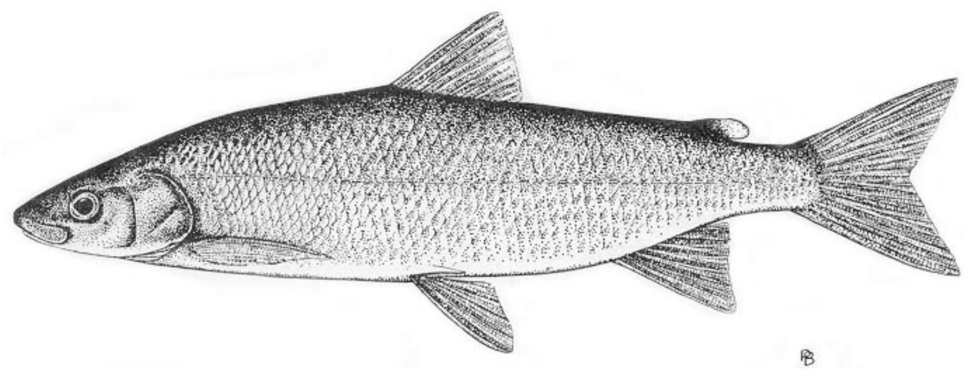
COSEWIC
Assessment and Update Status Report

on the

Lake Whitefish
Coregonus clupeaformis

in Canada

Lake Simcoe population



DATA DEFICIENT
2005

COSEWIC
COMMITTEE ON THE STATUS OF
ENDANGERED WILDLIFE
IN CANADA

COSEPAC
COMITÉ SUR LA SITUATION
DES ESPÈCES EN PÉRIL
AU CANADA

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

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Previous report:

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Lake whitefish — Illustration from Scott and Crossman (1973 [1998 reprint]) with permission of the authors.

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COSEWIC
Assessment Summary

Assessment Summary – May 2005

Common name
Lake Whitefish (Lake Simcoe population)

Scientific name
Coregonus clupeaformis

Status
Data Deficient

Reason for designation
Although this population is on its way to extirpation, there is inconclusive evidence regarding its distinctiveness and the best evidence available at this time is insufficient to resolve the species' eligibility for assessment.

Occurrence
Ontario

Status history
Designated Threatened in April 1987. Species considered in May 2005 and placed in the Data Deficient category. Last assessment based on an update status report.

COSEWIC
Executive Summary

Lake Whitefish

Coregonus clupeaformis

(Lake Simcoe population)

Species Information

Lake whitefish are elongate in form, the greatest body depth occurring at the front of dorsal fin. The mouth is inferior, being distinctly overhung by the snout. Overall colour is silvery and fins are usually clear or lightly pigmented in Great Lakes populations; the fins of more northerly populations are often darker and are usually black tipped. Scales are large and cycloid, numbering 70-97 in the lateral line. Breeding males develop nuptial tubercles on at least 3 rows of scales above the lateral line and on 6 rows below. Genetic, morphological and meristic differences suggest some difference from neighbouring populations; however, this evidence is inconclusive and does not support delineation of this population as a Designatable Unit.

Distribution

The lake whitefish is widely distributed throughout Canada and the northern United States. The Lake Simcoe population is a distinct stock found in Lake Simcoe, Ontario (44º25'N, 79º20'W). It has been separated from other whitefish stocks in the Great Lakes Basin for an estimated 7,000 to 10,000 years.

Habitat

In Lake Simcoe, adult lake whitefish are associated with the lake bottom and widely distributed throughout the lake, including the open basin, Cook Bay, and Kempenfelt Bay during the winter and spring. As water temperature increases in the late spring, Lake Simcoe lake whitefish move to the cool deep waters of the lake to depths of 20 to 40 m. Lake whitefish first move to spawning shoals in October and remain until early December. Lake whitefish spawn over shoals (1 to 3 m of depth) consisting of boulder, cobble and gravel.

Biology

Lake Simcoe lake whitefish abundance declined dramatically in the 1970s, largely as a result of recruitment failure. Annual stocking of lake whitefish began in 1982 and stocked fish now constitute the majority of the Lake Simcoe lake whitefish population.

However, wild lake whitefish continue to be present, three decades after recruitment problems began.

Lake whitefish diet shifts from a dominance of plankton to benthic organisms during their first summer. Adult lake whitefish are benthivores and their diet consists primarily of insect larvae, molluscs and amphipods.

Population Sizes and Trends

Generally, catches of Lake Simcoe lake whitefish were high during the 1960s and decreased sharply by the early 1970s. Since then, catch has remained relatively low compared to catches during the 1960s, but has increased somewhat as a result of the annual stocking of hatchery-reared fish. Wild lake whitefish continue to contribute to the recreational fisheries as well as to trap net catches on spawning shoals during the fall. However, catch rates of wild fish during the winter fishery have decreased since 1986, and catch has decreased during the fall index trap-netting program since 1992.

Currently, the Lake Simcoe lake whitefish population is made up largely of hatchery-reared fish along with a smaller population of wild fish. Catch rates of wild fish are extremely low compared with data from the 1960s. Evidence suggests that currently, the wild lake whitefish population is made up mostly of old individuals that were the result of successful recruitment in the 1960s. While it is possible that some successful natural recruitment to maturity still takes place, the magnitude of such events appears to be small and has little bearing on the size and age structure of the population.

Limiting Factors and Threats

The decline of lake whitefish, lake trout (*Salvelinus namaycush*) and cisco (*C. artedi*) has been attributed to nutrient loading and accelerated eutrophication and its impacts on spawning and hypolimnetic habitat in Lake Simcoe. More recently, declines in the abundance of burbot (*Lota lota*) have also been observed.

