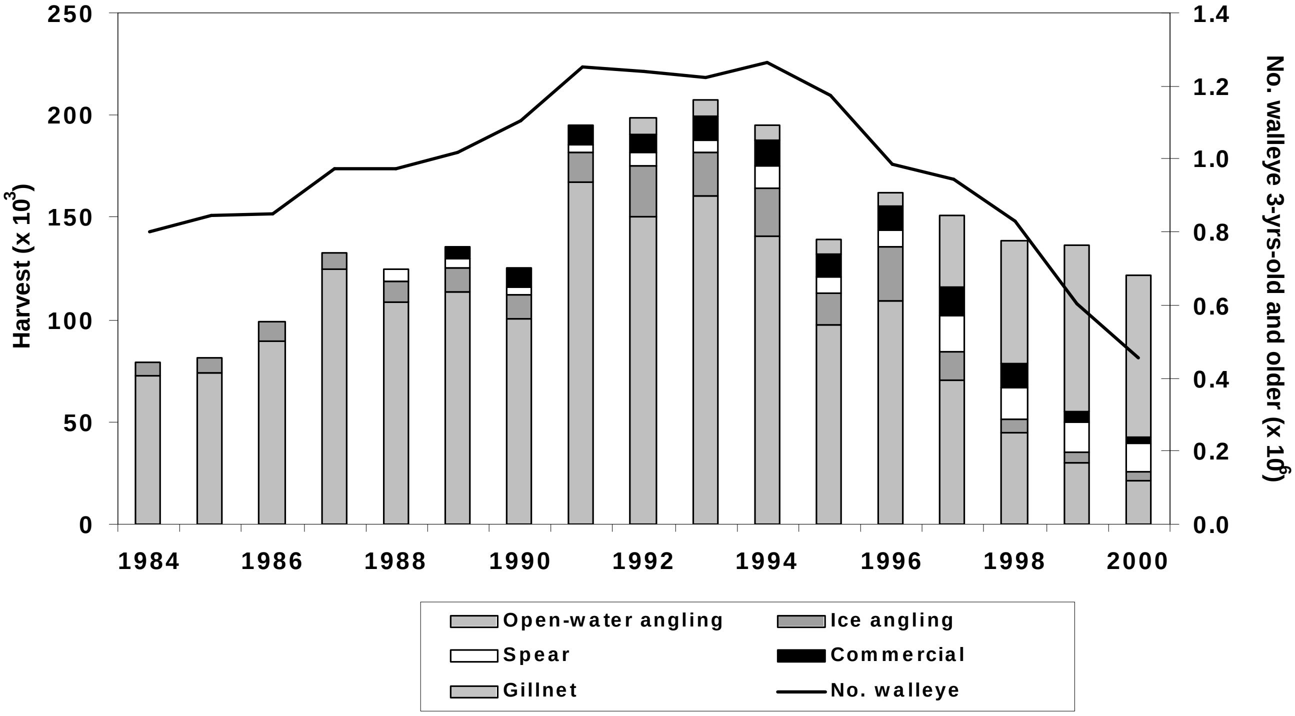

FIG. 6. FMSS simulation results: walleye population size, and harvest by fishery, 1984-2001.

(i.e., less than the reference exploitation rate of 8%) at population levels between 160,000 and 320,000 fish. We recommend a complete cessation of fishing once the population drops below the critical stock size threshold of 160,000 fish (Fig. 7).

Evaluating uncertainty

Determination of current or future exploitation rates and population size is problematic. The aboriginal gillnet fishery has recently become the largest fishery (Fig. 6) and its harvest level was determined with considerable uncertainty. Variable recruitment also results in uncertain future population sizes. However, using the FMSS to simulate various combinations of aboriginal gillnet harvest and recruitment, the predicted exploitation rate exceeds the recommend level of 8% in 2001 and 2005 for all simulations (Fig. 8). Exploitation rate changes were more sensitive to changes in the gillnet harvest compared to variation in simulated recruitment levels (Fig. 8). Under all simulations, the model predicts that the walleye population will be higher than twice the critical stock size in 2001, but will only stay above this level by 2005 if the aboriginal gillnet harvest is less than 50,000 kg (Fig. 8). The model predicts that the population will reach the critical stock size in 2005 under close to half (5 of 12) of the scenarios simulated.

Implications of recent mark-recapture population size estimates

The 1999 mark-recapture estimate of 417,052 walleye 3-yrs-old and older (Table 1) was 37% lower than that projected by FMSS under base conditions (0.66 million, Fig. 6). Either the 1999 population estimate was low or our original simulations of population size (Fig. 8) were high. If our original simulations were high, the population may reach critical stock size sooner than predicted as confirmed by the FMSS projections using the 1999 populations estimates and bounds as starting values. The population size was estimated to be below twice the critical stock size (320,000 fish) in 2001 in all but two simulations and did fall below the critical stock size (160,000 fish) under the assumption of the lower population bound and highest gillnet harvest (Fig. 9). These simulations resulted in higher exploitation rates ranging from 10.8 to 56.4% in 2001 (Fig. 9).

Discussion

We were concerned that the more recent CAGEAN estimates may be inaccurate due to potentially increasing prominence of the undocumented aboriginal gillnet fishery, and our inability to account for the uncertainty in the harvest estimate in the

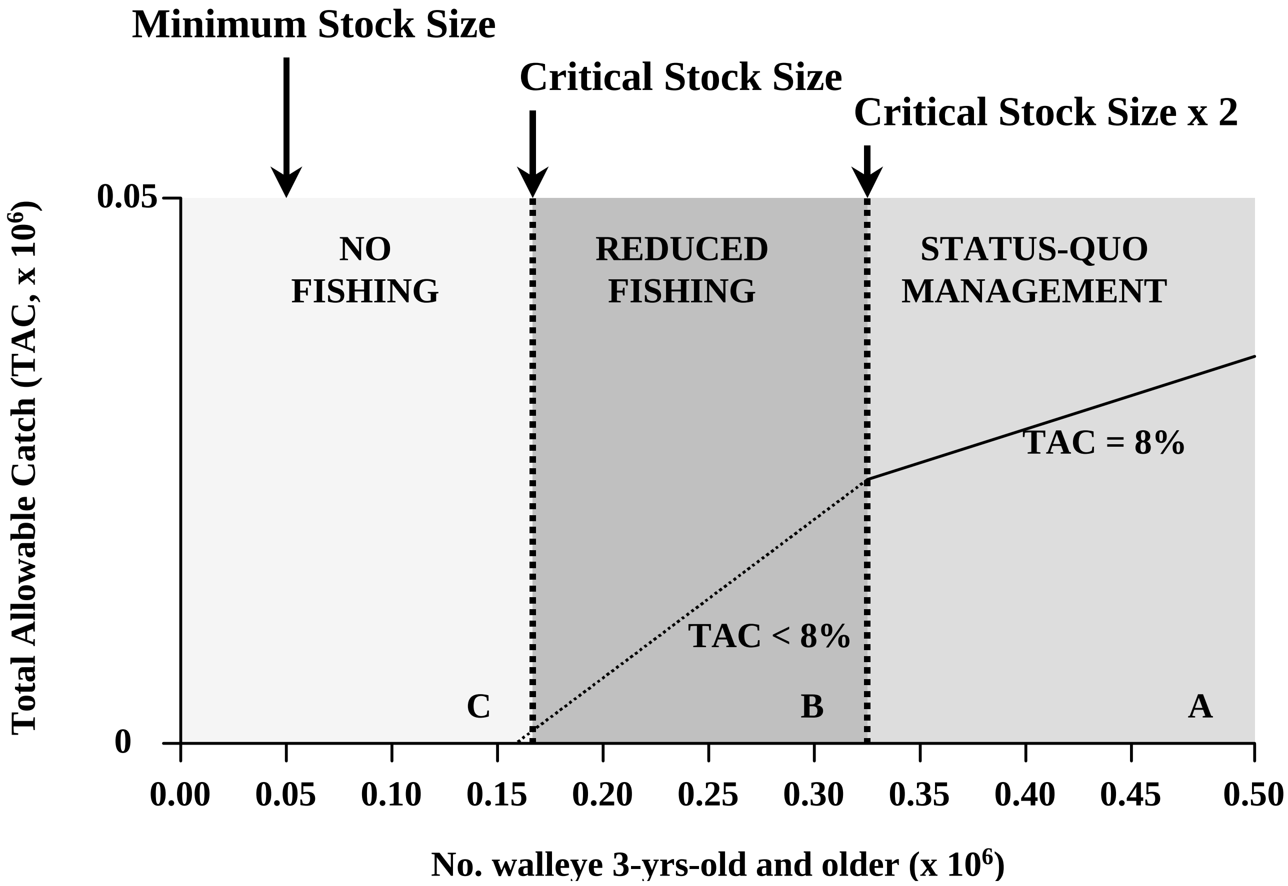

FIG. 7. A management decision model for the Bay of Quinte and eastern Lake Ontario walleye fishery showing selected biological reference points and associated recommended management actions. Three management decision zones are designated as a function of population size: status-quo management (shaded area A), reduced fishing (shaded area B), and no fishing (shaded area C). The solid portion of the line represents a total allowable catch of 8% of the population in the range of population size greater than 320,000 fish. The dashed portion of the line does not imply a specific TAC, rather that the TAC is below 8%.

CAGEAN analysis. However, mark-recapture population estimate from 1998 corresponded well with the CAGEAN estimates (Fig. 5) confirming our earlier calibration of CAGEAN and mark-recapture estimates up to 1991 (Table 3). The lower than expected abundance in 1999, and potential for increasing prominence of the undocumented aboriginal fishery harvest, warrants refining our catch-age analysis. Customized catch-age stock assessment methods using AD-Modeler as a platform (Quinn and Deriso 1998) would allow for the inclusion of more data sets simultaneously in the analysis, thus further improving the estimate. Moreover, while it would be desirable to have more timely and direct knowledge of all sources of harvests, particularly the aboriginal gillnet harvest, it will be possible to estimate the magnitude of unaccounted for fishing mortality using this approach. However, several years of additional mark-recapture estimates during the more recent period of increased aboriginal gillnet fishing effort will be required for this analysis to be robust.

Under the conditions of poor recruitment (Fig. 3) despite an abundant, albeit declining, population of mature fish (Fig. 5) it is difficult to determine appropriate biological reference points. The cause of the poor recruitment and the walleye decline is not known and continued poor recruitment or failure cannot be ruled out. The abrupt change in recruitment was coincident with Dreissenid invasion in 1994. Similar, but more severe recruitment declines have been observed in other fish populations coincident with Dreissenid invasion. Walleye recruitment declined in Lake St. Clair, another Great Lake walleye population, coincident with Dreissenid invasion (Don

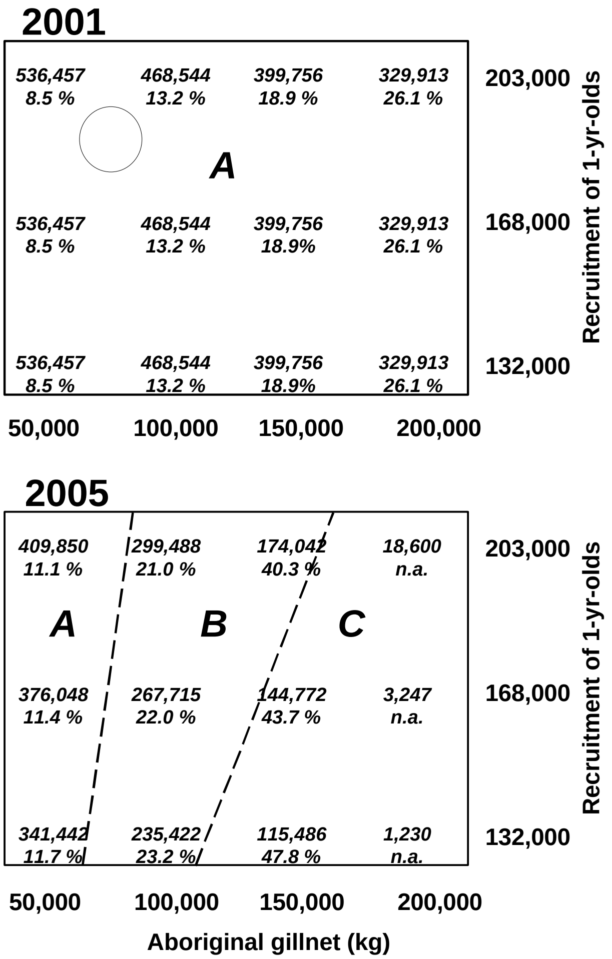

FIG. 8. Results of FMSS simulations for the years 2001 and 2005 using a range of assumptions about levels of aboriginal gillnet harvest, and walleye recruitment. The aboriginal gillnet harvest was simulated to reach the values indicated on the horizontal axis in 1999, and to remain constant thereafter (see Methods). The numbers inside the graph indicate the forecasted population of walleye 3-yrs-old and older and the total exploitation rate (lower number). The hatched lines categorize the forecasted populations relative to reference population levels and management decision zones in Fig. 7: above 320,000 fish or twice the critical stock size (shaded area A), between 160,000 (the critical stock size) and 320,000 fish (shaded area B), and less than 160,000 fish (shaded area C).

MacLennan, Lake Erie Management Unit, Ontario Ministry of Natural Resources, R.R. # 2, Wheatley, Ontario, N0P 2P0, personal communication). Also, recruitment failure of eastern Lake Ontario whitefish (*Coregonus clupeaformis*) has been associated with Dreissenid invasion and the sudden disappearance the deepwater amphipod *Diporeia* – the principal food of lake whitefish (Dermott 2001, Hoyle et al. 2001).

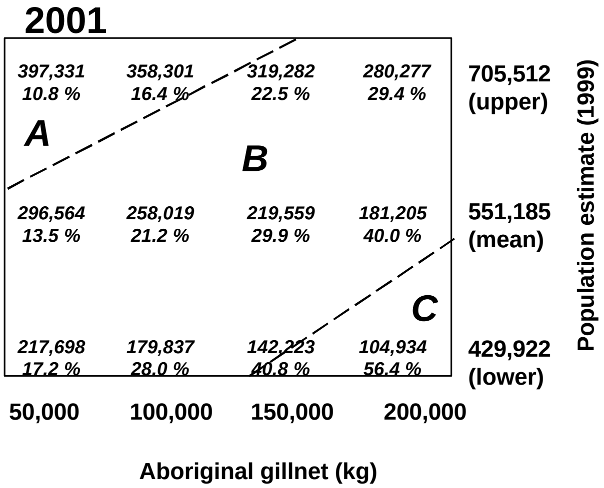

FIG. 9. Population forecasts based on the 1999 age structured mark-recapture estimate (Table 4). The simulation was started in January 2000, using the fall 1999 mark-recapture estimates, as well as its upper and lower 95% C.I., as the starting population. The aboriginal gillnet fishery was simulated with an annual harvest of 50,000 kg, 100,000 kg, 150,000 kg, and 200,000 kg. The hatched lines categorize the forecasted populations relative to reference population levels and management decision zones in Fig. 7: above 320,000 fish or twice the critical stock size (shaded area A), between 160,000 (the critical stock size) and 320,000 fish (shaded area B), and less than 160,000 fish (shaded area C).

Our recommended exploitation rate is less than the estimated rate of 14%, representing the lower quartile of the distribution of walleye exploitation rates for north-temperate lakes summarized by Colby et al. (1994) and much more conservative than $F_{0.1}$ or F=M criteria. Given the failure of more liberal harvest strategies to adequately protect stocks (Smith et al. 1993, Caddy and Mahon 1995, Walters and Martell 2001 in press), a lower exploitation rate seems more appropriate. In Lake Erie, recommended walleye commercial fishery exploitation rates were recently adjusted downward to protect stocks and now approximate our recommended rate of 8% (Phil Ryan, Lake Erie Management Unit, Ontario Ministry of Natural Resources, P.O. Box 429, Port Dover, Ontario, N0A 1N0, personal communication). Patterson's (1992) recommended exploitation criteria of 0.5 M, is comparable to our recommended exploitation rate.

A conservative exploitation rate is warranted given the current conditions in the Bay of Quinte. Lower walleye production and other fish community changes have likely resulted from the decline in nutrients and changing trophic conditions (Leach et al. 1977, Hurley and Christie 1977, Oglesby et al. 1987) and the walleye population is in transition to a lower state of production. During this transition, fish community stability may require sufficient walleye to ensure top-down predator control (McQueen et al. 1989) of prey species and prevent further reduction in walleye recruitment due to predation.

Our empirical approach to calculating the reference exploitation rate based on estimated harvest and population levels observed during a reference time period is also a departure from traditional methods that determine reference harvest levels using growth and production models (e.g., Deriso 1987). We felt justified in using this approach since our objective was to determine reference points approximating observed exploitation rates rather than theoretical optima.

One limitation of this approach is that the observed historical exploitation rate applies to a mixed fishery, with a diversity of ages and sizes of fish. If the age and size distributions of the harvests became skewed towards a predominance of small fish (such as that associated with an angling fishery with a restrictive maximum size limit) or a commercial or a spear fishery concentrating on only large fish, then appropriate levels of harvest may need to be reevaluated.

The recommended exploitation rate is based on the fish population, not biomass that is conventionally applied in commercial fishery management. Maximizing biomass metrics such as yield, yield per recruit, or spawning stock biomass are not appropriate goals for this mixed fishery. We believe population-based exploitation rates are more appropriate to fisheries dominated by angling or mixed fisheries where the intent is to maintain a variety of age groups and a diversity of fishing opportunities.

The choice of the 1977-1979 period to estimate the minimum stock size was based on the availability of data to estimate absolute population size and the fact that the population during these years produced sufficient recruitment to support development of fisheries. Analysis of other reference periods may suggest lower minimum stock sizes, as the walleye of the Bay of Quinte and eastern Lake Ontario persisted at low levels for close to a decade (Fig. 2). We do not think that persistence of a stock is an adequate management objective, and any alternative reference periods would be without evidence that resultant walleye populations could support substantive fisheries.