The introduction of exotic species may also have played a role in the Lake Simcoe lake whitefish population decline and could possibly affect their recovery. Rainbow smelt (*Osmerus mordax*) were first documented in Lake Simcoe in 1961 and by the early 1970s had become very well established. The timing of rainbow smelt expansion in the late 1960s coincides very closely with recruitment failure of lake whitefish. Zebra mussels (*Dreissena polymorpha*) and spiny waterflea (*Bythotrephes* sp.) were first observed in Lake Simcoe in 1992 and 1994, respectively. There is no evidence that these species have negatively affected growth or survival of hatchery-reared Lake Simcoe lake whitefish. However, the effect, if any, that these species would have on juvenile lake whitefish less than six months of age is unknown.

Special Significance of the Species

Along with other cold-water fish species in Lake Simcoe, the decline in lake whitefish abundance in the lake has indicated deteriorating habitat quality. As indicators of habitat quality, lake whitefish fulfill an important ecological role and should be protected. Successful rehabilitation of lake whitefish habitat could also result in rehabilitation of other cold-water species in Lake Simcoe.

The Lake Simcoe lake whitefish remains the species most targeted by recreational anglers. This fishery increases tourism to the area and provides an influx of money to the local economy, especially important to nearby communities in the winter. The lake whitefish fishery is also the only fishery accessible to the large human population of southern Ontario on a daily basis.

Existing Protection or Other Status Designations

The federal *Fisheries Act* serves as the primary legislation for the protection of fish and fish habitat in Canada.

To maintain the genetic strain of the Lake Simcoe lake whitefish, approximately 140,000 lake whitefish are stocked into Lake Simcoe annually. The status of the whitefish stock is monitored routinely by the Ontario Ministry of Natural Resources (OMNR) through the Lake Simcoe Fisheries Assessment Unit (LSFAU) programs.

The Lake Simcoe Environmental Strategy (LSEMS) was created to improve and protect the health of the Lake Simcoe watershed ecosystem and improve associated recreational opportunities by restoring a self-ustaining coldwater fishery, improving water quality, reducing phosphorus loads to Lake Simcoe and protecting natural heritage features and functions.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal agencies (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government members and the co-chairs of the species specialist and the Aboriginal Traditional Knowledge subcommittees. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(NOVEMBER 2004)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and it is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A wildlife species for which there is inadequate information to make a direct, or indirect, assessment of its risk of extinction.

* Formerly described as “Vulnerable” from 1990 to 1999, or “Rare” prior to 1990.
** Formerly described as “Not In Any Category”, or “No Designation Required.”
*** Formerly described as “Indeterminate” from 1994 to 1999 or “ISIBD” (insufficient scientific information on which to base a designation) prior to 1994.

Environment Canada — Environnement Canada
Canadian Wildlife Service — Service canadien de la faune

Canada

The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

Update
COSEWIC Status Report

on the

Lake Whitefish
Coregonus clupeaformis

in Canada

Lake Simcoe population

2005

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SPECIES INFORMATION

Classification

Class:	Actinopterygii
Order:	Salmoniformes
Family:	Salmonidae
Sub-family:	Coregoninae
Genus:	*Coregonus*
Scientific name:	*Coregonus clupeaformis* (Mitchell 1818)
Common name:	
English:	lake whitefish, Lake Simcoe population
Other names:	common whitefish, Sault whitefish, eastern whitefish, Great Lakes whitefish, humpback whitefish, inland whitefish and gizzard fish
French :	grand corégone, population du lac Simcoe

Description

Lake whitefish are elongate in form, the greatest body depth occurring at the front of the dorsal fin (Figure 1). The mouth is inferior, being distinctly overhung by the snout. Overall colour is silvery and fins are usually clear or lightly pigmented in Great Lakes populations; the fins of more northerly populations are often darker and are usually black tipped. Scales are large and cycloid, numbering 70-97 in the lateral line. Breeding males develop nuptial tubercles on at least 3 rows of scales above the lateral line and on 6 rows below (Scott and Crossman 1973). Lake Simcoe lake whitefish were found to have significant phenotypic and genetic differences compared to lake whitefish specimens from Lakes Huron, Ontario, Opeongo and Lavieille (Ihssen *et al*. 1981).

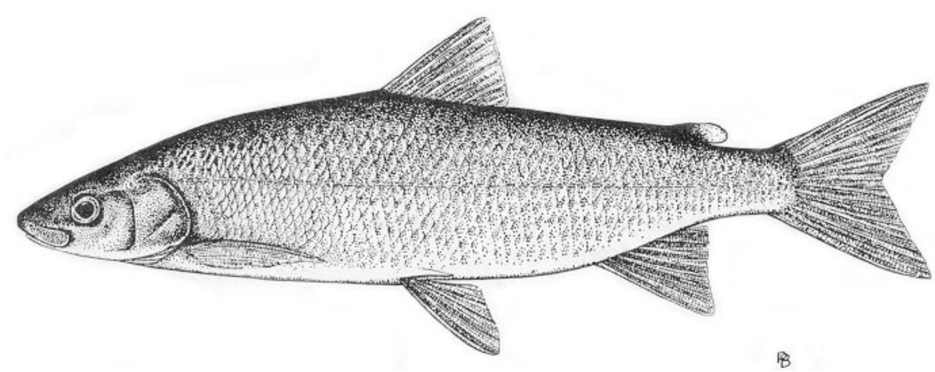

Figure 1. Lake whitefish (*Coregonus clupeaformis*). Illustration from Scott and Crossman (1973 [1998 reprint]) with permission of the authors. The specimen used for this sketch was a female collected from the Koksoak River, Quebec, July 1957.