The biological and ecological risk and high level of uncertainty associated with the estimate of minimum stock size required us to implement a margin of safety. We concluded that an assumption of intermittent complete recruitment failure and a total mortality of 50% were within the range of responses recently observed in the Bay of Quinte and eastern Lake Ontario walleye population. Since 1995, we have observed two extremely poor recruitment years, approaching complete failure (Fig. 3). Environment and fish community changes do not favour walleye, and a walleye population higher than minimum stock size may be required to suppress potential walleye predators and competitors. The higher stock size required to sustain fisheries reduces the risk of extirpation, and avoids very low stock size that is inherently unstable (Beddington and May 1977).

Our management decision model considers instability in the walleye population and uncertainties associated with the estimates of stock status and factors influencing the walleye. Although we did not have direct estimates of the aboriginal gillnet harvest this did not invalidate our biological reference points. The period chosen for our reference exploitation rate was before aboriginal gillnet activity became established. The minimum stock size and critical stock size reference points were estimated directly and did not require knowledge of harvest. The management decision model is based on population size and this will require that we maintain sufficient population assessment. The decline in nutrients and associated habitat changes make it very unlikely that walleye production will increase. Our management decision model is appropriate to a declining population and is intended to conserve the walleye population. Conservation, in this context implies sufficient walleye for self-sustaining reproduction, and a sustainable surplus to support utilization and optimization of fishery benefits.

Illustrating and communicating the consequences of uncertainty is an important aspect of incorporating risk into fisheries management decisions (Francis and Shotton 1997). This study could benefit from a more rigorous treatment of all sources of uncertainty, but the simple matrix approach presented here (Figs. 8 and 9) captures major sources of uncertainty and is relatively easy to understand and communicate. The lower than expected 1999 population estimate is a good illustration of the consequences of uncertainty. The 1999 estimates, although lower then the predicted population size from the FMSS, was within the range of the simulated uncertainty (Fig. 8). Simulations using the 1999 population estimate predicted increased levels of exploitation and increased occurrence of population sizes below thresholds (Fig. 9). This illustrates that uncertainty in predicting fish population responses to environmental or fishery influences has measurable consequences, and must be considered when making management decisions.

The walleye population of eastern Lake Ontario and the Bay of Quinte is projected to be over-exploited in 2001. All our simulations of harvest and recruitment scenarios exceed our recommended exploitation rate. Under reasonable assumption of recruitment, aboriginal gillnet harvest, and population level, many simulations estimated exploitation rates 2-4 times higher then the recommended level (Figs. 8 and 9). The most recent and direct estimate of total mortality (Table 2) exceeded the recommended benchmark of 50% total mortality (Ontario Ministry of Natural Resources 1983; Colby et al. 1994), providing independent evidence of excessive harvest. It is also possible that the walleye populations may have fallen below the critical stock size (Fig. 9). Management actions should be taken to reduce harvest and establish appropriate harvest controls and monitoring mechanisms.

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14

Abundance, Recruitment, and Mortality Rates of Walleye in Eastern Lake Ontario

J. N. Bowlby and J. A. Hoyle

Introduction

Walleye in eastern Lake Ontario has been prominent in providing fisheries and in structuring the nearshore fish community for more than 20 years. Walleye dominated the open-water and ice-angling fisheries in the Bay of Quinte over this period (Hoyle 2001). These fisheries accounted for 20% of the effort and 25% of the harvest in all Lake Ontario angling fisheries in Ontario (Savoie and Bowlby 1991). Walleye has been the dominant piscivore in the Bay of Quinte and the major influence in top-down control of fish community structure, especially of planktivores (Hurley 1986, Hurley et al. 1986, Ridgeway et al. 1990). However, the invasion of dreissenid mussels since 1995 has led to increases in water clarity, submergent aquatic plants, and populations of other piscivores such as largemouth bass and northern pike (Hoyle 2001). Walleye responded to these ecosystem changes with a decline in recruitment and abundance (Hoyle et al. 2001).

Recently, Mohawks of the Bay of Quinte (MBQ) have developed a significant gillnet fishery for walleye (Stewart et al. 2002). Concern about the effect of increasing harvest on a walleye population already saddled with declining recruitment led to harvest restrictions in the angling fishery for walleye in eastern Lake Ontario in 2002. The call for these restrictions was based on a variety of concerns, that included model projections of the possibility that future walleye populations could fall below a critical stock size (Stewart et al. 2002). The accuracy of these projections depends considerably on the assumptions of unknown sources of mortality, and estimates of the walleye harvest, population, and recruitment. Here, we provide estimates of population and recruitment for walleye in eastern Lake Ontario updated to 2001. These estimates are used in a companion paper to provide updated projections of the walleye population in eastern Lake Ontario (Schaner et al. 2002).

Methods

Index Netting

The relative abundance of walleye 1-yr-old and older was monitored during summer using bottom-set gillnets at two fixed sampling sites in the Bay of Quinte (Hay Bay: 1958 to 2001 excluding 1966, and Big Bay: 1972 to 2001 excluding 1985) and at one site in eastern Lake Ontario (Simcoe Island: 1977-1985, replaced with nearby Melville Shoal: 1986-2001). Gillnets were comprised of a 1.3 cm (½ inch) interval graded series of stretched mesh sizes from 3.8 to 12.7 or 15.2 cm. Multifilament nylon nets were replaced with monofilament nets in 1991 (Bay of Quinte) or 1992 (Lake Ontario). Gillnets were set parallel to the contour in depths ranging from 5.0-17.5 m. Catches were adjusted to represent 100 m of each mesh size, summed across mesh sizes, and referred to as catch-per-gillnet.

The relative abundance of walleye from age 0 to 3 was monitored annually using a bottom trawl at six fixed sampling sites (Trenton, Belleville, Big Bay, Deseronto, Hay Bay and Conway) in the Bay of Quinte (1972-2000 excluding 1989). Only three sites (Big Bay, Hay Bay and Conway) were sampled from 1981 to 1988, and another site was added (Deseronto) in 1990 and 1991. Sampling occurred in late summer (August and early September) and consisted of one to six replicates at each site.

For both the trawl and gillnet time series, missing data for some strata in some years were estimated with linear regressions involving data from other years or other gear.

Mark-Recapture

Marking and recapture sessions were conducted from 1985 to 1989, 1991, 1992 and 1998 to 2001. From 1985 to 1987, sessions were conducted during spring and fall, and in later years during fall only.

Walleye were captured in trapnets, throughout the Bay of Quinte and eastern Lake Ontario. Walleye were marked with double dorsal fin ray punches, and then released. Various combinations of fin rays were used to provide a binary code that uniquely identified year and location. All walleye were measured, and scales were taken from a subset for aging. Since 1998, all ages have been obtained from otoliths from a subset of sacrificed fish. All marked and recaptured fish were measured and the age by sex distribution was determined with a sex-age-length key. Because older female walleye were significantly longer than males, including sex in the age-length keys improved the accuracy of ages. Marking and recapture sessions in 1998-2000 were found to have concentrated effort earlier in the fall than in previous fall sessions, before older fish had completed their migration from Lake Ontario into the Bay of Quinte. To be consistent with previous years and to avoid non-random distribution of marked and unmarked fish, we determined the pattern and timing of the migration and included only recapture observations made after the migrating fish had reached the Bay of Quinte.

Population estimates were made using either the Petersen or Jolley-Seber methods (Ricker 1975), as appropriate. These estimates were made on an age-specific basis to better satisfy assumptions of mark-recapture studies. Analysis of covariance of the log transformed population estimates from 1985 to 1991 (spring and fall) was used to estimate a common, instantaneous mortality and survival among year-classes. Since the total mortality did not differ significantly among year-classes, we used the survival estimate to adjust the age-specific estimates of the population, particularly younger fish, to interpolate estimates for 1990 and to back-cast estimates for 1979-1984.

Unless stated otherwise, fall mark-recapture estimates were promoted one year in age for the period of November 1 to January 1. January 1 was chosen as the arbitrary “birthday” assigned to the fish. The choice of this birthday is convenient for summarizing various population and harvest statistics based on a calendar year. The fall mark-recapture estimates were promoted in age to January 1 on the assumption of negligible harvest or natural mortality during this period. This assumption was based on our documentation of harvest from 1985 to 1991, and our perception that most natural mortality for walleye occurs during spring, in association with overwintering and spawning stresses. Determination of biological reference points for the declining walleye were based on these January 1 population estimates of 3 year-old and older walleye (Stewart et al. 2002).

Catch-age analysis

Abundance estimates of walleye in eastern Lake Ontario from 1975 to 1998 were made with catch-age analysis (CAGEAN: Deriso et al. 1985) based on the open water angling (Hoyle 2001) and index trawling and gillnetting in the Bay of Quinte and Lake Ontario (described above). Due to limitations of the CAGEAN software, estimates were obtained separately for the years 1975-1989 and 1984-1998. Initial estimates of natural mortality and catch and effort lambdas were varied to account for fishing mortality from other fisheries and to calibrate the CAGEAN estimates with direct estimates from mark-recapture from 1985-1991. The CAGEAN population estimates were calibrated with mark-recapture estimates based on January 1. A decline in angling exploitation and increase in exploitation from other documented and undocumented sources required the termination of CAGEAN after 1998.

Index Netting Regressions

Index gillnet catch rates have been correlated with walleye populations in eastern Lake Ontario (Bowlby 1990). Here, we used regressions of index gillnet and trawl catch rates with CAGEAN or mark-recapture population estimates to estimate the walleye population. Because of site and gear changes from 1990 to 1992, we have used two separate sets of regressions for periods before and after 1991. For 1977 to 1990, we used a single multiple regression to estimate the 3 year-old and older population on January 1. For a dependent variable, we used the adjusted mark-recapture population estimates from 1979 to 1990. Three independent variables were used: index gillnet catch rates from I) Melville shoal in July, II) Big Bay in June, July, and August, and III) Hay Bay in June, July, and August.

For 1992 to 2001, age specific linear regressions were made to estimate the population on January 1. We used index gillnet and trawl catch rates, and CAGEAN population estimates from 1992 to 1998. Data were limited to post-1991 for consistency in gillnet design and in trawling sites, as described above. We used trawl data for ages 1 to 3, and gillnet data for ages 1 to 6, and 7 and older (combined). The total of gear-site combinations exceeded the number years of data available for the analysis, and so multiple regression could not be used. Rather, we chose to sum the catch rates on an age-specific basis to provide a dependent variable for the regression model. The units of catch rates are arbitrary, so we chose units that would weight gillnet and trawl data with a similar order of magnitude. Only catch rates at Melville Shoal were used for age 7+ since most fish in this age group migrate out of the Bay of Quinte during summer.

All data were log transformed before analysis. Accordingly, the regression for each age used a power function that reduced problems with dispersion (common to catch data), and forced small values to converge at one (i.e., near zero).

Sampling error or changes in fish distribution occasionally caused a cohort to increase from one year to another. However, a cohort can only decline in population due to natural and other mortality. Under the assumption that cohorts decline in numbers, we developed a regression model to smooth the population estimates made above. We determined that the total mortality of ages 2 to 6 for years 1992 to 2001 did not differ significantly among cohorts, using ANCOVA. Moreover, the patterns of the residuals showed no suggestions of age differences in mortality. Accordingly, we used the predicted age-specific populations estimates results from ANCOVA using a constant total mortality.

Results

Relative Abundance Indices

Following production of the 1977 and 1978 year classes the relative abundance of walleye increased first in the Bay of Quinte and later at Melville Shoal (Fig. 1). Walleye abundance indices peaked in the early 1990s and then declined. Abundance declined steadily and markedly in the Bay of Quinte; by 2001 gillnet abundance indices had declined by about 80% compared to the 1980s and early 1990s, and to its lowest level since the 1970s. At Melville Shoal, abundance indices declined only slightly until the last two years when declined by about 50% compared with early and mid-1990s levels.

Population estimates

The population estimates of 3 year-old and older walleye on January 1 are the appropriate values to compare with reference points in the management decision model (Stewart et al. 2002). As walleye grow, they start recruiting as 2 year-olds to the open-water angling and commercial fisheries in eastern Lake Ontario. By 3 years of age walleye are fully recruited to these fisheries. Female walleye mature as 4 year-olds and so the adult population is considered as 4 year-olds and older. The reference population was chosen as 3 year-old and older by Stewart et al. (2002) as a compromise to describe both a fully recruited population and one that is near maturity. Age-specific population estimates are provided in Appendices 1, 2, and 3.

Changes in various sampling programs barred us from using any one method to estimate the walleye population in eastern Lake Ontario since 1975. Except for the Petersen estimates for 1998 and 1999, all of the remaining methods were directly or indirectly calibrated to the mark-recapture estimates from 1985 to 1991 (Appendix 1). The ANCOVA adjusted mark-recapture estimates were back-cast and interpolated to provide January 1 population estimates from 1979 to 1992 (Fig. 2). CAGEAN extended our population estimates back to 1975 and forward to 1998 (Fig. 3). CAGEAN population estimates agreed with the index

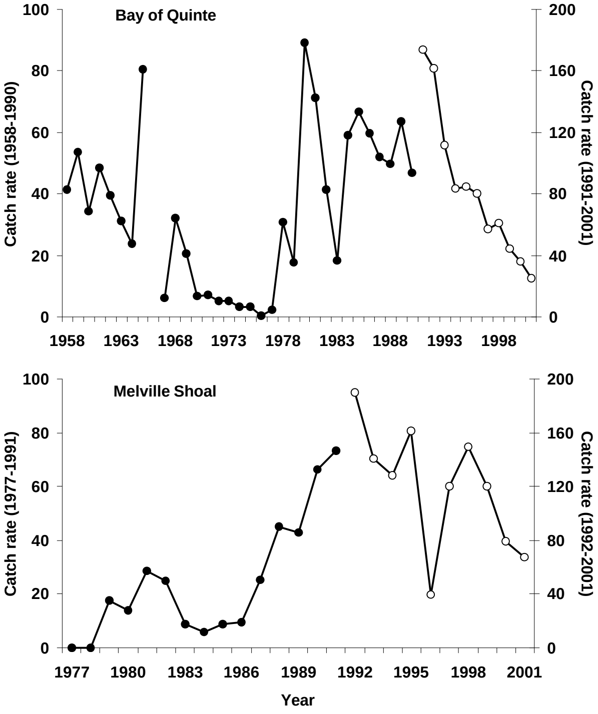

FIG. 1. Walleye abundance (least-square mean) in gillnets in the Bay of Quinte (Big Bay and Hay Bay), 1958 to 2001 (no gillnetting in 1966) and at Melville Shoal, 1977 to 2001, during summer. Multifilament gillnets (x-axis) were replaced with monofilament (y-axis) in 1991 in the Bay of Quinte and in 1992 at Melville Shoal. The secondary y-axis is scaled by a factor of two relative to the primary y-axis because mono/ multifilament gear comparisons showed that monofilament gillnets caught twice as many walleye.

netting from which they were derived (Fig. 1). Index netting population estimates extended our population estimates forward to 2001 (Fig. 4).

The general trends in all of these population estimates (Fig. 5) confirm the trends observed in the relative abundance indices (Fig. 1), including the mark-recapture estimates that were independent of the index netting. The age-specific estimates make it clear that the 1977 and 1978 year classes began a resurgence in population (Figs. 2 and 3) to levels higher than the 1950s (Fig. 1). However, the relationship between the population estimates and index catch rates was not in a straight line (see below). Using a straight line relationship, lower index netting catch rates would underestimate the population, compared to higher levels. Accordingly, the declines in the relative abundance indices (Fig. 1) exaggerate the real decline in the population in recent years.

Two years of mark-recapture data for the marking years 1998 and 1999 are insufficient for statistical comparisons with index netting population estimates and recalibration of the predictive equations. Regardless, the age-specific mark-recapture estimates can be visually compared with index netting population estimates. Mark-recapture population estimates for 2 year-olds on January 1, 1999 and 2000 tended to be lower than the index netting population estimates for the same time (Fig. 6). Moreover, the mark-recapture estimates for 2 year-olds in 1999 were lower than the estimates for 3 year-olds in 2000. This observation is consistent with the results from 1985 to 1991, where mark-recapture underestimated the population of younger fish (OMNR unpublished data). This was a reason we used age-specific mark-recapture estimates. The two mark-recapture estimates for 2000 were much different (Fig. 6), and clearly point to the need for longer-term data sets to understand the variability in our estimates.

Recruitment Indices

Recruitment is measured as the population at the age fish enter a fishery. As they grow, walleye partially recruit at 2 years old to the open-water angling fishery and commercial fishery in eastern Lake Ontario. By 3 years of age, walleye are totally recruited to these fisheries. Indices of recruitment are indicators of recruitment based on younger ages. These indices give us advance knowledge of recruitment.

During the mid-1970s recruitment of walleye in the Bay of Quinte was extremely low (Fig. 7). Resurgence

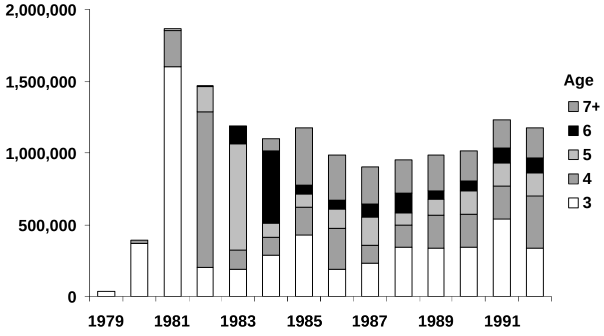

FIG. 2. Population of 3 year-old and older walleye on January 1 from 1979 to 1992 in eastern Lake Ontario. Populations were estimated with Jolley-Seber or Petersen mark-recapture and adjusted assuming constant total mortality, and then projected back in time using the resulting mortality.

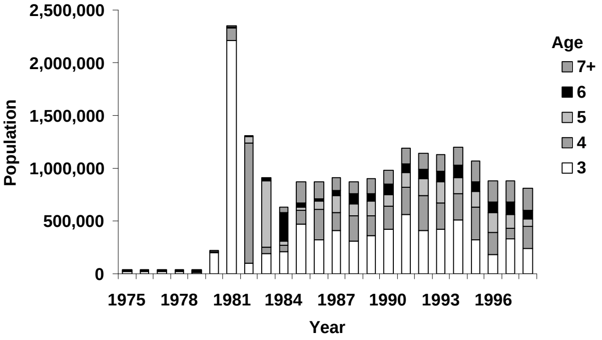

FIG. 3. Population of 3 year-old and older walleye on January 1 from 1975 to 1998 in eastern Lake Ontario. Populations were estimated with CAGEAN.