Taxonomy

The lake whitefish has one of the broadest distributions (all of Canada excepting the Arctic archipelago) of any Canadian freshwater fish. At the species level there would be no consideration of risk; however, the species presents a confused taxonomic picture (*see* Scott and Crossman 1973) and assorted forms and morphs are variously suggested. Taxonomic relationships in coregonines have been difficult to resolve due to morphological plasticity, character convergence, and the effects of Pleistocene glaciations (Reist *et al*. 1998).

Electrophoresis has been used to study biochemical variation among allopatric and sympatric whitefish populations. Enzyme differences between lake whitefish in the Yukon and western Canada were demonstrated by Lindsey *et al*. (1970) and Franzin and Clayton (1977), indicating that these races were descended from fish that had survived glaciations in Beringian, and Mississippi-Missouri refugia. Foote *et al*. (1992) demonstrated the presence of a third Nahanni glacial refuge race in British Columbia and the Northwest Territories. Lindsey *et al*. (1970) had also postulated an Atlantic refugium based on present day distribution and morphological differentiation of fishes in the area of the Laurentian Great Lakes and the St. Lawrence River drainage. Bernatchez and Dodson (1990; 1991) examining mtDNA variation concluded that there were five glacial refuge races in North America. An Acadian race in lakes of New Brunswick, Nova Scotia, Maine and the Gaspé Peninsula descended from fish surviving glaciation in a Northeastern Banks refugium. The Atlantic race occurring in Maine and southern Quebec survived in an Atlantic glacial refugium. Although two Beringian races occur in the extreme northwest of the species range, the largest part of the current distribution including all of Ontario was colonized from a Mississippian refugium (Bernatchez and Dodson 1991). Allozyme evidence presented by Bodaly *et al*. (1992) is consistent with the conclusions of Bernatchez and Dodson (1991) based on mtDNA results, and they postulated the existence of at least four genetically and geographically definable races of lake whitefish: a Bering glacial refuge race in central and southern Yukon, a Mississippi-Missouri race occupying most of the central range, a Nahanni race in British Columbia and the southwest sector of the Northwest Territories, and an Acadian race occupying the Gaspé peninsula and the Maritimes. Bernatchez and Dodson (1994) suggested that the Atlantic race sould be included as a fifth race based on their earlier (Bernatchez and Dodson 1991) and subsequent work.

There is evidence to suggest that sympatric forms have diverged in morphological and life history traits such as gill raker counts, feeding traits, growth, age at maturity, and differences in place and timing of spawning, and that most are reproductively isolated (Kennedy 1943; Fenderson 1964; Bodaly 1979; Kirkpatrick and Selander 1979; Bruce 1984; Fortin and Gendron 1990; Bodaly *et al*. 1991). Bodaly *et al*. (1992) found no evidence of reproductive isolation where geographic races overlap, but they did find that historic, geographic, and environmental barriers have limited the mixing of alleles between races and sympatric pairs. This is not surprising since the study was designed to examine differences between, not within races; they postulated that geographic races have diverged, genetically, to a greater extent than sympatric populations, and that the amount of genetic divergence, as measured by allozyme frequencies is a poor predictor of reproductive isolation within races. Bernatchez and Dodson (1990) on the other hand, postulated that mtDNA data may indicate differences in forms within races, at least in sympatric forms in Maine, and Como Lake in Ontario.

The Lake Simcoe whitefish have been separated from nearby stocks in Georgian Bay for some 7000 to 10000 years by geographic and man-made barriers (Prest 1976; Bailey and Smith 1981). Ihssen *et al*. (1981) examined morphological, ecological, and electrophoretic variation among five allopatric populations of lake whitefish in Ontario (lakes Huron, Ontario, Simcoe, Opeongo and Lavielle) and found that the populations differed in terms of diet, growth rate, movement patterns, fecundity, egg size, larval size, morphological characters (number of gill rakers, number of pyloric ceca, size) and allele frequency differences. Some of the differences, especially those related to life history and ecological parameters may be explained by differences in environmental and ecological factors in the habitats of the five lakes, for example, water temperature, availability of food, nature of substrates, etc., whereas others may reflect local adaptation resulting in genetic differentiation. Allele frequency differences were found at 6 of 32 loci examined, and standard genetic distances between the populations correspond roughly to the order in which they are thought to have become isolated following the retreat of the glaciers (Ihssen *et al*. 1981).

Ihssen *et al*. (1981) caution that electrophoretic differences among stocks may not necessarily reflect recent local adaptation, but on the other hand speciation can occur with little electrophoretic differentiation as shown in sympatric stocks of lake whitefish in the Allegash Basin (Kirkpatrick and Selander 1979). Wilson *et al*. (1977) and Clayton (1981) argue that organismal and biochemical evolution are not coupled and that biological differentiation may involve only regulatory genes rather than the structural genes that have been studied with electrophoretic techniques. MtDNA analysis was not available at the time of these earlier studies and the argument here is similar to the differences discussed by Bodaly *et al*. (1992) regarding the differences in their electrophoretic results and the mtDNA results of Bernatchez and Dodson (1990, 1991, 1994).

Designatable units

The inference drawn from Ihssen *et al*. (1981) is that Lake Simcoe whitefish have been geographically isolated from nearby stocks for an adequate period of time for local adaptation to occur, and that genetic divergence has probably taken place as a result of adaptation to local conditions. Recognizing the perceived importance of genetic diversity and the evidence of local adaptation and uniqueness as presented by Ihssen *et al*. (1981), COSEWIC, in 1987, accepted the eligibility of the Lake Simcoe population of lake whitefish as a distinct stock and assigned a status of Threatened to the population (Evans *et al*. 1988).