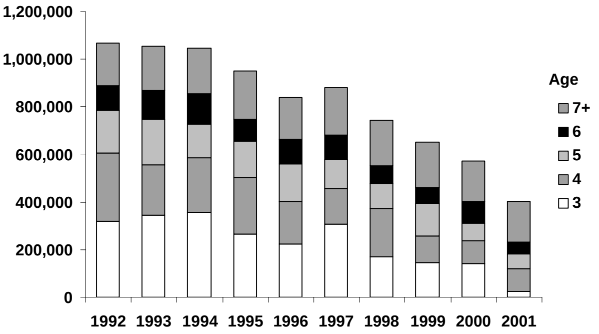

FIG. 4. Population of 3 year-old and older walleye on January 1 from 1992 to 2001 in eastern Lake Ontario. Populations were estimated with index netting-CAGEAN regressions and adjusted assuming constant total mortality.

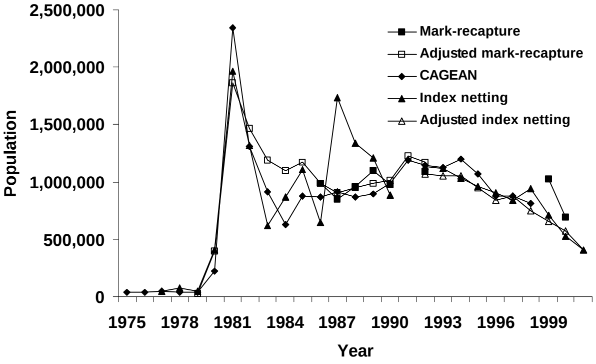

FIG. 5. Population of 3 year-old and older walleye on January 1 from 1975 to 2001 in eastern Lake Ontario.

in the population started with the 1977 year class that was immediately followed by the exceptional 1978 year class (Fig. 7). The 1988 year class is of note as the second largest (next to the 1978 year class) in the last 30 years, and it led to the high population in the early 1990s (Fig. 5). Excluding the 1978 year class, the variability in walleye year class strength since 1977 in the Bay of Quinte has been low compared with many other Great Lakes walleye populations (Colby et al. 1991). However, after the 1994 cohort we see a shift to lower walleye recruitment, coincident with ecosystem changes resulting from zebra mussels in the Bay of Quinte. Since the 1995 year class, we have seen consistent, but lower, recruitment of walleye in the eastern Lake Ontario except for the failed 1998 cohort (Fig. 7).

We have traditionally reported young-of-the-year (YOY) catch in index trawls as our indicator of recruitment because it gives us the most advanced warning. Also, catches in index gillnets and trawls at age 1 are useful indices of recruitment (Fig. 8). The suspension of trawling at some sites from 1981 to 1991 has resulted in a less than satisfactory recruitment index. Our most reported recruitment index, YOY trawl catches at 3 sites, was not significantly correlated with the corresponding abundance of 2 year-old fish of the 1978 to 1999 year classes (Table 1). Yearling catch in gillnets (the only other index with as complete at data series) and was highly correlated with subsequent recruitment (Table 1). Due to changes in fishing gear, program design, and the habitat in the Bay of Quinte, the index data since 1992 may be more consistent. For this period all of the recruitment indices, except yearlings at 3 trawl sites were significantly correlated with the subsequent recruitment of 2 year-olds (Table 1).

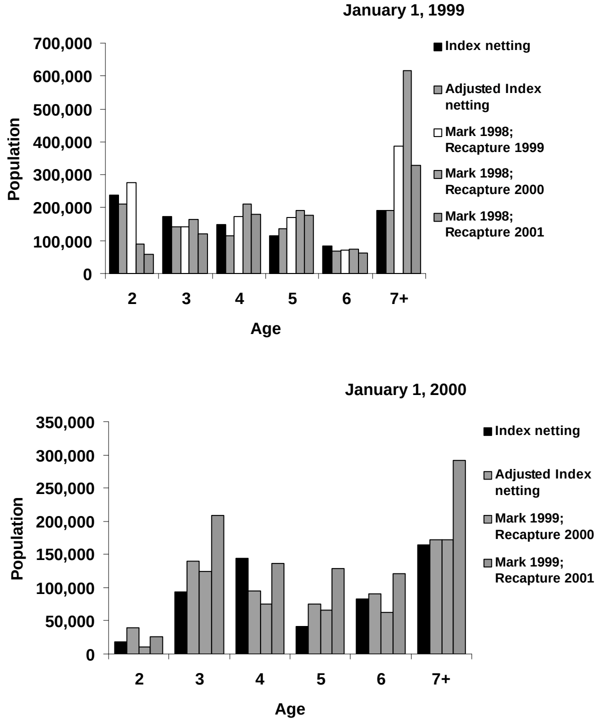

FIG. 6. A comparison population estimates by age for walleye in eastern Lake Ontario on January 1, 1999 and 2000.

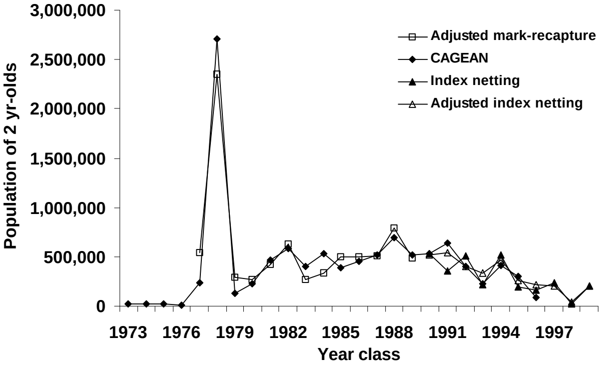

FIG. 7. Population of 2 year-old walleye by year class on January 1 in eastern Lake Ontario.

As the recruiting population approaches zero, the recruitment index should also approach zero. Simple linear regressions with these data suggest a large population when the index catch reaches zero (i.e., the intercept is a large positive number). We examined alternatives, including log transforming the data and forcing a simple linear regression to intercept the population axis at zero. Power functions (log transforming population and index data) gave the best fit with these indices (Fig. 9) and provided better fit than a straight line (Table 1).

Moreover, the power functions demonstrate that a decline in these recruitment indices cannot be interpreted as an equal decline in the population. Rather, at lower populations the recruitment indices decline faster than the population (Fig. 9). Comparing the relative abundance of gillnet indices (Fig. 1) with population estimates (Fig. 5), this effect was also evident for older fish (OMNR unpublished data).

These relationships (Fig. 9) can be used to estimate the population of 2 year-olds one or two years in advance. Only the relationship involving YOY can estimate 2 years in advance. For estimating one year in advance we combined YOY in trawls (6 sites), yearlings in trawls (6 sites), and yearlings in gillnets into a multiple regression (all data were log transformed). This multiple regression further refined our recruitment estimates ($R^2 = 0.980$). The population estimates for 2-year-olds on January 1, 2002 and 2003 are 153,676 and 263,159, respectively. A low coefficient of variation in recruitment since 1997 (39.8%) implies relatively stable recruitment since 1997 with a mean of 192,411 2 year-old walleye (Fig. 10).

Total Mortality

The ANCOVAs with the mark-recapture population estimates from 1985 to 1991 and with the index netting population estimates from 1992 to 2001 provided direct estimates of instantaneous total mortality. For the years 1985 to 1991 mortality did not differ significantly among year-classes (p=0.996), and the annual mortality was 31.9%. Similarly, for the years 1992 to 2001 mortality did not differ significantly among year-classes (p=0.946), and the annual mortality was 33.4%. Moreover, these analyses suggest that annual mortality has increased slightly, by 1.6%, between the 1980s and 1990s. Due to the differences in population estimation methods, we did not test whether this increase in mortality was statistically significant. Clearly, annual mortality did not change in any meaningful manner either within or between these periods (Fig. 11).

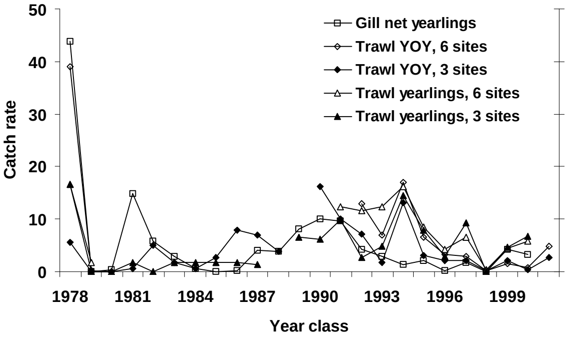

FIG. 8. Indices of walleye recruitment by year class in eastern Lake Ontario. The catch rate for gillnets is catch per standard gillnet lift. The catch rate for trawls is catch per standard tow. The right-hand scale is for trawl yearlings.

Table 1. Simple correlations between the population of 2 year-olds and recruitment indices for walleye in eastern Lake Ontario. Statistically significant correlations are bolded.

Gear	Age	Number of sites	R^2	p	N
1978 to 1999 year classes					
Trawl	YOY	6	**0.868**	**0.000**	11
Trawl	YOY	3	0.061	0.279	21
Trawl	Yearling	6	**0.385**	**0.042**	11
Trawl	Yearling	3	**0.346**	**0.005**	21
Gillnet	Yearling	3	**0.823**	**0.000**	22
1992 to 1999 year classes					
Trawl	YOY	6	**0.866**	**0.001**	8
Trawl	YOY	3	**0.688**	**0.011**	8
1991 to 1999 year classes					
Trawl	Yearling	6	**0.835**	**0.001**	9
Trawl	Yearling	3	0.413	0.062	9
Gillnet	Yearling	3	**0.482**	**0.038**	9

Discussion

All of the estimates of walleye populations in eastern Lake Ontario, presented here, were calibrated directly or indirectly, with mark-recapture estimates from 1985 to 1991. CAGEAN population estimates (1984-1998) were calibrated directly with the older mark-recapture (1985-1991) and more recent index netting estimates (1992-2001) were calibrated to these CAGEAN estimates. The mark-recapture estimates for 3 year-old and older walleye on January 1, 1999 and 2000 suggest that the index netting population estimates were low (70% - 76%: Fig. 2). However, as yet we have insufficient mark-recapture data to recalibrate index netting population estimation methods.

Habitat changes in the Bay of Quinte and eastern Lake Ontario embayments induced by dreissenid

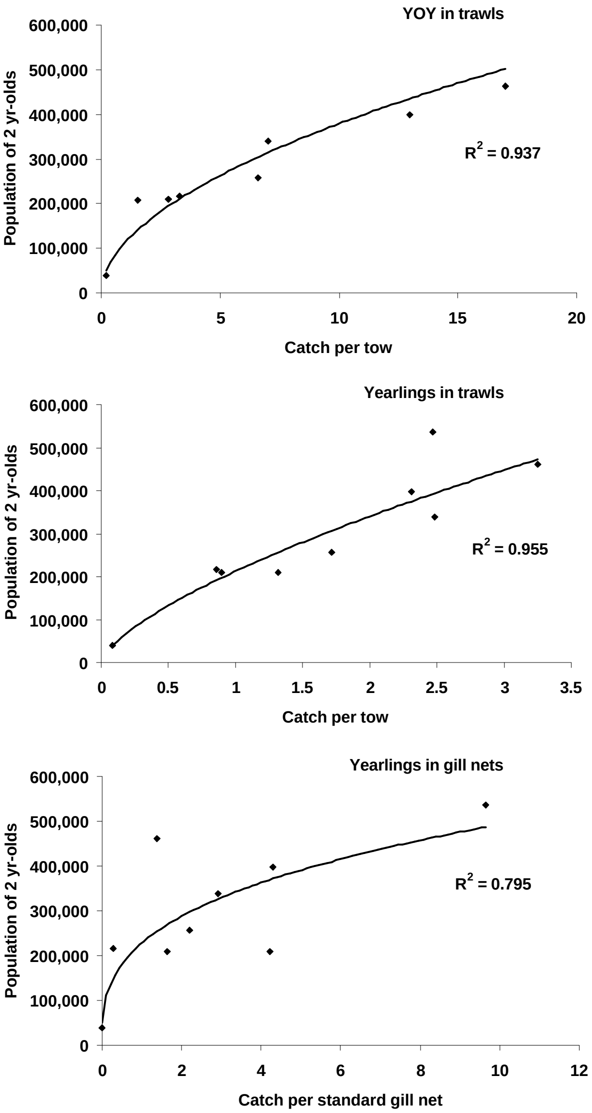

FIG. 9. The relationship between recruitment indices and population of 2 year-olds for the same year class of walleye in eastern Lake Ontario. The population estimate is for 1992-2001 using adjusted index netting estimates. The fit for a power function and it's R^2 is indicated.

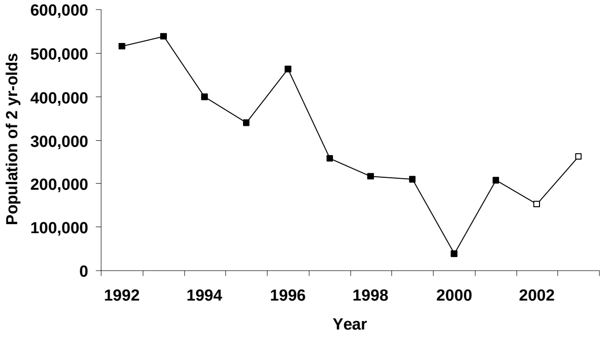

FIG. 10. Population of 2 year-old walleye on January 1 in eastern Lake Ontario. Open squares indicate the predicted populations.

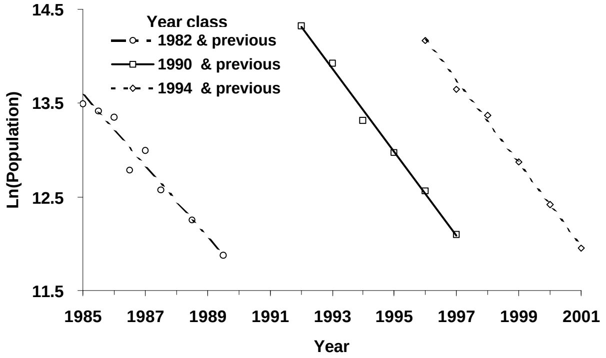

FIG. 11. Mortality curves for walleye in eastern Lake Ontario from 1985 to 2001. Data are combined for the selected year classes as indicated.

mussels may have reduced the catchability of index gillnets and anglers through the 1990s and led to the lower population estimates. Water clarity and aquatic vegetation increased in the Bay of Quinte following dreissenid mussel invasion in 1993. This could impact walleye distribution and activity patterns, and as a result, catchability of walleye in index nets and by anglers. The most dramatic change in water clarity occurred in 1995, and aquatic vegetation density probably peaked by 1998. The index netting analysis was designed to mimic CAGEAN for the time-period 1992 to 1998, and therefore encompasses this time-period of dramatic habitat change.

In addition, there is considerable netting data (6 locations) from outside the Bay of Quinte in eastern Lake Ontario where increases in water clarity has been less dramatic, and therefore, may be less affected by changes in catchability of walleye. Ages were unavailable for inclusion in this analysis, but as ages become available these data should be incorporated into this analysis.

Index netting population estimates have an advantage of being more up to date than mark-recapture population estimates. As well, index netting population estimates of recruitment allow the projection of the population up to 2 years in the future. However, the index netting population estimates are low compared with the mark-recapture estimates, which we believe are more accurate. Accordingly, the projections based on the index netting population estimates (Schaner et al. 2002) may be low. However, this provides a margin of safety for management of the walleye population.

Despite the low recruitment by the 1998 year class in 2000, the variability in walleye recruitment in eastern Lake Ontario since 1997 (Fig. 10) is less than observed in many Great Lakes walleye populations (Colby et al. 1991). Recruitment has stabilized at a lower level than we were accustomed prior to the mid 1990s. Since total mortality has not changed greatly since 1985, recruitment remains as the major influence on walleye abundance. The time lags in recruitment and in mortality of the older walleye have delayed the stabilization of the population at a lower level. However, after seven lower year classes the population has reached an age structure that will provide some stability for at least the next 2 years.

The 3 year-old and older population of walleye in eastern Lake Ontario on January 1, 2001, was estimated at 401,000-402,000, well above the 160,000 critical stock size defined by Stewart et al. (2002). Moreover, the population remained above the 320,000 zone of caution defined by Stewart et al. (2002).

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Appendices

APPENDIX 1.1. Population of walleye from spring 1985 to fall 1991 in eastern Lake Ontario. Populations were estimated with Jolley-Seber or Petersen mark-recapture. The 1976 year class includes all previous year classes.

MARK SEASON	MARK YEAR	AGE									
		2	3	4	5	6	7	8	9	10	11
Spring	1985			227,001	135,413	76,706	163,978	73,334	2,801		
Fall	1985	97,282	353,481	201,832	82,537	40,538	152,930				
Spring	1986			223,873	89,614	56,288	34,502	312,089	54,031	8,006	
Fall	1986	182,403	61,706	164,176	44,539	26,965	29,377	159,992	25,326		
Spring	1987			94,178	194,052	52,820	37,170	36,763	129,896	40,403	1,999
Fall	1987	212,134	100,000	70,810	109,804	30,661	23,949	30,162	121,913	5,979	
Fall	1988	176,759	224,908	160,582	94,687	111,436	62,655	23,685		73,650	8,442
Fall	1989	180,458	229,277	157,930	93,781	33,286	72,083	84,710	37,479		34,899
Fall	1991	204,541	222,912	159,960	80,597	75,597	27,532	6,066	24,825	11,404	6,090

APPENDIX 1.2. Population of walleye on January 1 from 1986 to 1992 in eastern Lake Ontario. Populations were estimated during fall with Jolley-Seber or Petersen mark-recapture. Age 3 estimates were adjusted upward by 1.64 to account for unequal distribution of marked and unmarked fish.

YEAR	AGE				
	3	4	5	6	7+
1986	159,485	353,481	201,832	82,537	193,836
1987	299,035	103,499	164,176	44,539	241,781
1988	328,734	234,712	70,810	109,804	212,681
1989	335,120	224,908	160,582	94,687	279,868
1990	233,803	229,277	157,930	93,781	262,457
1992	365,445	335,327	159,960	80,597	151,514

APPENDIX 1.3. Population of walleye on January 1 from 1979 to 1992 in eastern Lake Ontario. Populations were estimated with Jolley-Seber or Petersen mark-recapture and adjusted assuming constant total mortality, and then projecting back in time using the resulting mortality. The 1976 year class includes all previous year classes.

YEAR	AGE					
	2	3	4	5	6	7+
1979	544,721	31,887				
1980	2,344,914	371,192	21,729			
1981	293,401	1,597,907	252,943	14,807		
1982	274,854	199,934	1,088,870	172,365	10,090	
1983	423,176	187,295	136,242	741,994	117,455	6,876
1984	626,238	288,367	127,629	92,840	505,621	80,038
1985	271,948	426,741	196,503	86,971	63,264	399,089
1986	338,120	185,315	290,796	133,904	59,265	315,064
1987	499,164	230,407	126,280	198,159	91,247	255,081
1988	493,755	340,148	157,007	86,052	135,032	236,000
1989	505,518	336,462	231,789	106,990	58,639	252,835
1990	786,996	344,478	229,277	157,949	72,907	212,249
1991	492,090	536,287	234,739	156,237	107,632	194,315
1992		335,327	365,445	159,960	106,466	205,757

APPENDIX 1.4. Population of walleye in fall 1998 and 1999 in eastern Lake Ontario. Populations were estimated with Petersen mark-recapture.

MARK	RECAPTURE	AGE						
YEAR	YEAR	1	2	3	4	5	6	7+
1998	1	276,438	143,885	173,536	171,296	71,373	68,600	318,009
1998	2	88,741	163,501	211,721	192,420	75,476	67,779	549,606
1998	3	60,362	119,313	178,695	175,127	63,468	45,589	283,306
1998	average	141,847	142,233	187,984	179,614	70,106	60,656	383,640
1999	1	10,552	123,586	74,915	65,531	62,611	32,880	138,303
1999	2	25,555	208,639	136,990	128,607	121,959	70,499	220,849
1999	average	18,054	166,113	105,953	97,069	92,285	51,690	179,576

Appendix 2. Population of walleye on January 1 from 1975 to 1998 in eastern Lake Ontario. Populations were estimated with CAGEAN.

	AGE					
YEAR	2	3	4	5	6	7+
1975	19,785	19,384	9,358	4,014	840	2,895
1976	22,606	16,098	11,192	5,403	2,317	2,156
1977	19,254	18,483	10,091	7,015	3,387	2,804
1978	12,059	15,712	11,173	6,100	4,241	3,742
1979	240,761	9,861	9,852	7,006	3,825	5,006
1980	2,709,120	196,897	6,192	6,179	4,391	5,535
1981	125,615	2,212,940	120,997	3,803	3,794	6,094
1982	232,535	101,521	1,140,858	62,304	1,957	5,088
1983	468,634	190,147	60,729	625,564	34,149	3,862
1984	589,696	209,343	56,016	49,375	267,201	45,467
1985	399,029	468,555	131,559	34,566	31,913	207,342
1986	528,151	316,054	289,325	80,043	22,138	160,730
1987	391,477	409,526	173,586	160,169	48,215	119,235
1988	453,197	308,383	245,423	103,091	100,978	111,067
1989	524,476	357,921	187,556	147,474	65,475	140,387
1990	695,243	415,382	221,238	114,161	94,424	137,442
1991	523,032	555,107	268,544	139,615	74,822	156,505
1992	527,944	411,647	331,992	159,103	87,699	152,380
1993	642,357	417,175	251,735	200,242	101,089	158,920
1994	404,103	505,774	249,920	149,372	125,961	171,219
1995	223,624	319,216	308,279	150,401	94,868	196,723
1996	414,608	178,877	208,499	196,152	99,034	197,399
1997	298,612	326,739	107,578	124,137	123,743	196,062
1998	88,661	238,339	210,806	67,780	81,235	215,582

Appendix 3.1. Population of 3 year-old and older walleye on January 1 from 1977 to 1990 in eastern Lake Ontario. Populations were estimated with index netting-adjusted mark-recapture (App. 1.3) regressions.

	AGE
YEAR	3+
1977	46,222
1978	71,635
1979	44,094
1980	410,008
1981	1,967,119
1982	1,323,670
1983	617,013
1984	868,896
1985	1,109,165
1986	641,598
1987	1,730,559
1988	1,334,380
1989	1,210,733
1990	888,265

Appendix 3.2. Population of walleye on January 1 from 1992 to 2001 in eastern Lake Ontario. Populations were estimated with index netting-CAGEAN (App. 2) regressions.

	AGE					
YEAR	2	3	4	5	6	7+
1992	533,582	319,234	335,460	194,297	101,662	180,515
1993	353,188	410,168	233,569	190,330	113,080	169,712
1994	505,631	433,549	201,654	116,730	107,876	176,975
1995	212,601	187,801	339,835	158,159	102,743	170,184
1996	523,493	300,867	178,454	134,142	89,769	197,399
1997	191,693	303,201	132,241	120,148	109,550	178,927
1998	165,474	303,201	240,273	107,355	84,167	208,827
1999	239,774	174,230	149,993	113,680	84,866	191,928
2000	17,893	93,786	144,630	40,766	82,992	163,614
2001	208,666	26,208	120,117	45,262	53,731	156,124

Appendix 3.3. Population of walleye on January 1 from 1992 to 2001 in eastern Lake Ontario. Populations were estimated with index netting-CAGEAN (App. 2) regressions and adjusted assuming constant total mortality.

	AGE					
YEAR	2	3	4	5	6	7+
1992	516,407	318,464	285,861	181,687	101,662	180,515
1993	537,393	343,712	211,964	190,265	120,928	187,812
1994	398,454	357,680	228,769	141,080	126,637	193,445
1995	339,600	265,204	238,066	152,265	93,901	202,079
1996	462,176	226,032	176,516	158,453	101,345	175,771
1997	256,909	307,617	150,443	117,486	105,464	198,839
1998	215,852	170,994	204,745	100,133	78,197	189,286
1999	209,241	143,668	113,811	136,275	66,647	191,038
2000	39,377	139,267	95,623	75,751	90,702	172,103
2001	208,666	26,208	92,694	63,645	50,419	169,269

15

Model Simulation of Walleye in Eastern Lake Ontario

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

Introduction

Simulation modeling was used extensively in the recent discussions of issues surrounding the Bay of Quinte walleye. A model was constructed to forecast the population trends in the short term, and to examine risks and consequences associated with these actions. A series of evolving versions of the model based on catch-at-age population estimates for years 1984-1998 have been used since 1999 (Stewart et al. 2002). A new, substantially revised version of the model was constructed recently to take advantage of new series of mark-recapture population estimates (Bowlby and Hoyle 2002). This chapter describes the new model, and the results from the latest set of simulations.

Model Description

The model was implemented through the Fisheries Management Support System (FMSS, Korver and Kuc, 2000). This is a population modeling application with a comprehensive set of features that can be used to describe exploitation. The simulations discussed in this chapter covered the period between 1998 and 2006. Each year was divided into five seasons to account for the changing pattern of exploitation in the course of a year. The walleye population was represented by a size-at-age matrix driven by recruitment, growth, natural mortality and exploitation.

The exploitation patterns were modeled with a fair degree of fidelity. The two angling fisheries (open water and ice), and the Bay of Quinte gillnet fishery were controlled through fishing effort. This reflects our belief that the harvest in these fisheries is determined by the combination of fishing effort and population levels. The harvests in the remaining two fisheries – spring spear fishery and the commercial fishery – were specified directly as harvested biomass, since we believe that within reasonable bounds these fisheries achieve given harvest levels regardless of availability of fish. All fisheries were modeled as size-selective, reflecting the differences in sizes of fish that they take.

Fitting the model

Growth and maturation parameters were based on values obtained from LOMU's long-term assessment data. Mortality rates were based on age-structured population analysis (Bowlby and Hoyle 2002). Size selectivity profiles and catchability coefficients (q) for the five fisheries were based, with some adjustments, on values used in the previous implementation of the model, which in turn were obtained through trial-and-error, matching modeled and real harvests.

The fishing effort for the two angling fisheries (open water and ice fishery) was obtained from Lake Ontario Management Unit's (LOMU) creel survey data up to and including year 2001. For the ice fishery, we assumed that the effort in 2002 and subsequent years would remain at the 200l level. For the open water angling fishery, we assumed an effort of 180,000 angler-hours for years 2002 and beyond - lower than in 2001, and reflecting the downward trend in effort observed in recent years. A protected slot between 19 and 25 inches was simulated starting in year 2002 in open water angling fishery, and in 2003 in ice angling fishery.

The Bay gillnet fishery has recently gained prominence, but it is not well documented. In 2001, the fishing effort was estimated to be 177 trips, resulting in a harvest of 57,300 fish (LOMU, unpublished data). Based on indications that the fishery has increased to reach its current level in 1999, we modeled the effort as 70%, 100%, and 100% of the 2001 value for the years 1998, 1999, and 2000 respectively. For 2002 and subsequent years we assumed a set of scenarios based on the 2001 effort.

The commercial and spear fisheries were modeled as direct removals of specified biomass. For both fisheries we used LOMU harvest estimates for years 1998-2001, and assumed that the harvests would continue at the 2001 level in subsequent years.

The walleye population used to initiate the model, and also to test it, was based on 1998-2001 population estimates from Bowlby and Hoyle 2002 (Chapter 14, Appendix 3.2). To eliminate random error contained in these individual independent estimates, the estimates were adjusted so that the cohorts were forced to follow a common over-the-lifetime survival profile (least squares fit to logarithmically transformed abundance data). The profile was derived from preliminary runs of the model, and reflected the pattern of mortality resulting from the combined fishing pressures and size selectivities in the various fisheries.

The model population at the start of simulation was initiated with adjusted 1998 abundance estimates for 2-year old and older fish. The estimates of 2-year old fish for years 1999-2001 (Bowlby and Hoyle 2002, Chapter 14, Appendix 3.3) were projected backwards to estimate abundances of yearlings entering the model one year earlier in years 1998-2000. Abundance of yearlings for years 2001-2002 was similarly projected backwards from abundance estimates of 2-year old fish in 2002-2003 (Bowlby and Hoyle 2002). The abundance of yearlings entering the model in 2003 and in subsequent years was assumed to be constant and various scenarios were simulated, based on the average value from years 1998-2002.

The fit of the model was assessed by comparing 1998-2001 model abundances with corresponding population estimates (Fig. 1), and 1998-2001 model harvests with actual harvests (Figs. 2 and 3). Overall, there was good agreement between the two sets of values, suggesting a well balanced model that fairly represents the population and the various fisheries. The model harvests in the spear and commercial fisheries underestimate the actual harvests in terms of numbers of fish, despite being simulated explicitly as harvested biomass. This indicates a discrepancy in the size composition between the model and actual

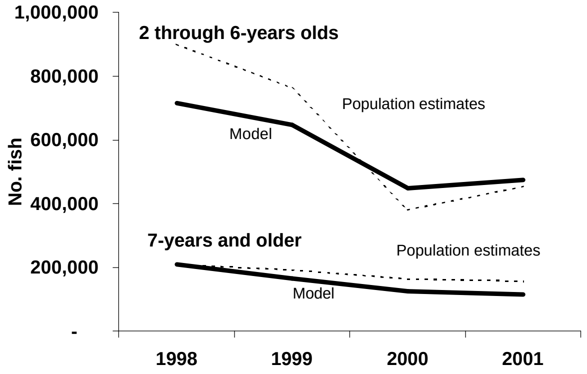

FIG. 1. Comparison of walleye abundances in the model with regression abundance estimates (Bowlby and Hoyle 2002, Chapter 14, Appendix 3.2).

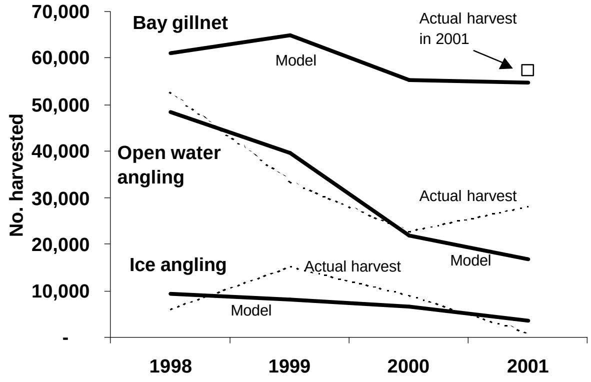

FIG. 2. Comparison of harvests in the model with estimated actual harvests in Bay gillnet fishery and in the two angling fisheries.

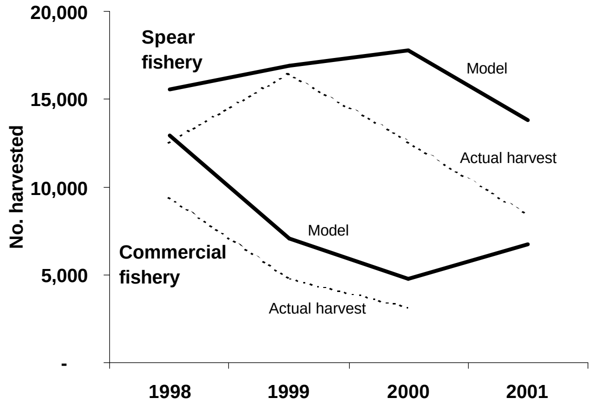

FIG. 3. Comparison of harvests in the model with estimated actual harvests in the spear and commercial fisheries.

harvest. However, the commercial harvest is small, and the spear harvest consists largely of old fish, and thus the discrepancy has no serious bearing on our ability to model younger age classes and the fisheries that exploit them.

Simulation scenarios

The two principal forces controlling the walleye population in the Bay of Quinte are reproduction and exploitation. We explored possible future scenarios by simulating a range of levels in these two factors. In both cases best-guess baseline values were bracketed by reasonable low and high assumptions. All combinations of three levels in the two variables were simulated, resulting in nine simulation runs.

Reproduction was modeled as the number of yearling fish entering the population. We had abundance estimates for yearlings up to and including 2002. For subsequent years we assumed that the abundance of yearlings would remain at a constant level equal to the mean value for years 1998-2002 (203,625 yearlings) as the baseline scenario, but we also explored extreme possibilities of yearling abundance at constant levels equal to lower and upper 95% confidence limits for the estimated 1998-2002 mean value (96,201 or 311,050 yearlings). Although the assumed reproduction levels were used through to the end of the simulation in 2006, only the assumed yearling abundances in 2003 and 2004 have any bearing on the abundance of 3-year old and older fish during the simulation period.

A range of fishing pressure assumptions was explored by varying the simulated effort in the Bay of Quinte gillnet fishery. This is a fishery for which we have little information, but we suspect that it currently accounts for the largest portion of the harvest, exceeding the second largest fishery (open water angling) by more than two-fold. We therefore chose to explore a wide range of possibilities, and in addition to the baseline assumption of 177 gillnet sets, we also simulated half and twice the baseline level starting in 2002.

Results

Baseline scenario

Simulations using the most likely anticipated values for future levels of reproduction and exploitation suggest that the recent decline in abundance of 3-year old and older fish is about to cease and the population levels should stabilize around 400,000 fish (Fig. 4). The simulated harvests under those conditions leveled off around 75,000 fish. Exploitation rate on 3-year old and older fish rose slightly in the first years of the simulation period, and then remained around 20%. The relatively stable exploitation rate throughout most of the simulation period was due to the fact that the major portion of the harvest was modeled through fishing effort. Effort was assumed to be constant in the Bay gillnet fishery most of the simulation period, and constant in the open water angling fishery throughout the second half of the simulation period.

The age structure of the population shifted over the 1998-2006 simulation period towards a state where young fish become relatively more dominant (Fig. 5). The principal cause for the shift was the

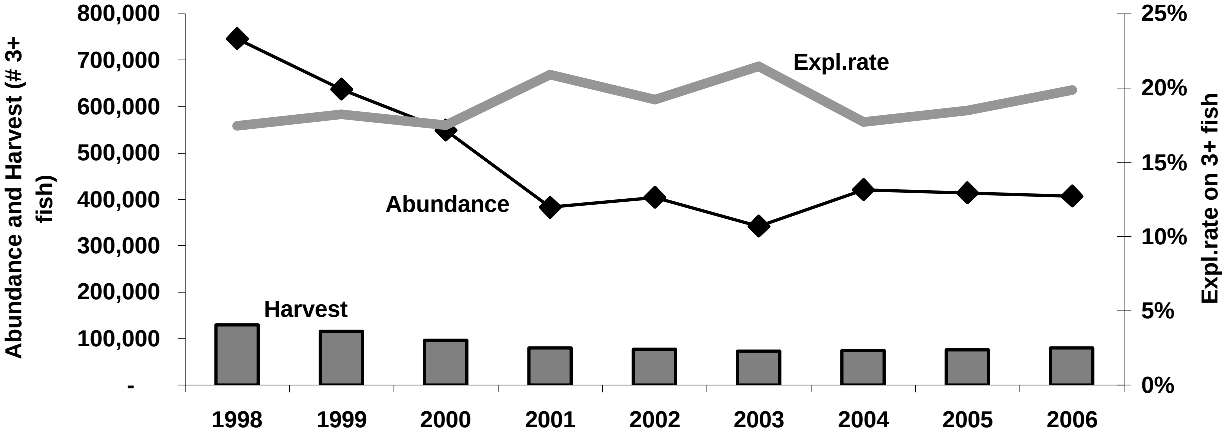

FIG. 4. Walleye population abundance, total harvest, and overall exploitation rate from simulation using best estimates of reproduction and exploitation levels (baseline scenario). All statistics are based on 3-years old and older fish.