Although there is little or no new information related specifically to distinctness of this population, the work of Bodaly *et al*. (1992) and Bernatchez and Dodson (1990, 1991, 1994) suggests that there may be a relationship between electrophoretic and mtDNA analysis and their respective usefulness in predicting genetic divergence and reproductive isolation. However, the inferences of Ihssen *et al*. (1981) may not be valid in that regard since they are probably not justified by their genetic data. Although significant differences were observed among the set of five populations examined, these differences were driven by the distinctiveness of the Opeongo population versus all others. Examination of the genetic distance estimates (Table 11 of Ihssen *et al*. 1981) shows that the Lake Simcoe population lies between but is not significantly different from either the Lake Huron or Lake Ontario populations. Thus, without further work to clarify the distinctness of this population the information at hand is not an adequate basis for identifying this population as a Designatable Unit under the current COSEWIC guidelines [Committee on the Status of Endangered Wildlife in Canada (COSEWIC) 2004].

DISTRIBUTION

The lake whitefish is widely distributed throughout Canada and the northern United States (Scott and Crossman 1973). The Lake Simcoe lake whitefish is a distinct stock found in Lake Simcoe, Ontario (44º25'N, 79º20'W). Lake Simcoe is the fifth largest inland lake in Ontario with a surface area of 725 km^2 and a perimeter of 231 km. The main basin of the lake including Kempenfelt Bay has a maximum depth of 41 m and is classified as mesotrophic while Cook Bay, with a maximum depth of 15 m, is considered eutrophic. Lake Simcoe is located less than 100 km north of Toronto and is part of the Trent-Severn waterway which connects Bay of Quinte on Lake Ontario to Georgian Bay of Lake Huron (Figure 2). Geographic barriers and a series of locks prevent migration of Lake Simcoe lake whitefish into lakes Huron and Ontario.

During the early 1980s, when population levels were low and recruitment problems continued to limit natural reproduction, Lake Simcoe lake whitefish were stocked into Upper Roslyn Lake (49º15'N, 87º29'W) in an attempt to maintain the genetic strain. The status of the population in Upper Roslyn Lake remains unknown and needs to be determined.

HABITAT

Habitat requirements

Generally, lake whitefish spend most of the year in deep water areas of lakes moving to shallower water in the early spring as well as during the fall (Scott and Crossman 1973). In Lake Simcoe, adult lake whitefish are associated with the lake bottom and widely distributed throughout the lake, including the open basin, Cook Bay, and Kempenfelt Bay during the winter and spring (MacCrimmon and Skobe 1970). As water temperature increases in the late spring, Lake Simcoe lake whitefish move to the cool deep waters of the lake to depths of 20 to 40 m.

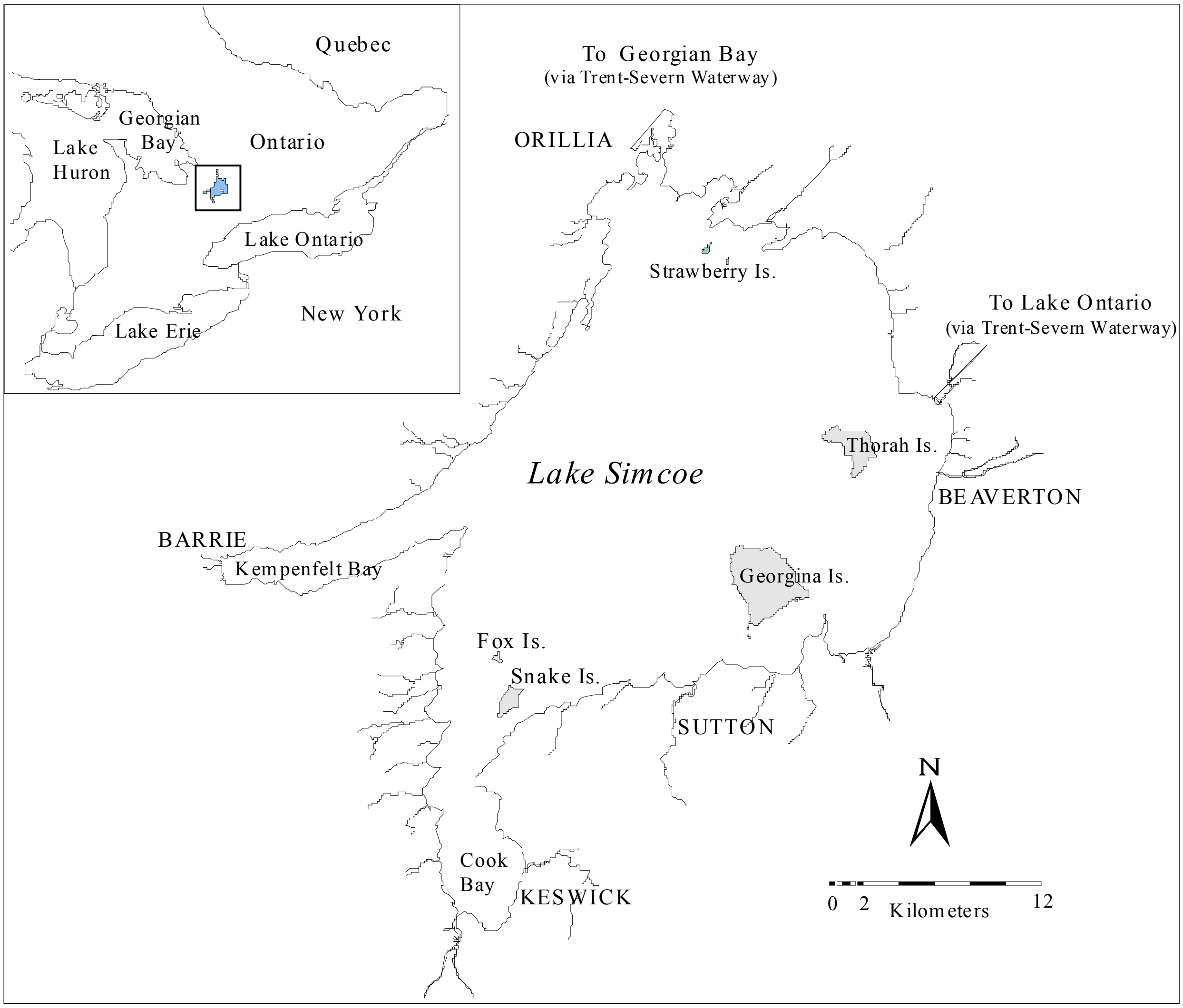

Figure 2. Lake Simcoe, including tributaries and selected urban centres.