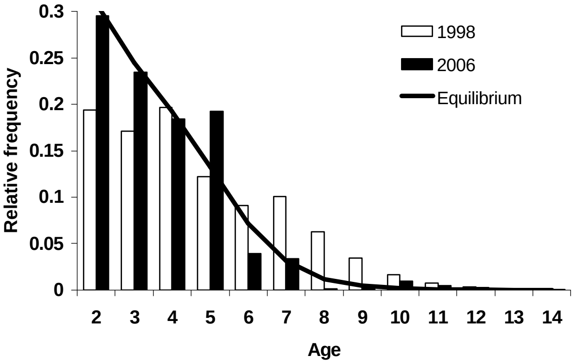

FIG. 5. Age structure of the simulated population at the beginning (1998) and end (2006) of the simulation period. The equilibrium line represents the expected age distribution achieved under the conditions of the baseline scenario.

recent decline in recruitment working its way through the age structure, rather than fishing pressure on older fish. By the end of the simulation period in 2006 the age structure was close to the equilibrium state that would be expected under the assumed levels of reproduction and exploitation.

Alternative scenarios

The trends in abundance of 3-year old and older fish varied considerably depending on assumed recruitment and exploitation levels. There was a nearly three-fold divergence in predicted abundance levels reached by the year 2006. The effects of alternative assumptions about Bay gillnet effort were felt by year 2003, but remain relatively weak compared to the effects of alternative recruitment assumptions. The latter were not felt until 2005 but by the end of simulation in 2006 they lead to major differences in abundance. Two out of the three scenarios involving the lowest recruitment level suggested that abundance of 3-year old and older fish in 2006 would fall below 320,000 fish, which is the benchmark where corrective action is suggested (Stewart et al. 2002). None of the scenarios lead to levels below 160,000 fish, the benchmark at which cessation of all fishing is recommended, although the trends suggested that such low abundance could be approached by 2007 under the most unfavourable combination of assumptions.

The variation in simulated harvests under the various scenarios was less than the variation in abundances, ranging by approximately two-fold

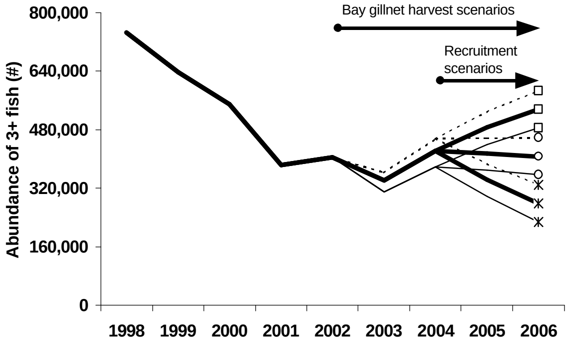

FIG. 6. Abundance of 3-year old and older fish predicted from simulations under various reproduction and exploitation scenarios. The line styles represent the three Bay gillnet effort scenarios starting in 2002 (thick solid: baseline; dashed: half baseline; thin solid: double baseline) and the symbols represent the three reproduction scenarios starting in 2003 (circle: reproductive level equal to 1998-2002 mean; square: upper 95% confidence limit on the mean; star: lower 95% confidence limit on the mean).

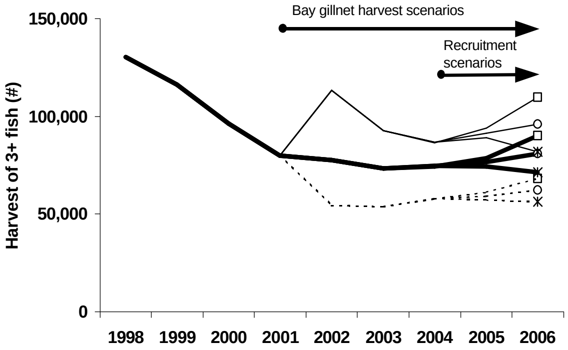

FIG. 7. Harvest of 3-year old and older fish predicted from simulations under various reproduction and exploitation scenarios. See Fig. 6 for interpretation.

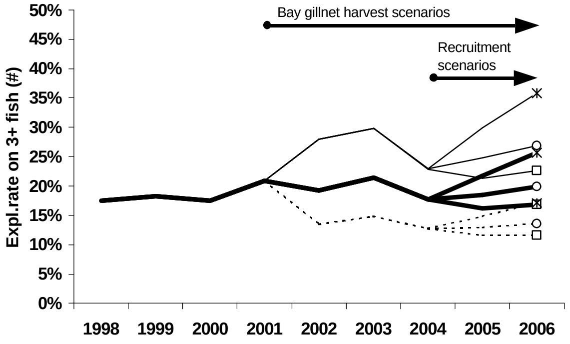

FIG. 8. Exploitation rate on 3-year old and older fish predicted from simulations under various reproduction and exploitation scenarios. See Fig. 6 for interpretation.

between 52,000 and 110,000 fish 3-years old and older in year 2006. A large divergence in simulated total harvest was seen immediately after the alternative harvest assumptions came into effect, but the harvests converged in subsequent years as the simulated populations compensated for the new levels of effort. By 2006 there was considerable overlap between outcomes due to recruitment assumptions and those due to fishing effort assumptions.

Exploitation rate expresses the harvest relative to the abundance of the fish. Like the harvest, the exploitation rate in the simulation responded immediately to the Bay gillnet effort assumptions, and just like the harvest, the range of responses diminished in subsequent years. Starting in 2005 however the exploitation rates started diverging again in response to variation in abundances caused by recruitment assumptions. Most combinations of assumptions lead to rates between 15% and 25%, although the combination of lowest reproduction level with the highest exploitation pressure resulted in exploitation rate of 36% by year 2006.

Discussion

The model provides a well integrated description of the Bay of Quinte walleye population and its fisheries, and fits well the available data for the 1998-2001 period. The model's minor biases in the description of older fish, and the spear and commercial fisheries do not hamper its ability to describe the bulk of the population and the major fisheries. We therefore believe that within limits of our ability to predict recruitment and harvests, the short term forecasts provided by the simulations are realistic.

The range of assumptions that we chose for reproduction and Bay gillnet largely determined the range of outcomes. Within the examined ranges in both variables, we saw that the population abundance was driven principally by reproduction and less so by the harvest. It is debatable whether the levels of reproduction would persist for a number of years at the extreme low or high levels which we used in the simulation, however the wide range of outcomes was produced by only two consecutive years of extreme values. By the same token, the period of stable abundance which we saw in the baseline simulation starting around year 2001 was very much a consequence of the recent period of relatively stable reproduction, and of our assumption that the reproduction will remain stable in the near future.

The model summarizes our current understanding of the dynamics of the walleye population, and the baseline assumptions represent our best estimate of the reproduction and exploitation levels. The resulting simulations suggested that the Bay of Quinte walleye population is about to stabilize, albeit at levels that are considerably lower than those observed in the 1980s and 1990s. The lower population levels, combined with our best forecast of harvest levels, result in exploitation rates currently stabilizing around 20%, which is approximately twice the rate recommended as part of the management strategy. Furthermore, plausible variations in modeling assumptions resulted in widely varying population levels, including low levels previously flagged as reason for concern.

Having come close to, or exceeding, some of the management reference points (Stewart et al. 2002), it is obviously time to proceed with caution. From the assessment point of view this means that not only will the need for timely information continue, but there will also be a need for increased precision of our estimates, and forecasts. This will require continued monitoring of reproduction and improved information on harvests.

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16

Diet of Round Goby in the Bay of Quinte, Lake Ontario

Ana Carolina Taraborelli[1], and Ted Schaner

Introduction

The round goby (*Neogobius melanostomus*) first appeared in the Bay of Quinte in 1999, and is now spreading locally throughout the bay and the adjacent waters of eastern Lake Ontario (Hoyle and Schaner 2002 in this report). The goby is a voracious forager with a diverse diet comprised mainly of benthic invertebrates (Jude et al. 1992). Of particular interest in the Great Lakes is the goby's interaction with the recently established zebra and quagga mussels (*Dreissena polymorpha* and *D. bugensis*). In the Bay of Quinte, the mussels have preceded the goby by only five years, but during that time they have become a dominant feature of the nearshore aquatic environment. Similarly, the round goby is fast becoming a key member of the nearshore community (more than half the fish in the beach seine catches made for this study were round gobies). In this study we examined the diet of the round goby, with particular attention to the goby's consumption of *Dreissena* mussels.

Methods

The round gobies for stomach analysis were collected in July 16-20, 2001, at a single location in Picton Bay, Lake Ontario (Fig. 1), along the shore in depths less than 1.7 meters. Thirty-one round gobies were collected with beach seine, and hook and line, and one additional large individual was also obtained from a bottom trawl made outside the study area, in deeper water. The examined fish were selected to evenly cover all available goby sizes, rather than to represent the size composition of the goby population. They were processed within 2 hours of capture. The round weight and total length of each fish were recorded, and the entire digestive tract was removed and preserved in 70% ethyl alcohol. Later the food items were identified to the lowest possible taxon and counted, using a dissecting microscope. Full classification was not attempted because most of the items were partially digested.

Dreissena mussels were not distinguished by species (*D. polymorpha* and *D. bugensis*). They were counted and their total lengths were measured or estimated. Although the majority of the mussels were damaged, their umbones mostly remained intact, allowing for reliable counts. We were able to measure the shells of undamaged mussels but sizes of the broken mussels had to be estimated. For this purpose, we set up a reference series of measured whole mussels ranging between 4 and 19 mm, and used it as visual reference in estimating sizes of the broken shells.

Samples of living *Dreissena* were collected at the same location from solid substrate (rocks) and from

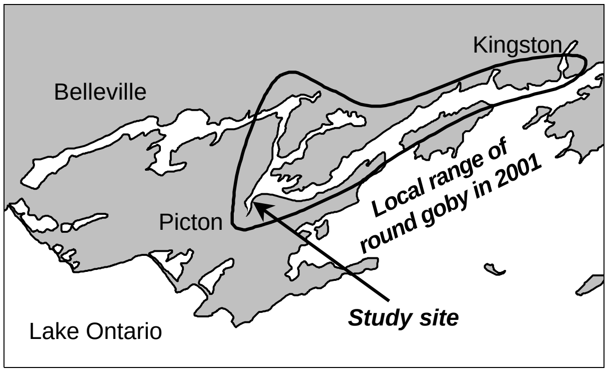

FIG. 1. The study site - McFarland's Conservation Area, Picton, Ontario.

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aquatic macrophytes. Depths between 2 and 6 feet were randomly sampled, the collected samples were pooled by substrate type (rocks and macrophytes), and random subsamples from each substrate type were measured to determine the size composition.

Results

All stomachs contained identifiable food items. Copepods were the most abundant item, followed by chironomids, cladocerans, amphipods, and dreissenid mussels. No fish were found in stomachs. There were small stones present in every stomach analyzed, some of which appeared to have mussel byssal threads attached.

The diet varied with the size of the gobies (Fig. 2). Cladocerans and copepods were found only in the stomachs of gobies less than approximately 8 cm, and typically in quantities of tens of individuals. Dipterans were equally important in the diet of small gobies, but large gobies consumed them as well. Small gobies also consumed lesser quantities of other items (Trichoptera, Coleoptera, Hydracarina, Ostracoda, small snails and fingernail clams). Amphipods appeared to be important in the diet of medium size gobies. *Dreissena* were consumed mainly by gobies larger than approximately 8 cm, and were most important in the diet of the largest gobies, although some *Dreissena* were found in the stomachs of gobies under 8 cm.

The size of *Dreissena* found in the diet varied with the size of the gobies (Fig. 3). The smallest gobies (<8 cm), which relied mostly on other food

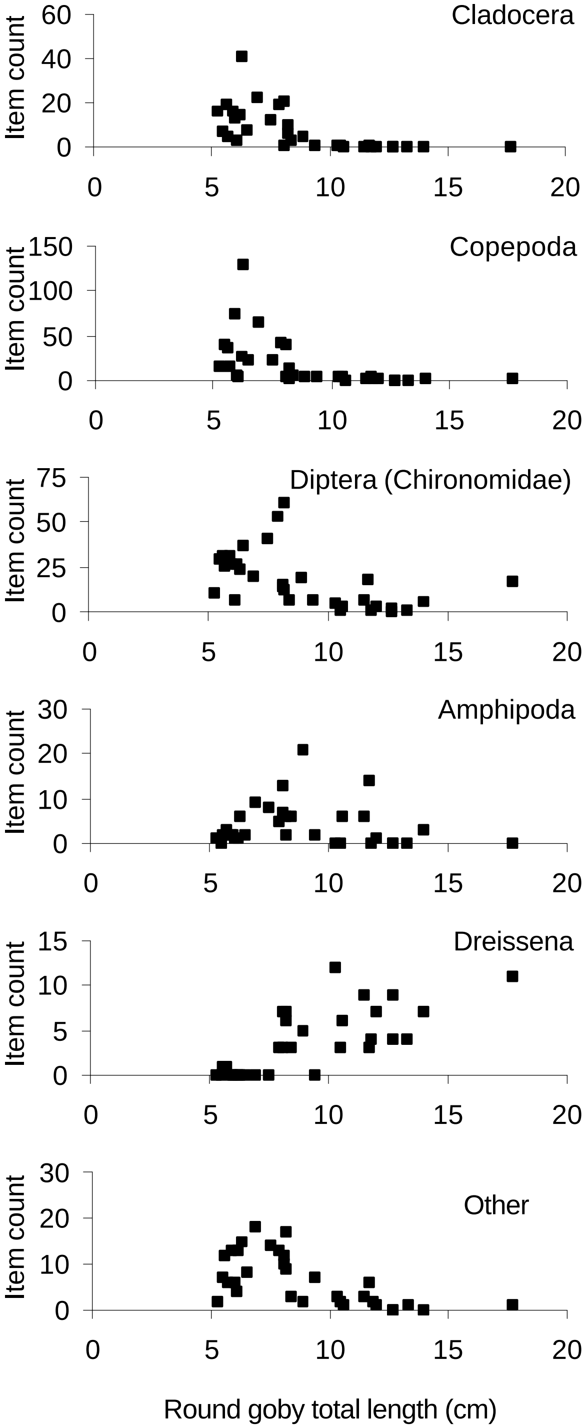

FIG. 2. Counts of items found in the stomachs of round gobies of various sizes. The 'other' category includes trichoptera, coleoptera, gastropoda, hydracarina, and fingernail clams (Sphaeridae).

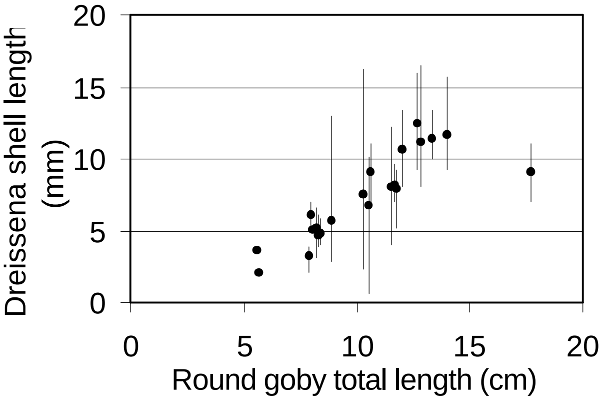

FIG. 3. Mean size and range of Dreissena found in the stomachs of the round gobies.

types but also consumed some *Dreissena*, had only mussels less than 4 mm in their stomachs. The smallest gobies that appreciably relied on *Dreissena* (approximately 8 cm) generally consumed mussels smaller than 7 mm. The size of consumed mussels increased with the size of the gobies, and the largest gobies from our study area generally consumed mussels over 10 mm, and as large as 16.5 mm. The largest examined goby (17.7 cm), caught in deeper water outside our study area, actually consumed smaller mussels (7-11 mm).

We also examined the sizes of *Dreissena* available to the gobies (Fig. 4 A, B). The mode of the size distribution of mussels found on rocks was in the 12-16 mm range. Mussels found attached to macrophytes had a mode around 8-10 mm, and very few individuals over 19 mm. We made no attempt to reconstruct an overall size composition because we did not measure the relative contributions by these two segments of the population.

The aggregate size composition of *Dreissena* found in our sample of goby stomachs had a mode in the 8-12 mm range (Fig. 4 C). It should be noted, however, we selected gobies to provide an even sample across the available sizes, rather than to represent the size composition of the goby population. We suspect that a representative sample would have been weighted towards small fish, resulting in higher overall consumption of smaller *Dreissena*.

Discussion

The overall dietary patterns found in our Bay of Quinte study closely matched those reported in other published accounts from Europe and North America (Skora and Rzeznik 2001, Weimer and Sowinski 1999, French and Jude 2001, Jude et al. 1995 as cited in Charlebois 1997). Small gobies rely on a variety of small mobile invertebrates (in this case mainly chironomids, cladocerans and copepods), and as they grow, the gobies switch to a more restricted diet of mainly mollusks (in this case dreissenid mussels). The intermediate size gobies in the Bay of Quinte also consume significant numbers of amphipods.

The preferred sizes of dreissenid mussels appeared to be related to the size of the goby. Previous reports suggested a preference for smaller mussels by gobies of all sizes (Weimer and Sowinski 1999, Ray and Corkum 1997), and no relationship between size of the gobies and size of the mussels that they consume (Thomas 1997). The mussels found in goby stomachs in our study increased from 2-7 mm range in gobies under 8.5 cm, to 8-16 mm range in gobies 12-14 cm, and the mean size of consumed mussels increased uniformly over the examined range of goby sizes.