Lake whitefish move into shallow waters during the fall to spawn, usually in November to December in the Great Lakes region and earlier farther north (Scott and Crossman 1973). In Lake Simcoe, lake whitefish first move to spawning shoals in October and remain until early December (Willox 1986; McMurtry 1989; Amtstaetter 1997). Lake whitefish spawn over shoals consisting of boulder, cobble and gravel. Eggs are deposited randomly and settle within the interstitial spaces of the shoals. Spawning takes place over a wide area of Lake Simcoe as indicated by the catch of lake whitefish during the fall on many known spawning shoals. Amtstaetter (1997) reported that ripe Lake Simcoe lake whitefish females were usually present on spawning shoals from mid- to late November at water temperatures ranging from 0.5 to 10°C and were captured in trap nets that were set in approximately 3 m of water.

Lake whitefish eggs hatch in April or May and young fish leave the shallow inshore waters by early summer and move to deeper water (Scott and Crossman 1973). Surface trawls on Lake Simcoe first captured larval lake whitefish when water temperature reached 4°C. Catch sharply declined once water temperature exceeded 9°C and very few fish were caught when temperature reached 14°C (DesJardine 1979). These fish were widely distributed both inshore and offshore over various depths up to 31 m (located 8 km from shore). Juvenile lake whitefish were caught by gillnets in Lake Simcoe, July 2002 at depths of 20-38 m, where temperatures were approximately 9-11°C.

Trends

The decline of lake whitefish has been attributed to nutrient loading and an accelerated eutrophication and its impacts on spawning and hypolimnetic habitat in Lake Simcoe (Evans 1978; Evans *et al*. 1988; Evans *et al*. 1996; McMurtry and Amtstaetter 1999). There has been a threefold increase in phosphorus (P) loading from pre-settlement rates which has affected water quality (Johnson and Nicholls 1989). Evans *et al*. (1996) reported that the volume-weighted temperature-corrected hypolimnetic dissolved oxygen concentration from August 30th to September 19th declined from approximately 4.5 mg/L in 1975 to 2.0 mg/L by 1993. Nicholls (2001) reported that recent analyses of long-term data indicated some improvements in Lake Simcoe water quality. It was noted that the volume-weighted deep-water oxygen depletion rate (normalized to 4°C) has been decreasing since the 1990s, in contrast to the increasing trend observed through the 1980s. However, it was cautioned that oxygen depletion rates are still high and that meeting interim objectives for end-of-summer dissolved oxygen under the Lake Simcoe Environmental Management Strategy (LSEMS) was unlikely.

Lake Simcoe lake whitefish reproduction relies upon the presence of suitable spawning shoal habitat for successful egg incubation and fry emergence. Although degradation of shoal spawning habitat has been noted as a potential factor in the recruitment failure of cold-water fish species in Lake Simcoe (Evans *et al*. 1988; McMurtry *et al*. 1997), the actual impact on the hatching success of lake whitefish in Lake Simcoe is unknown. It is unknown whether zebra mussels, introduced in the mid-1990s, have impacted Lake Simcoe's shoal spawning habitat.

Protection/ownership

Much of the Lake Simcoe shoreline is privately owned, consisting of year-round residences and summer cottages. There are also numerous marinas, three provincial parks (Sibbald Point, McRae and Mara) and two provincially protected areas: the Holland Marsh Provincial Wildlife Area and the Duclos Point Provincial Nature Reserve also border Lake Simcoe. However, parks and protected areas offer little in the way of direct protection of spawning habitat of Lake Whitefish.

BIOLOGY

Reproduction

Lake Simcoe lake whitefish abundance declined dramatically in the 1970s, largely as a result of recruitment failure. Annual stocking of Lake Simcoe strain lake whitefish began in 1982 and stocked fish now constitute the majority of the Lake Simcoe lake whitefish population. However, wild lake whitefish continue to be present, three decades after recruitment problems began. There are several possible explanations for the continued presence of wild lake whitefish including: some successful natural reproduction still takes place, hatchery reared fish being mistaken for wild fish, or the fish are extremely long-lived.

The age of wild lake whitefish is a key factor in determining whether successful natural reproduction has taken place during the past three decades. Unfortunately, the accuracy of scale age assessment can be very poor, particularly for older fish. There is a high degree of confidence in scale age assessment of hatchery-reared fish less than 7 years of age, when using fin clips to identify possible ages of the fish. All lake whitefish stocked into Lake Simcoe since 1982 have been fin clipped with one of nine possible fin clips or fin clip combinations. The proportion of wild fish assessed as less than 7 years of age in the catch on spawning shoals and during the winter fishery has generally been very low. There were several peaks indicating the potential for occasional successful year classes of wild fish (1976 and 1999 in fall index trap netting as well as 1982, 1987, 1990 and 1992 in the winter fishery). However, none of the peaks were observed in both the catch on spawning shoals and during the winter fishery or in successive years, suggesting that they may not be the result of sporadic successful recruitment of wild year classes.