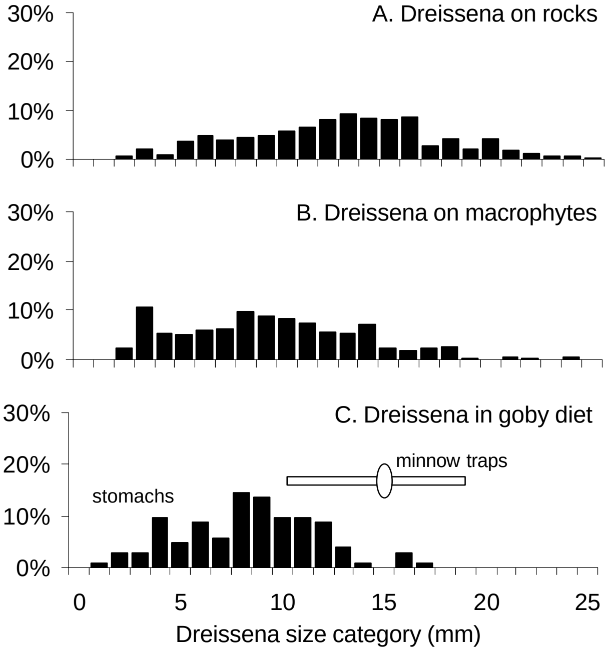

FIG. 4. Size composition of Dreissena *at large and in the round goby diet. A.* Dreissena *on the bottom attached to rocks. B.* Dreissena *above the bottom, attached to macrophytes.* C. Dreissena *found in the goby stomachs, and the range and mode of empty* Dreissena *shells found ejested in minnow traps (see Discussion).*

It is not clear from our data whether the preference for increasingly larger mussels continues in gobies beyond the examined range. The largest goby that we examined was caught outside the study area, and it actually contained smaller mussels than those found in the largest gobies from the study area. This fish, however, may have foraged on a different spectrum of available prey. We have since collected anecdotal evidence suggesting that mussels larger than those seen in our study are taken by gobies. Empty mussel shells were routinely found in minnow traps used to collect round gobies at the Glenora Fisheries Station, Picton, Ontario, in the summer of 2002. Since the traps were thoroughly emptied and cleaned before each re-deployment, the empty shells presumably came from mussels that were taken outside the trap by gobies who masticated them, ingested the bodies, and then ejested the shells inside the trap (Ghedotti et al. 1995). A sample of 77 empty shells ranged from 10 to 20 mm with mode at 15 mm (Fig. 4 C). Although it is impossible to tell which of the gobies consumed the mussels (the gobies in the traps ranged from 7 to 17 cm), the observation indicates that gobies consume mussels that are larger than those seen in our study, and that most sizes of mussels are vulnerable to goby predation.

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17

Occurrence of the Fish Parasite *Heterosporis sp.* (Microsporidea: Pleistophoridae) in Eastern Lake Ontario Yellow Perch

J. A. Hoyle and T. J. Stewart

Introduction

Heterosporis sp. is a recently identified parasite in Wisconsin, Minnesota and Ontario that infects fish muscle tissue. Reports of *Heterosporis* from these areas, the first in North America, primarily involve yellow perch. Until 2000, this genus of microsporidea parasites had only been reported in aquarium species (http://www.dnr.state.wi.us/org/water/fhp/fish/health/disease.htm).

The muscle of infected fish appears white and opaque, as if the flesh was cooked or freezer burnt. Spores of the parasite cause the muscle tissue to degenerate. More than 90% of an infected fish's filet can be made up of the parasite's spores rather than muscle tissue.

This report documents the first confirmed cases of *Heterosporis* in yellow perch from Lake Ontario and the Bay of Quinte. Yellow perch were turned in by anglers (unsolicited), purchased from local commercial fishers, and caught in routine or targeted assessment gillnet projects in eastern Lake Ontario, Bay of Quinte and the St. Lawrence River. Fish were examined for the tell-tale symptoms of *Heterosporis*. Selected samples of suspected cases were sent to Dr. Daniel R. Sutherland (Department of Biology and River Studies Center, University of Wisconsin-La Crosse, 1725 State Street, La Crosse, WI, 54601) or Steve Lord (Fish Health Lab, Department of Microbiology, University of Guelph, Guelph, ON, N1G 2W1) for confirmation.

Observations

In hindsight, the first unconfirmed cases of *Heterosporis* symptoms were observed in a small number of angled yellow perch from eastern Lake Ontario and the lower Bay of Quinte by LOMU staff in the summer/fall of 1999. Subsequently, and following reports of the *Heterosporis* parasite in Wisconsin yellow perch, the first confirmed occurrence of *Heterosporis* in the Lake Ontario region reportedly came from Prince Edward Bay in eastern Lake Ontario (Table 1; Fig. 1). Two yellow perch, both showing the characteristic signs of the parasite, were turned in by an angler in July 2000. The total number of fish caught by the angler was not determined. Dr. Dan Sutherland confirmed the identification.

In 2001, over 1,000 yellow perch were examined for *Heterosporis* in eastern Lake Ontario and the Bay of Quinte (Table 1; Fig. 1). All suspected cases of *Heterosporis*, that were sent for positive identification, were confirmed. No cases of *Heterosporis* were observed in routine assessment gillnetting in a variety of locations (zero for 403 fish). No cases were observed in 200 fish purchased from a commercial fisher in the Prince Edward Bay area but seven cases were detected in 199 fish purchased from a second commercial fisher in the lower Bay of Quinte area (note however, that Prince Edward Bay was the location of the first confirmed *Heterosporis* infections the previous year). Ten of 292 fish angled in Prinyer Cove (lower Bay of Quinte) were infected with *Heterosporis*. Finally, no cases were observed in 181 yellow perch caught in a targeted gillnetting project in the Prescott area of the St. Lawrence River (note however, that a local angler had reported *Heterosporis*-like symptoms in angler caught yellow perch in this area).

TABLE 1. Summary statistics of yellow perch samples collected to examine for the fish parasite Heterosporis*. * Reported fork lengths are for the seven infected fish and not the 200 angled fish.*

				Number			Fork Length (mm)		
Location	Sample	Date(s)	Source	Total	Infected	Confirmation	Min	Max	Mean
Prince Edward Bay	1	Jul-00	Angler		2	U. of Wisconsin (D. Sutherland)			
Melville Shoal	2	4-Jul-01	Index Gillnetting	62	0		124	231	167
Flatt Point	3	4-Jul-01 and 12-Jul-01	Index Gillnetting	58	0		126	214	175
Grape Island	4	5-Jul-01 and 10-Jul-01	Index Gillnetting	18	0		124	197	158
Big Bay	5	24-Jul-01 and 2-Aug-01	Index Gillnetting	91	0		123	230	171
Conway	6	25-Jul-01	Index Gillnetting	56	0		125	193	152
Wellington	7	31-Jul-01	Index Gillnetting	50	0		129	199	165
Middle Ground	8	31-Jul-01 and 8-Aug-01	Index Gillnetting	54	0		130	239	157
Hay Bay	9	2-Aug-01 and 14-Aug-01	Index Gillnetting	14	0		106	233	182
Prince Edward Bay	10	30-Aug-01	Commercial Fisher	200	0		170	230	198
Prinyer Cove	11	21-Sep-01	Angler	200	7*	LOMU Staff	184*	231*	201*
Prinyer Cove	12	28-Sep-01	Angler	92	3	LOMU Staff	130	195	159
St. Lawrence River	13	10-Oct-01	Targeted Gillnet	181	0		135	245	165
Adolphus Reach	14	26-Nov-01	Commercial Fisher	199	7	U. of Guelph (S. Lord)	175	230	197
				1275	12				

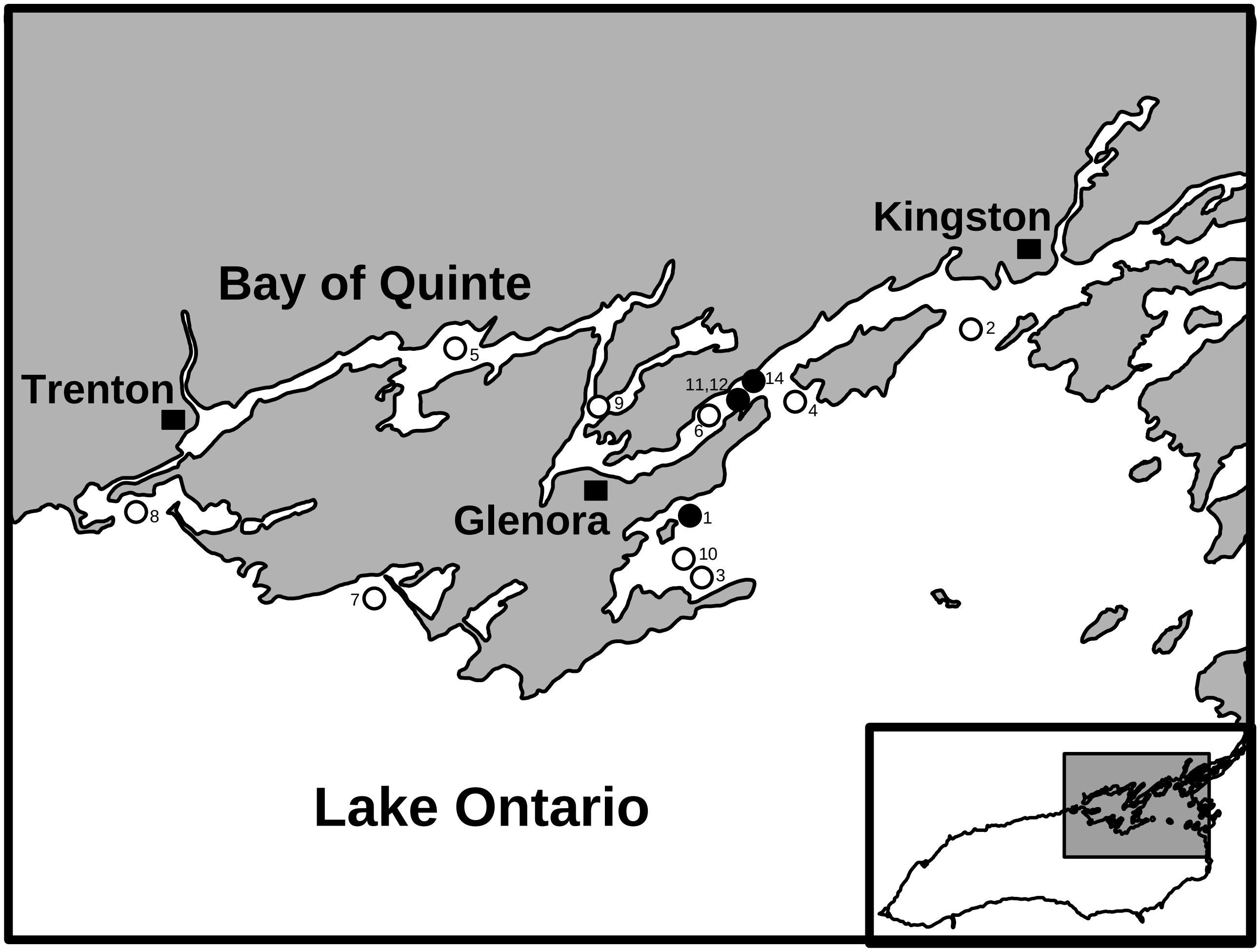

FIG. 1. Map of eastern Lake Ontario and the Bay of Quinte indicating locations of yellow perch samples examined for the fish parasite Heterosporis*. Sampling locations are indicated by circles (open circles, no* Heterosporis*; closed circles* Heterosporis *detected). The St. Lawrence River sampling location, near Prescott, is not shown.*

Discussion

Aside form the original two infected yellow perch turned in by an angler in 2000, 12 of 1,275 fish (1%) were found to be infected in a rather informal survey conducted in 2001. This survey is highly biased, and does not represent a precise measure of the actual infection rate in the eastern Lake Ontario region. Nonetheless, *Heterosporis* is present, apparently with a rather sporadic distribution and relatively low incidence rate, in eastern Lake Ontario and lower Bay of Quinte yellow perch.

18

Zebra Mussels in the Bay of Quinte, 2000

Ron Dermott[1]

The following is a preliminary report on zebra mussels survey conducted in the Bay of Quinte in the summer of 2000 by Fisheries and Oceans Canada. The data and discussion are provisional, and not to be cited without permission of the author.

Zebra mussels have been common in the Bay of Quinte only since the summer of 1993. Surveys conducted between 1993 and 1999 indicated that there was a rapid increase in mussel density in 1994-1995, followed by fluctuating densities (Table 1). These surveys were limited to Ponar grabs and samples collected wading near shore. The Ponar samples were collected along several benthic transects established by Johnson and Brinkhurst (1971), and Johnson and McNeil (1986).

In the 2000 survey, divers were used in addition to Ponar grabs at 68 sites throughout the bay. Comparison of density estimates at four shoals in 2000 showed that there was no significant difference between Ponar grabs and samples collected by divers. This was partly due to the layer of dead shells under the mussel colonies into which the Ponar could easily penetrate in 2000, but also to the huge variability in density of mussels in the 3 to 5 replicate samples at each site.

Table 1. Dreissena *density at Amherst Island (lower bay), Big Bay (upper bay) and Trenton (upper bay) at littoral sites in depths less than 2 meters.*

Survey	Amherst Island		Big Bay (Big Island)		Trenton (Oderdonk Pt)	
	Dens. (m^{-2})	S.E.	Dens. (m^{-2})	S.E.	Dens. (m^{-2})	S.E.
Oct. 1993	879	293	0	0	0	0
Jul. 1994	2,400	1,192	154	40	n.a.	n.a.
Jun. 1995	1,661	542	6,241	2,053	3,518	1,104
Jul. 1995	409	225	3,817	865	n.a.	n.a.
Jul. 1995 (> 2 m)	1,080	330	n.a	n.a.	n.a.	n.a.
Oct. 1995	2,764	546	17,221	2,254	n.a.	n.a.
Aug. 1996	1,182	451	2,532	1,046	n.a.	n.a.
Aug. 1997	n.a.	n.a.	2,612	486	n.a.	n.a.
Aug. 1998	n.a.	n.a.	5,903	957	n.a	n.a
Oct. 1998	n.a.	n.a.	16,370	1,163	23,730	2,237
Aug. 1999	n.a.	n.a.	232	46	n.a.	n.a.
Oct. 2000	n.a.	n.a.	35,225	4,963	49,482	3,967

In the upper bay above Telegraph Narrows, suitable hard habitat is limited to a narrow zone in water less than 3 m deep, on bedrock, gravel, logs and docks. Below 3 m, much of the upper bay is soft black mud that is easily suspended by storms, and can smother the mussels settled on the mud. As a result, near Trenton at depths beyond 3 m mussel densities were very low (5 m^{-2} and 150 m^{-2} in 1998, and 2000 respectively). However, the dense macrophyte beds in the bay also serve as temporary mussel substrate. In late summer, densities of young mussels (<5 mm) attached to macrophytes were up to 400,000 m^{-2} in the Trenton and Belleville areas. Most of these mussels die in the fall as the plants rot and sink to the bottom. The mussels that survive the first year can live 2 to 4 years and grow to 30 mm. In water less than 2 m deep, the density of mature mussels (>12 mm) on the rocks near shore was often less than 2,000 m^{-2}, due to high mortality from strong surf during storms and ice scour over the winter. Thus the information at shore sites (Table 1) reflects mostly summer reproduction and is not a good measure of adult population beyond 2 m depth. Most mussels which survive the winter settled at depths between 2 and 3 meters on the gravel and rocky shoals such as near Makatewis and Snake Islands.

Mussel density varied considerably by year and location, as well as in replicate samples (Fig. 1, Table 3). In the upper bay during October 1998 densities averaged 4,700 m^{-2}, ranging from 2,840 m^{-2} at Belleville, to 8,526 m^{-2} in Big Bay. In Oct. 2000, the densities averaged 38,800 m^{-2} in the upper bay between Trenton and Big Bay (Fig. 1). This is comparable to eastern Lake Erie with an average of 4,800 m^{-2} on soft mud and 68,000 m^{-2} on rocky shoals (Jarvis et al. 2000). Although densities in the upper bay had increased by Oct. 2000, the majority of the

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Table 2. Density and biomass (wet weight with shells) of Dreissena *in the Bay of Quinte, October 2000. Combined diver and/or Ponar samples.*

Area	No. samples	Total Dreissena				Zebra Mussels				Quagga Mussels			
		Density (m^{-2})		Biomass ($g.m^{-2}$)		Density (m^{-2})		Biomass ($g.m^{-2}$)		Density (m^{-2})		Biomass ($g.m^{-2}$)	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Upper bay (Trenton)													
0-3.0 m	31	41,874	13,655	2,224	779	41,859	13,655	2,205	771	14	8	19	10
3.1-5.0 m	10	149	71	0.7	0.3	149	71	0.7	0.3	0	0	0	0
Pooled depths	41	31,697	10,666	1,682	606								
Upper bay (Belleville - Big Bay)													
0-3.0 m	36	51,119	12,578	3,233	504	51,078	12,576	3,211	500	41	28	22	13
3.1-5.0 m	19	31,115	14,753	3,809	1,648	31,082	14,737	3,784	1,634	34	19	25	16
Pooled depths	55	44,209	9,688	3,432	650								
Middle bay													
0-3.0 m	21	45,287	15,279	3,639	725	44,465	15,320	2,979	609	822	317	660	253
3.1-5.0 m	12	27,851	24,890	2,558	1,015	24,000	22,070	782	280	3,851	2,865	1,775	830
5.0-15 m	6	30	22	0.1	0.1	30	22	0.1	0.1	0	0	0	0
Pooled depths	39	32,960	11,318	2,747	532								
Lower bay													
<5 m	19	39,085	10,169	4,111	861	18,733	7,186	438	142	20,352	4,269	3,673	753
5.1-10 m	31	30,031	3,299	7,269	731	331	149	35	16	29,701	3,332	7,234	728
10.1-15 m	4	18,158	4,387	3,753	950	34	11	0.8	0.4	18,124	4,383	3,752	950
15.1-20 m	10	9,828	3,908	2,153	785	81	33	29	15	9,747	3,913	2,124	788
20.1-35 m	8	1,361	618	664	354	39	33	51	41	1,322	586	613	314
Pooled depths	72	25,769	3,385	4,796	491								

mussels in 2000 were young, less than 5 mm in length. As a result the biomass of the mussels in the upper bay increased from 0.41 kg.m^{-2} in 1998 to 1.68 kg.m^{-2} (with shells) near Trenton due to young mussels on macrophytes, but did not change in Big Bay.