Other evidence indicates that Lake Simcoe lake whitefish did reproduce naturally, even during times of recruitment problems. Larval lake whitefish were captured during larval surface trawling conducted from 1975 to 1981, indicating that viable gametes were deposited and were capable of incubating and hatching. Unfortunately, larval trawling records for Lake Simcoe do not exist prior to the decline of the lake whitefish population for comparative purposes.

Survey work conducted by the Lake Simcoe Fisheries Assessment Unit (LSFAU) in 2002 found that lake whitefish are still reproducing naturally in Lake Simcoe, although the magnitude or significance of these events is still unknown. Larval lake whitefish were captured in May 2002 during an equipment testing exercise by the LSFAU. In July 2002, 13 one-year-old and 1 three-year-old wild lake whitefish were captured in small mesh gillnets. It is unlikely that the 13 unclipped one-year-old specimens were unclipped hatchery-reared fish given the low incidence (0.9%) of observed clip error in the 2001 hatchery-reared year class.

Rainbow smelt, an exotic species first introduced to Lake Simcoe in 1961, has also been implicated as a factor contributing to recruitment failure of Lake Simcoe lake whitefish. Evans and Waring (1987) suspected that the decline in lake whitefish recruitment was probably caused by competition between young rainbow smelt and lake whitefish and predation by adult rainbow smelt on young lake whitefish, and that predation appeared to be of lesser importance. The role that rainbow smelt may have played in lake whitefish recruitment failure in Lake Simcoe remains unclear.

The catch of rainbow smelt during the winter fishery on Lake Simcoe has declined since 1989. By 1999, catch decreased to levels observed during the mid-1960s and has remained low since 2001. To date, a response in the success of lake whitefish recruitment has not been detected. However, LSFAU long-term monitoring programs did not capture juvenile fish and as a result, a lag time of several years exists between a potential change in the success of natural recruitment and observations of results. Preliminary survey work conducted in 2002 cannot be used to draw conclusions about the extent of natural reproduction because there are no comparable surveys during times of recruitment failure. Continued sampling over the next few years may provide insight into the possible interaction between rainbow smelt and lake whitefish. However, drawing firm conclusions will be difficult given the multitude of other changes Lake Simcoe has experienced (e.g., changes in nutrient loads, and the introduction of zebra mussels and spiny water flea).

Lake Simcoe lake whitefish begin to reach sexual maturity at approximately 4 to 5 years of age, full maturity being reached by 8+ years for both sexes (Evans *et al*. 1988). The relative fecundity of Lake Simcoe lake whitefish was estimated at 21,662 eggs/kg in 1966 (Semple 1968), 18,498 eggs/kg in 1977 (Evans 1978) and 25,425 eggs/kg in 2001.

Nutrition

Lake whitefish diet shifts from a dominance of plankton to benthic organisms during their first summer. Reckahn (1970) observed that major food items of young whitefish in South Bay, Lake Huron consisted of copepods in May, cladocerans in June and early July, dipteran larvae and ostracods in late July and August, ostracods and cladocerans in September and pelecypods and dipteran larvae in October and November.

Adult lake whitefish are benthivores and their diet consists primarily of insect larvae, molluscs and amphipods (Scott and Crossman 1973). The prominent food items found in adult Lake Simcoe lake whitefish during several diet investigations were molluscs and insect larvae (Rawson 1930; Burns 1985; Amstaetter 1999, 2000; Johanson 2001). The main difference between stomach contents from earlier studies and those conducted from 1999 to 2001 was the presence of zebra mussels and spiny water flea (*Bythotrephes* sp.). These species were introduced into Lake Simcoe in the early 1990s. Zebra mussels were the most dominant and spiny waterflea were the fourth most abundant prey item by weight during recent summer and spring diet investigations (Amtstaetter 1999, 2000; Johanson 2001). It is important to note that the weight of zebra mussels included the shell, which does not contribute energetically to fish diet (Pothoven *et al*. 2001). The weights of spiny waterflea included the spine which were found by Parker *et al*. (2001) to have slower evacuation rates than other prey items and as a result, overestimate predation rates. Although fish and fish remains in lake whitefish stomachs were relatively rare in number, they were one of the top three items when ranked by weight (Burns 1985; Amtstaetter 1999, 2000; Johanson 2001). Lake Simcoe lake whitefish also feed on items such as salted minnows, grain, sago and macaroni which are placed in the water by winter anglers attempting to attract fish (MacCrimmon and Skobe 1970; DesJardine and Lawrence 1977).

There is no evidence that food availability is limiting the abundance or growth of Lake Simcoe lake whitefish. The size of Lake Simcoe lake whitefish is much larger than historical values (Figure 3). Since the early 1960's, the mean weight and length of wild Lake Simcoe lake whitefish has increased by approximately 360% and 60% respectively. Possible explanations of the increase in size include an increase in the predominance of old individuals in the population and decreased intra-specific competition resulting in increased growth rate.