Suitable substrate is more common in the lower bay between Picton and the Upper Gap, and occurs as deep as 20 m. In the stable environment at 21 m depth in the Upper Gap (site 13F), density of *Dreissena* increased steadily between 1995 and 2000, from 120 to 3,015 m^{-2} (Table 3). Mussel density in the lower bay ranged between 1,000 and 39,000 m^{-2} (Table 2). In the lower bay, mussels were older and larger than in the upper bay. This resulted in biomass as great as 7.3 kg.m^{-2} (wet weight with shells) near Glenora, compared to upper bay near Trenton where a similar density of mussels resulted in biomass of only 1.6 kg.m^{-2} (Table 2). Large mussels have a greater ecological impact, with each adult mussel able to filter up to a litre of water per day.

Both the zebra mussels (*Dreissena polymorpha*) and the quagga mussels (*D. bugensis*) are present in the Bay of Quinte, although in different areas (Table 2). Quagga mussels are less able to attach to macrophytes than zebra mussels (Diggins et al. 2002). Over 90% of the mussels in the lower bay were quagga mussels, but less than 5% of the mussels found between Hay Bay and Trenton were quagga mussels. The net downstream current in the bay may prevent the quagga mussel veliger larvae from drifting up the bay beyond Deseronto. The quagga mussels appear to be more energy efficient in cooler, more oligotrophic conditions (Baldwin et al. 2002), and would thus survive better in the clearer water of the lower bay. Both mussels are responsible for the increased water clarity in the Bay of Quinte as they remove the algae and silt from the water.

Table 3. Density and biomass (wet weight with shells) of Dreissena *at lower bay sites 9D (Conway) and 13F (Upper Gap).*

Survey	Site 9D (21-21.5m)		Site 13F(20-21m)	
	Density (m^{-2})	Biomass ($g.m^{-2}$)	Density (m^{-2})	Biomass ($g.m^{-2}$)
Jul. 1994	20	1	n.a.	n.a.
Jul. 1995	n.a.	n.a.	120	90
Aug. 1998	960	4	2,380	230
Oct. 2000	675	373	3,015	1,685

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Appendix A

Fish stocked in the Province of Ontario waters of Lake Ontario in 2001

Appendix A

Atlantic salmon stocked in the Province of Ontario waters of Lake Ontario, 2001.

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	11	2001	Partnership	LaHave/Normandale	0		None	12,000
	12	2001	Partnership	LaHave/Normandale	0		None	28,000
								40,000
				ATLANTIC SALMON - DELAYED FRY				
BRONTE CREEK								
Lowville Dam	5	2000	Partnership	LaHave/Normandale	2		None	**100**
CREDIT RIVER								
Above Belfountain	5	2000	Ringwood	LaHave/Normandale	4		None	42,758
Belfountain	3	2000	Partnership	LaHave/Normandale	1		None	3,720
Black Creek - Limehouse	5	2000	Ringwood	LaHave/Normandale	4		None	57,500
Credit - Belfountain	4	2000	Partnership	LaHave/Normandale	1		None	1,462
Snows Creek - Gorge	5	2000	Partnership	LaHave/Normandale	2		None	100
W Credit - Belfountain	4	2000	Partnership	LaHave/Normandale	1		None	750
W Credit - Belfountain	5	2000	Partnership	LaHave/Normandale	1		None	3,000
								109,290
				ATLANTIC SALMON - ADVANCED FRY				
CREDIT RIVER								
Below Belfountain	5	2000	Ringwood	LaHave/Normandale	5	1.0	None	20,000
Forks of the Credit	5	2000	Ringwood	LaHave/Normandale	5	1.0	None	47,743
Park Gate to Forks	5	2000	Ringwood	LaHave/Normandale	5	1.0	None	25,000
								92,743
ROUGE RIVER								
Parkview Hatchery	3	2000	Partnership	LaHave/Normandale	6		None	**2,436**
				ATLANTIC SALMON - ADULTS				
CREDIT RIVER								
Grange Sideroad	10	1996	Codrington	LaHave/Normandale	60	2324	Floy tag	9
	10	1995	Codrington	LaHave/Normandale	72	2520	Floy tag	71
								80
COBOURG BROOK								
Site #1	10	1995	Codrington	LaHave/Normandale	72	2520	Floy tag	10
Site #2	10	1996	Codrington	LaHave/Normandale	60	2324	Floy tag	2
	10	1995	Codrington	LaHave/Normandale	72	2520	Floy tag	16
Site #3	10	1996	Codrington	LaHave/Normandale	60	2324	Floy tag	3
	10	1995	Codrington	LaHave/Normandale	72	2520	Floy tag	15
Site #4	10	1995	Codrington	LaHave/Normandale	72	2520	Floy tag	14
								60
TOTAL - ATLANTIC SALMON EGGS								**40,000**
TOTAL - ATLANTIC SALMON DELAYED FRY								**109,390**
TOTAL - ATLANTIC SALMON ADVANCED FRY								**95,179**
TOTAL - ATLANTIC SALMON ADULTS								**140**
TOTAL - ATLANTIC SALMON								**244,709**

Brown trout stocked in the Province of Ontario waters of Lake Ontario, 2001.

SITE NAME	MONTH STOCKED	YEAR SPAWNED	HATCHERY/ SOURCE	STRAIN/ EGG SOURCE	AGE (MO.)	MEAN WT (G)	MARKS	NUMBER STOCKED
BROWN TROUT - FALL FINGERLINGS								
CREDIT RIVER								
Norval	10	2000	Partnership	Wild - Credit R.	9		None	**1,400**
BROWN TROUT - SPRING YEARLINGS								
BRONTE CREEK								
Bronte Beach Park	3	1999	Normandale	Ganaraska/Normandale	16	54.9	RV	**15,049**
DUFFIN CREEK								
401 Bridge	4	1999	Harwood	Ganaraska/Normandale	18	63.0	RV	**10,785**
LAKE ONTARIO								
Ashbridge's Bay Ramp	3	1999	Harwood	Ganaraska/Normandale	17	47.0	RV	6,067
	4	1999	Harwood	Ganaraska/Normandale	18	64.0	RV	9,399
Bluffer's Park	3	1999	Harwood	Ganaraska/Normandale	17	49.0	RV	6,087
	4	1999	Harwood	Ganaraska/Normandale	18	63.0	RV	9,089
Burlington Canal	3	1999	Normandale	Ganaraska/Normandale	16	50.9	RV	15,011
Fifty Point CA	3	1999	Normandale	Ganaraska/Normandale	16	54.7	RV	15,008
Jordan Harbour	3	1999	Normandale	Ganaraska/Normandale	16	53.3	RV	16,340
Lakefront Promenade	3	1999	Normandale	Ganaraska/Normandale	16	60.0	RV	10,078
Lakeport	4	1999	Harwood	Ganaraska/Normandale	18	59.0	RV	11,122
Millhaven Wharf	3	1999	Harwood	Ganaraska/Normandale	17	51.0	RV	11,999
	4	1999	Harwood	Ganaraska/Normandale	18	63.0	RV	8,237
Oshawa Harbour	4	1999	Harwood	Ganaraska/Normandale	18	64.0	RV	10,338
Port Dalhousie East	3	1999	Normandale	Ganaraska/Normandale	16	51.1	RV	17,731
								146,506
TOTAL - BROWN TROUT FALL FINGERLINGS								**1,400**
TOTAL - BROWN TROUT SPRING YEARLINGS								**172,340**
TOTAL - BROWN TROUT								**173,740**

Appendix A

Chinook salmon stocked in the Province of Ontario waters of Lake Ontario, 2001.

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	2000	Ringwood	Wild - Credit R.	5	4.0	None	**25,304**
BRONTE CREEK								
2nd Side Rd Bridge	4	2000	Ringwood	Wild - Credit R.	5	4.0	None	25,398
5th Side Rd Bridge	4	2000	Ringwood	Wild - Credit R.	5	4.0	None	25,398
								50,796
COBOURG BROOK								
South of King St	4	2000	Partnership	Wild - Credit R.	5	3.0	AdRV	1,000
	4	2000	Ringwood	Wild - Credit R.	5	4.0	None	15,327
								16,327
CREDIT RIVER								
Eldorado Park	4	2000	Ringwood	Wild - Credit R.	5	4.0	None	33,846
Huttonville	4	2000	Ringwood	Wild - Credit R.	5	4.0	None	33,854
Norval	4	2000	Ringwood	Wild - Credit R.	5	4.0	None	33,862
								101,562
LAKE ONTARIO								
Ashbridge's Bay Ramp	4	2000	Ringwood	Wild - Credit R.	5	3.0	None	25,392
Bluffer's Park	4	2000	Ringwood	Wild - Credit R.	5	4.0	None	50,747
Burlington Canal	4	2000	Ringwood	Wild - Credit R.	5	4.0	None	50,748
Consecon	5	2000	Ringwood	Wild - Credit R.	6	4.0	None	25,635
Jordan Harbour	4	2000	Ringwood	Wild - Credit R.	5	3.0	None	25,392
Oshawa Harbour	4	2000	Ringwood	Wild - Credit R.	5	4.0	None	25,392
Port Dalhousie East	4	2000	Ringwood	Wild - Credit R.	5	4.0	None	101,588
Wellington Channel	5	2000	Ringwood	Wild - Credit R.	6	4.0	None	25,634
Whitby Harbour	4	2000	Ringwood	Wild - Credit R.	5	4.0	None	25,392
								355,920
			CHINOOK - FALL YEARLINGS					
ROUGE RIVER								
Parkview Hatchery	10	2000	Partnership	Wild - Credit R.	12		None	**5,000**
TOTAL - CHINOOK SPRING FINGERLINGS								**549,909**
TOTAL - CHINOOK FALL YEARLINGS								**5,000**
TOTAL - CHINOOK SALMON								**554,909**

Coho salmon stocked in the Province of Ontario waters of Lake Ontario, 2001.

SITE NAME	MONTH STOCKED	YEAR SPAWNED	HATCHERY/ SOURCE	STRAIN/ EGG SOURCE	AGE (MO.)	MEAN WT (G)	MARKS	NUMBER STOCKED
				COHO - FALL FINGERLINGS				
CREDIT RIVER								
Eldorado Park	10	2000	Ringwood	Wild - Salmon R.	10	20.0	AdRV	17,618
	11	2000	Ringwood	Wild - Salmon R.	11	19.0	AdRV	4,884
Huttonville	10	2000	Ringwood	Wild - Salmon R.	10	20.0	AdRV	17,264
	11	2000	Ringwood	Wild - Salmon R.	11	19.0	AdRV	5,238
Norval	10	2000	Ringwood	Wild - Salmon R.	10	18.0	AdRV	19,189
	11	2000	Ringwood	Wild - Salmon R.	11	19.0	AdRV	3,213
								67,406
				COHO - SPRING YEARLINGS				
CREDIT RIVER								
Eldorado Park	3	1999	Ringwood	Wild - Blue Jay Cr.	14	21.5	Ad	32,218
Huttonville	3	1999	Ringwood	Wild - Blue Jay Cr.	14	21.5	Ad	4,879
	3	1999	Ringwood	Wild - Root R.	15	21.5	LV	27,348
Norval	2	1999	Ringwood	Wild - Blue Jay Cr.	13	18.0	Ad	18,665
	2	1999	Ringwood	Wild - Root R.	14	20.0	LV	13,716
								96,826
TOTAL - COHO FALL FINGLERINGS								**67,406**
TOTAL - COHO SPRING YEARLINGS								**96,826**
TOTAL - COHO SALMON								**164,232**

Appendix A

Lake trout stocked in the Province of Ontario waters of Lake Ontario, 2001.

SITE NAME	MONTH STOCKED	YEAR SPAWNED	HATCHERY/ SOURCE	STRAIN/ EGG SOURCE	AGE (MO.)	MEAN WT (G)	MARKS	NUMBER STOCKED
				LAKE TROUT - SPRING YEARLINGS				
LAKE ONTARIO								
Fifty Point CA	3	1999	Harwood	Seneca Lake/Harwood	15	33.2	AdRP	30,219
	3	1999	Harwood	Slate Islands/Dorion	16	22.7	AdRP	33,377
Cobourg Harbour Pier	3	1999	Harwood	Slate Islands/Dorion	16	25.0	AdRP	33,181
N of Main Duck Sill	4	1999	Harwood	Michipicoten Island/Dorion	18	40.4	AdRP	19,820
	5	1999	Harwood	Michipicoten Island/Dorion	19	42.0	AdRP	626
	4	1999	Harwood	Mishibishu Lakes/Tarentorus	17	34.1	AdRP	20,676
	4	1999	White Lake	Seneca Lake/Harwood	15	21.0	AdRP	34,351
	5	1999	Harwood	Seneca Lake/Harwood	17	36.9	AdRP	26,732
Pigeon Island	4	1999	Harwood	Seneca Lake/Harwood	16	43.0	AdRP	11,605
S of Long Point	4	1999	Harwood	Michipicoten Island/Dorion	18	38.7	AdRP	20,396
	4	1999	Harwood	Mishibishu Lakes/Tarentorus	17	32.0	AdRP	20,602
	4	1999	White Lake	Seneca Lake/Harwood	15	21.0	AdRP	25,339
	4	1999	Harwood	Seneca Lake/Harwood	16	39.0	AdRP	26,902
	5	1999	Harwood	Seneca Lake/Harwood	17	35.3	AdRP	28,605
Scotch Bonnet Shoal	5	1999	Harwood	Michipicoten Island/Dorion	19	42.4	AdRP	22,422
	5	1999	Harwood	Mishibishu Lakes/Tarentorus	17	33.1	AdRP	18,401
	5	1999	Harwood	Seneca Lake/Harwood	17	37.5	AdRP	80,993
TOTAL - LAKE TROUT								**454,247**

Appendix A

Rainbow trout stocked in the Province of Ontario waters of Lake Ontario, 2001.

SITE NAME	MONTH STOCKED	YEAR SPAWNED	HATCHERY/ SOURCE	STRAIN/ EGG SOURCE	AGE (MO.)	MEAN WT (G)	MARKS	NUMBER STOCKED
				RAINBOW TROUT - FRY				
CREDIT RIVER								
Black Cr - Stewarttown	7	2001	Partnership	Wild - Credit R.	1		None	3,500
Papermill Dam	6	2001	Partnership	Wild - Credit R.	1		None	100,000
Silver Cr - Meadowview	7	2001	Partnership	Wild - Credit R.	1		None	10,000
Silver Creek	7	2001	Partnership	Wild - Credit R.	1		None	52,000
								165,500
OSHAWA CREEK								
Central W Collegiate	6	2001	Partnership	Wild - Oshawa Cr.	1		None	500
Oshawa Golf Course	6	2001	Partnership	Wild - Oshawa Cr.	1		None	500
								1,000
				RAINBOW TROUT - FALL FINGERLINGS				
CREDIT RIVER								
Black Cr - Stewarttown	9	2001	Partnership	Wild - Credit R.	4		None	7,500
Silver Creek	9	2001	Partnership	Wild - Credit R.	4		None	1,000
								8,500
LAKE ONTARIO								
Glenora	10	2001	Partnership	Ganaraska/Normandale	5	3.0	None	**1,975**
ROUGE RIVER								
Berczy Creek		2001	Partnership	Wild - Rouge R.	6		None	6,438
Little Rouge River	10	2001	Partnership	Wild - Rouge R.	6		None	14,564
								21,002
				RAINBOW TROUT - SPRING YEARLINGS				
BRONTE CREEK								
5th Side Rd Bridge	5	2000	Normandale	Ganaraska/Normandale	14	18.0	AdRV	6,267
Lowville Park	5	2000	Normandale	Ganaraska/Normandale	14	18.0	AdRV	6,267
								12,534
CREDIT RIVER								
Huttonville	4	2000	Normandale	Ganaraska/Normandale	13	20.7	AdRV	10,046
Norval	4	2000	Normandale	Ganaraska/Normandale	13	21.0	AdRV	10,022
								20,068
HUMBER RIVER								
E B Rutherford	4	2000	Normandale	Ganaraska/Normandale	13	20.0	AdRV	10,008
King Vaughan Line	5	2000	Normandale	Ganaraska/Normandale	14	18.8	AdRV	3,419
								13,427
LAKE ONTARIO								
Glenora	4	1999	White Lake	Ganaraska/Normandale	12	20.0	AdRP	12,200
Jordan Harbour	4	2000	Normandale	Ganaraska/Normandale	13	17.0	AdRV	10,997
Long Pt - P.E. Bay	4	2000	White Lake	Ganaraska/Normandale	12	20.0	AdRP	5,000
Millhaven Wharf	4	1999	White Lake	Ganaraska/Normandale	12	20.0	AdRP	5,000
Port Dalhousie East	5	2000	Normandale	Ganaraska/Normandale	14	18.4	AdRV	12,483
								45,680
ROUGE RIVER								
Berczy Creek	5	2000	Normandale	Ganaraska/Normandale	14	21.0	AdRV	6,710
Bruce Creek	5	2000	Normandale	Ganaraska/Normandale	14	20.0	AdRV	6,670
Silver Spring Farms	5	2000	Normandale	Ganaraska/Normandale	14	21.0	AdRV	6,710
								20,090
TOTAL - RAINBOW TROUT FRY								**166,500**
TOTAL - RAINBOW TROUT FALL FINGERLINGS								**31,477**
TOTAL - RAINBOW TROUT SPRING YEARLINGS								**111,799**
TOTAL - RAINBOW TROUT								**309,776**

Appendix A

Walleye stocked in the Province of Ontario waters of Lake Ontario, 2001.

SITE NAME	MONTH STOCKED	YEAR SPAWNED	HATCHERY/ SOURCE	STRAIN/ EGG SOURCE	AGE (MO.)	MEAN WT (G)	MARKS	NUMBER STOCKED
				WALLEYE - FRY				
ST. LAWRENCE RIVER								
Gananoque River	5	2001	Partnership	Wild - Hoople Cr.	1		None	8,000
	5	2001	Partnership	Wild - Napanee R.	1		None	7,000
								15,000
				WALLEYE - FINGERLINGS				
HUMBER RIVER								
Hwy #7	7	2001	Partnership	Wild - Bay of Quinte	2		None	29,488
	8	2001	Partnership	Wild - Bay of Quinte	2		None	5,000
Pine Park	7	2001	Partnership	Wild - Bay of Quinte	2		None	39,784
								74,272
TOTAL - WALLEYE FRY								**15,000**
TOTAL - WALLEYE FINGERLINGS								**74,272**
TOTAL - WALLEYE								**89,272**

Appendix B

Catches in the index netting program in eastern Lake Ontario and the Bay of Quinte in 2001

Appendix B

Species-specific catch-per-standard-gillnet lift, Northeast Lake Ontario, 2001.

Species/Site Depth (m)	Brighton					Middle Ground	Wellington				
	08	13	18	23	28	05	08	13	18	23	28
Alewife	16.3	400.0	16.3	601.1	597.3	5.4	16.3	38.0	182.6	410.9	38.0
Black crappie	-	-	-	-	-	-	-	-	-	-	-
Bluegill	-	-	-	-	-	-	-	-	-	-	-
Brown bullhead	16.9	-	-	-	-	13.2	1.6	-	-	-	-
Brown trout	-	-	-	-	-	-	1.6	-	1.6	1.6	-
Burbot	-	-	-	-	1.6	-	-	-	-	1.6	1.6
Channel catfish	-	-	-	-	-	-	-	-	-	-	-
Chinook salmon	-	-	-	-	3.3	-	-	-	1.6	1.6	-
Common carp	-	-	-	-	-	3.3	-	-	-	-	-
Coregonus sp.	-	-	-	-	-	-	-	-	-	-	-
Freshwater drum	-	-	-	-	-	-	-	-	-	-	-
Gizzard shad	-	-	-	-	-	-	-	-	-	-	-
Lake chub	-	-	-	-	-	-	-	-	-	-	-
Lake herring	-	-	-	-	-	-	-	-	-	-	-
Lake sturgeon	-	-	-	-	-	-	-	-	-	-	-
Lake trout	-	1.6	3.3	18.1	19.7	-	-	3.3	14.8	13.2	47.7
Lake whitefish	-	-	-	-	1.6	-	-	-	-	1.6	1.6
Longnose gar	-	-	-	-	-	-	-	-	-	-	-
Moxostoma sp.	-	-	-	-	-	-	-	-	-	-	-
Northern pike	-	-	-	-	-	-	-	-	-	-	-
Pumpkinseed	-	-	-	-	-	-	-	-	-	-	-
Rainbow smelt	-	-	-	-	-	-	-	-	-	-	-
Rock bass	-	-	-	-	-	7.1	-	5.4	-	-	-
Slimy sculpin	-	-	-	-	-	-	-	-	-	-	-
Smallmouth bass	-	-	-	-	-	-	-	-	-	-	-
Stonecat	-	-	-	-	-	-	-	-	-	-	-
Walleye	-	-	-	-	-	1.6	-	-	-	-	-
White perch	-	-	-	-	-	-	-	-	-	-	-
White sucker	-	-	-	-	-	9.9	-	-	-	-	-
Yellow perch	-	-	-	-	-	285.4	282.4	129.1	-	5.4	-

Species-specific catch-per-standard-gillnet lift, Northeast Lake Ontario, 2001 (continued).

Species/Site Depth (m)	Rocky Point								
	08	13	18	23	28	40	60	80	100
Alewife	43.5	577.2	329.4	1,488.3	1,029.2	46.1	167.8	31.3	77.3
Black crappie	-	-	-	-	-	-	-	-	-
Bluegill	-	-	-	-	-	-	-	-	-
Brown bullhead	-	-	-	-	-	-	-	-	-
Brown trout	-	-	-	-	-	-	-	-	-
Burbot	-	-	-	1.6	3.3	-	-	-	-
Channel catfish	-	-	-	-	-	-	-	-	-
Chinook salmon	-	-	-	-	-	-	-	-	-
Common carp	-	-	-	-	-	-	-	-	-
Coregonus sp.	-	-	-	-	-	-	-	-	-
Freshwater drum	3.3	-	-	-	-	-	-	-	-
Gizzard shad	-	-	-	-	-	-	-	-	-
Lake chub	-	-	-	5.4	-	-	-	-	-
Lake herring	-	-	-	-	-	-	-	-	-
Lake sturgeon	-	-	-	-	-	-	-	-	-
Lake trout	-	-	1.6	30.1	23.0	4.9	108.6	42.8	23.0
Lake whitefish	-	-	-	-	1.6	-	-	-	3.3
Longnose gar	-	-	-	-	-	-	-	-	-
Moxostoma sp.	-	-	-	-	-	-	-	-	-
Northern pike	-	-	-	-	-	-	-	-	-
Pumpkinseed	-	-	-	-	-	-	-	-	-
Rainbow smelt	-	-	-	-	-	-	-	-	-
Rock bass	7.1	3.3	-	-	-	-	-	-	-
Slimy sculpin	-	-	-	-	-	-	-	-	1.6
Smallmouth bass	13.2	9.9	-	-	-	-	-	-	-
Stonecat	21.2	1.6	-	-	-	-	-	-	-
Walleye	-	-	-	-	-	-	-	-	-
White perch	-	-	-	-	-	-	-	-	-
White sucker	-	1.6	-	-	-	-	-	-	-
Yellow perch	-	-	-	-	-	-	-	-	-

Appendix B

Species-specific catch-per-standard-gillnet lift, Outlet Basin Lake Ontario, 2001.

Species/Site Depth (m)	Outlet Basin		Flatt Point				
	30 (02)	30 (06)	08	13	18	23	28
Alewife	117.3	103.1	141.3	244.6	289.7	613.1	223.6
Black crappie	-	-	-	-	-	-	-
Bluegill	-	-	-	-	-	-	-
Brown bullhead	-	-	-	-	-	-	-
Brown trout	0.5	-	-	-	1.6	1.6	-
Burbot	0.5	1.1	-	-	3.3	-	-
Channel catfish	-	-	-	-	-	-	-
Chinook salmon	1.6	-	-	-	-	-	-
Common carp	-	-	-	-	-	-	-
Coregonus sp.	-	-	-	-	-	-	1.6
Freshwater drum	-	-	-	-	-	-	-
Gizzard shad	-	-	-	-	-	-	-
Lake chub	-	-	-	-	-	-	-
Lake herring	-	-	-	-	-	-	-
Lake sturgeon	-	-	-	-	-	-	-
Lake trout	10.4	10.4	1.6	3.3	13.2	28.0	35.0
Lake whitefish	1.6	3.8	-	-	1.6	93.8	55.9
Longnose gar	-	-	-	-	-	-	-
Moxostoma sp.	-	-	-	-	-	-	-
Northern pike	-	-	3.3	-	-	-	-
Pumpkinseed	-	-	-	-	-	-	-
Rainbow smelt	-	-	-	-	-	-	-
Rock bass	-	-	15.8	1.6	-	-	-
Slimy sculpin	-	-	-	-	-	-	-
Smallmouth bass	-	-	-	-	-	-	-
Stonecat	-	-	1.6	-	-	-	-
Walleye	-	-	-	-	-	-	-
White perch	-	-	-	-	-	-	-
White sucker	-	-	9.9	4.9	-	-	-
Yellow perch	-	-	140.7	20.2	11.5	-	-

Species-specific catch-per-standard-gillnet lift, Outlet Basin Lake Ontario, 2001 (continued).

Species/Site	Grape Island					Melville Shoal				
Depth (m)	08	13	18	23	28	08	13	18	23	28
Alewife	168.0	670.1	1,132.2	1,375.1	1,757.7	72.3	125.0	311.4	276.7	557.6
Black crappie	-	-	-	-	-	-	-	-	-	-
Bluegill	-	-	-	-	-	-	-	-	-	-
Brown bullhead	-	-	-	-	-	-	-	-	-	-
Brown trout	-	-	-	-	-	-	-	-	-	-
Burbot	-	-	-	-	-	-	-	-	-	-
Channel catfish	-	-	-	-	-	-	-	-	-	-
Chinook salmon	-	-	-	-	-	-	-	-	-	-
Common carp	-	-	-	-	-	-	-	-	-	-
Coregonus sp.	-	-	-	-	-	-	-	-	-	-
Freshwater drum	-	1.6	-	-	-	1.6	-	-	-	-
Gizzard shad	-	-	-	-	-	-	-	-	-	-
Lake chub	-	-	-	-	-	-	-	-	-	-
Lake herring	-	-	-	-	-	-	-	-	-	-
Lake sturgeon	-	1.6	-	-	-	-	-	-	-	-
Lake trout	-	-	-	-	9.9	-	-	-	-	3.3
Lake whitefish	-	-	-	3.3	3.3	-	-	-	-	3.3
Longnose gar	-	-	-	-	-	-	-	-	-	-
Moxostoma sp.	-	-	-	-	-	-	-	-	-	-
Northern pike	-	-	-	-	-	1.6	1.6	-	-	-
Pumpkinseed	-	-	-	-	-	-	-	-	5.4	-
Rainbow smelt	-	-	-	-	-	-	-	-	-	-
Rock bass	14.2	12.0	7.1	-	-	12.5	31.6	4.9	16.3	-
Slimy sculpin	-	-	-	-	-	-	-	-	-	-
Smallmouth bass	3.3	-	1.6	-	-	-	10.4	1.6	1.6	-
Stonecat	-	-	-	-	-	10.9	-	-	-	-
Walleye	8.2	4.9	3.3	-	-	91.5	42.8	4.9	13.2	-
White perch	-	-	-	-	-	-	-	-	-	-
White sucker	-	-	-	-	-	-	-	-	-	1.6
Yellow perch	16.3	37.0	59.9	3.3	-	-	245.1	59.4	109.1	-

Appendix B

Species-specific catch-per-standard-gillnet lift, Bay of Quinte, Lake Ontario, 2001.

Species/Site Depth (m)	Big Bay	Hay Bay		Conway				
	05	08	13	08	13	20	30	45
Alewife	-	184.2	69.1	1.6	177.6	88.8	3.3	-
Black crappie	1.6	-	-	-	-	-	-	-
Bluegill	46.9	-	-	-	-	-	-	-
Brown bullhead	44.4	11.5	-	1.6	-	-	-	-
Brown trout	-	-	-	-	-	3.3	-	-
Burbot	-	-	-	-	-	-	-	-
Channel catfish	-	-	-	-	1.6	-	-	-
Chinook salmon	-	-	-	-	-	1.6	-	-
Common carp	-	-	-	-	-	-	-	-
Coregonus sp.	-	-	-	-	-	-	-	-
Freshwater drum	139.8	3.3	-	1.6	-	-	-	-
Gizzard shad	14.0	-	-	-	-	-	-	-
Lake chub	-	-	-	-	-	-	-	-
Lake herring	-	6.6	6.6	-	-	4.9	1.6	-
Lake sturgeon	-	-	-	-	-	-	-	-
Lake trout	-	-	-	-	-	-	18.1	6.6
Lake whitefish	-	-	1.6	-	-	6.6	8.2	-
Longnose gar	6.6	-	-	1.6	-	-	-	-
Moxostoma sp.	0.8	-	-	-	-	-	-	-
Northern pike	0.8	8.2	3.3	1.6	-	-	-	-
Pumpkinseed	111.8	14.8	-	1.6	-	-	-	-
Rainbow smelt	-	-	-	-	-	1.6	1.6	3.3
Rock bass	-	-	-	11.5	3.3	-	-	-
Slimy sculpin	-	-	-	-	-	-	-	-
Smallmouth bass	3.3	1.6	-	1.6	-	-	-	-
Stonecat	-	-	-	-	-	1.6	-	-
Walleye	29.6	29.6	3.3	18.1	11.5	3.3	-	-
White perch	144.7	6.6	-	-	-	-	-	-
White sucker	23.0	34.5	39.5	21.4	26.3	57.6	3.3	-
Yellow perch	1,254.1	1,131.6	764.8	738.5	824.0	544.4	47.7	-

Species-specific catch-per-trawl, Lake Ontario and Bay of Quinte, 2001.

	Eastern Basin			Rocky Point	Bay of Quinte					
Species/Site	EB02	EB03	EB06	RP01	Trenton	Belleville	Big Bay	Deseronto	Hay Bay	Conway
Alewife	204.5	57.4	5.6	5.5	149.3	0.3	-	180.1	566.2	-
American eel	-	-	-	-	-	-	0.1	-	-	-
Black crappie	-	-	-	-	0.1	0.4	0.6	0.1	-	-
Bluegill	-	-	-	-	1.1	0.3	124.9	0.5	-	-
Brown bullhead	-	-	-	-	10.6	32.0	16.4	69.3	32.8	-
Burbot	-	-	-	-	0.1	-	-	-	-	-
Common carp	-	-	-	-	-	0.1	0.3	-	0.3	-
Freshwater drum	-	-	-	-	6.8	163.8	21.8	16.5	4.4	0.1
Gizzard shad	-	-	-	-	4.1	99.2	-	32.0	2.6	-
Lake chub	-	-	-	-	-	-	-	0.1	-	-
Lake herring	-	-	-	-	-	-	-	-	1.0	-
Lake trout	-	-	0.1	1.0	-	-	-	-	-	-
Lake whitefish	0.2	-	-	-	-	-	-	-	-	1.0
Largemouth bass	-	-	-	-	2.4	0.1	-	-	0.3	-
Moxostoma sp.	-	-	-	-	-	-	-	-	-	0.1
Pumpkinseed	-	-	-	-	84.8	21.8	83.8	118.1	19.6	-
Rainbow smelt	29.7	18.1	21.4	165.7	-	-	-	-	-	-
Rock bass	-	-	-	-	0.6	-	-	0.1	-	-
Slimy sculpin	0.4	-	0.1	2.5	-	-	-	-	-	-
Smallmouth bass	-	-	-	-	0.4	0.1	0.1	0.5	-	-
Walleye	-	-	-	-	9.6	5.4	7.5	12.5	7.1	1.3
White bass	-	-	-	-	-	0.1	-	-	-	-
White perch	-	-	-	-	54.3	6.6	18.3	10.3	9.3	-
White sucker	-	-	-	-	0.5	0.4	0.8	0.6	3.5	134.8
Yellow perch	-	-	-	-	200.7	37.9	381.1	413.0	726.6	134.7
Spottail shiner	-	-	-	-	217.4	10.6	12.1	25.3	63.5	0.6
Ictalurus sp.	-	-	-	-	-	-	0.4	-	-	-
Three-spine stickleback	18.8	67.4	2.6	-	-	-	-	-	-	-
Trout-perch	0.3	170.7	-	-	0.5	13.0	1.4	4.8	5.8	139.4
Sunfish Family	-	-	-	-	33.3	48.1	50.0	0.4	-	-
Johnny darter	-	-	-	-	2.5	12.5	1.3	0.6	-	-
Logperch	-	-	-	-	2.0	0.3	0.1	1.0	0.3	-
Round goby	-	-	-	-	-	-	-	1.3	0.1	-

Appendix C

Catches in the index netting program in the Thousand Islands area of the St. Lawrence River in 2001

Appendix C

Species-specific catch-per-standard-gillnet lift, Thousand Islands area, St. Lawrence River 1987 to 2001. All catches prior to 2001 have been adjusted by a factor of 1.58 to be comparable to the new netting standard used in 2001.

	1987	1989	1989	1991	1993	1995	1997	1999	2001
Lake Sturgeon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
Longnose gar	0.00	0.00	0.00	0.03	0.00	0.00	0.03	0.00	0.00
Bowfin	0.08	0.13	0.09	0.00	0.06	0.03	0.07	0.00	0.02
Alewife	0.49	0.00	0.00	0.09	0.03	0.03	0.00	0.00	0.00
Gizzard shad	0.00	0.41	0.36	0.46	0.00	0.00	0.00	0.03	0.06
Chinook salmon	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.03	0.02
Brown trout	0.00	0.05	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Rainbow trout	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00
Lake trout	0.00	0.13	0.16	0.00	0.16	0.13	0.13	0.00	0.00
Lake herring	0.00	0.00	0.03	0.00	0.00	0.06	0.00	0.00	0.00
Northern pike	4.46	6.73	6.26	4.35	3.62	2.61	2.40	2.14	1.33
Muskellunge	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.02
Esocidae hybrids	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00
Mooneye	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
White sucker	1.09	2.10	2.04	1.39	1.49	1.37	1.25	1.78	0.75
Moxostoma sp.	0.00	0.08	0.13	0.06	0.13	0.33	0.00	0.23	0.08
Common carp	0.05	0.13	0.09	0.09	0.03	0.09	0.36	0.13	0.08
Chub	0.00	0.05	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Golden shiner	0.05	0.05	0.03	0.00	0.06	0.03	0.00	0.03	0.00
Brown bullhead	2.56	1.79	1.79	2.46	1.06	0.95	1.91	3.85	3.00
Channel catfish	0.81	0.08	0.13	0.55	0.16	0.30	0.30	0.56	0.25
White perch	0.08	0.00	0.00	0.36	0.03	0.06	0.00	0.07	0.10
White bass	0.05	0.60	0.73	0.43	0.24	0.00	0.07	0.00	0.00
Rock bass	4.14	4.46	4.87	5.44	4.77	5.56	4.87	7.54	9.48
Pumpkinseed	4.61	6.19	5.80	5.81	3.89	2.80	2.40	3.23	1.40
Bluegill	0.65	0.88	0.76	0.43	0.06	0.00	0.16	0.07	0.02
Smallmouth bass	3.16	5.67	5.44	4.31	2.34	1.55	1.48	3.19	1.67
Largemouth bass	0.13	0.36	0.40	0.13	0.16	0.16	0.03	0.23	0.08
White crappie	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00
Black crappie	0.13	0.16	0.13	0.09	0.06	0.03	0.03	0.10	0.06
Yellow perch	27.79	17.62	17.02	15.41	16.23	22.67	21.33	22.22	18.06
Walleye	0.21	0.60	0.55	0.33	0.33	0.27	0.59	0.07	0.19
Freshwater drum	0.00	0.00	0.03	0.09	0.00	0.03	0.10	0.00	0.06
Total Catch	50.56	48.25	46.94	42.39	34.90	39.11	37.56	45.49	36.75