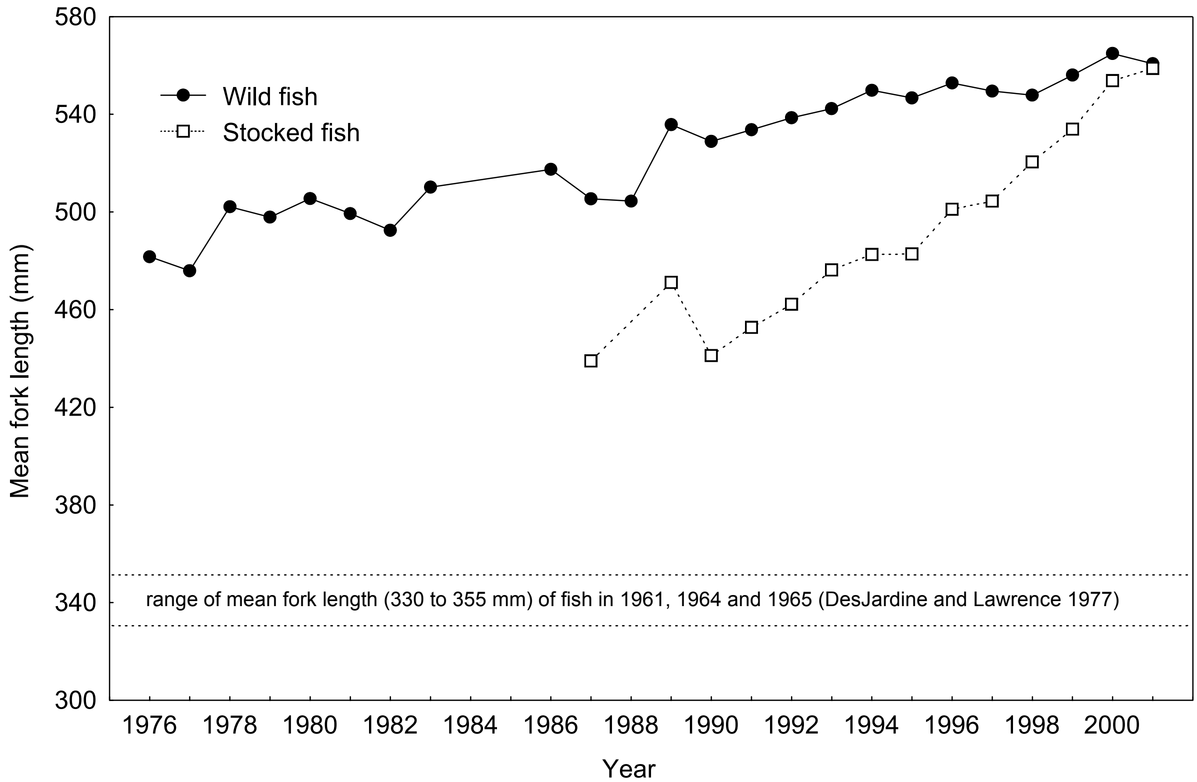

Figure 3. Mean fork length of Lake Simcoe lake whitefish captured during the winter fishery on Lake Simcoe, 1976 to 2001.

Fish health and contaminants

All Lake Simcoe lake whitefish used for egg collection purposes since 1981 have been screened for disease. Very few infections have been found (S. Lord, Fish Health Laboratory, University of Guelph, pers. comm.). One case of enteric redmouth disease was found in 1989. The causative agent of bacterial kidney disease has been found sporadically in Lake Simcoe lake whitefish and is considered by the Fish Health Laboratory to be endemic in the province. A harmless parasite (*Tetracotyle* sp.) has been found in the hearts of almost 100% of the lake whitefish screened.

Lake whitefish are collected by the LSFAU on an ongoing basis for analysis by the Ontario Ministry of the Environment (OMOE) as part of the provincial Sport Fish Contaminant Monitoring Program. Lake Simcoe lake whitefish are tested for mercury, PCBs, mirex/photomirex, pesticides, dioxins, and furans (Ontario Ministry of the Environment 2001). Results of contaminant sampling indicate that Lake Simcoe lake whitefish have always had very low contaminant levels.

Stocking history

Lake whitefish fry were stocked into Lake Simcoe periodically from 1888 to 1955. MacCrimmon and Skobe (1970) reported that lake whitefish stocked into Lake Simcoe as fry were, for many years, from Georgian Bay stock reared at the provincial fish hatchery in Collingwood. It is possible that fry of Georgian Bay origin that were released into Lake Simcoe survived to contribute to the spawning population, but the probability of such an event or the contribution that these fish have made to Lake Simcoe's lake whitefish population is unknown. Millar (1946), Dymond (1956), Christie (1963), MacCrimmon and Skobe (1970), Tuunainen (1982) and Salojärvi (1992b) suggested that planting fry in a lake with a naturally reproducing population does not have an affect on adult abundance.

In the early 1980s, lake whitefish recruitment failure had become evident and efforts to conserve the stock had become a major priority for the OMNR. Through the combined efforts of fish research and culture, the OMNR pioneered the development of rearing techniques that allowed the production of sufficient numbers of yearling whitefish to maintain a viable population.

In 1982, an intensive stocking program began where advanced life stages (yearling and fall fingerling) of Lake Simcoe lake whitefish were stocked into Lake Simcoe. From 1982 to 2002, 2,538,657 lake whitefish were stocked into Lake Simcoe (Table 1). To maintain the genetic strain, only fish captured in Lake Simcoe were used as parent stock since 1982. This stocking program was initiated as a rehabilitation action in response to the decline in lake whitefish abundance detected in the 1970s. The primary objective of the Lake Simcoe lake whitefish stocking program is to maintain the native stock until such time that natural reproduction can be restored while also maintaining a large recreational fishery for this species.

Table 1. History of Lake Whitefish stocking in Lake Simcoe.

Year	Fin clip	Age at stocking	Number stocked
2002	LVAD	FF	141,360
2001	RPAD	FF	150,524
2000	RV	FF	164,190
1999	RP	FF	188,068
1998	RVAD	FF	118,068
1997	AD	FF	144,210
1996	LV	FF	134,432
1995	LVAD	FF	79,301
1994	LPAD	FF	146,121
1993	RPAD	FF	143,319
1992	LP	FF	141,691
	RV	Y	60,480
1991	RP	FF	76,862
	RVAD	Y	63,067
1990	AD	FF	62,351
	LV	Y	73,620
1989	LPAD	FF	53,072
	LVAD	Y	87,789
1988	RPAD	FF	81,909
	RV	Y	95,349
1987	LP	FF	64,949
	LVAD	Y	99,699
1986	RP	FF	67,861
	RVAD	Y	29,971
1985	LV	Y	27,074
1984	AD	Y	15,388
1983	RV	Y	14,661
1982	LVAD	Y	13,192
1955		Fry	4,500,000
1954		Fry	5,000,000
1953		Fry	5,000,000
1950		Fry	1,000,000
1949		Fry	500,000
1944		Fry	1,000,000
1941		Fry	3,000,000
1940		Fry	1,500,000
1939		Fry	1,500,000
1938		Fry	2,500,000
1937		Fry	2,200,000
1936		Fry	34,000
1889		Fry	200,000
1888		Fry	200,000

Legend

AD	Adipose
LP	Left pectoral
LPAD	Left pectoral and Adipose
LV	Left pelvic (ventral)
LVAD	Left pelvic (ventral) and adipose
RP	Right pectoral
RPAD	Right pectoral and Adipose
RV	Right pelvic (ventral)
RVAD	Right pelvic (ventral) and adipose
FF	Fall fingerling
SY	Spring yearling

POPULATION SIZES AND TRENDS

Total catch of lake whitefish during their spawning run at two shoals in Lake Simcoe decreased from the late 1970s to the late 80s, then increased to 1991 (Figure 4). The increase in catch in the 1990s was largely the result of hatchery-reared fish, which have been planted in Lake Simcoe annually since 1982. It is interesting to note that when hatchery-reared lake whitefish began showing up on the spawning shoals in large numbers (1990 and 1991) that the catch of wild fish also increased. Since 1991, total catch has been variable and has not indicated any changing trend. However, the catch of wild fish has decreased while the catch of hatchery-reared fish has increased.

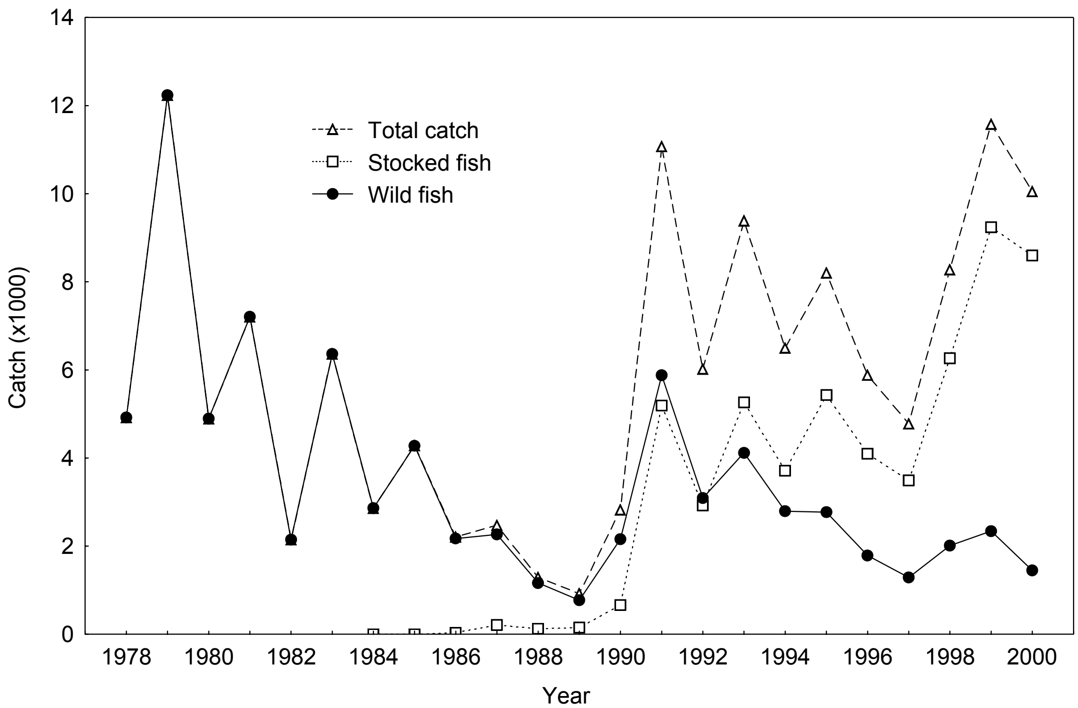

Figure 4. Catch of lake whitefish during the fall index trap netting program at the North Georgina and Strawberry Island spawning shoals in Lake Simcoe, 1978 to 2000.

Fall index trap netting methodology was inconsistent with respect to net size, sampling period and location prior to 1978 making comparisons of total catch at the North Georgina and Strawberry Island sites difficult. However, historical comparisons can be made to a portion of the catch at Strawberry Island. A season of October 15th to the 26th was netted at Strawberry Island for many years dating back to 1959. This time represents only the early portion of the lake whitefish spawning run. Figure 5 indicates that catch of lake whitefish at Strawberry Island was much greater during the early years of the program, especially during the mid-1960s, than it was over the past two decades. The only other explanation would be that the timing of the spawning run has changed over time (i.e., lake whitefish moved to spawning shoals earlier in the year during the 1960s and 70s). However, the timing of the spawning run has not changed since 1977 (Amtstaetter 2002) and MacCrimmon and Skobe (1970) reported similar results with respect to timing of the spawning run during the 1960s. Although the catch data in Figure 5 includes a short period of time (11 days) during a very early portion of the spawning run, it sheds insight into the historical magnitude of the spawning run.

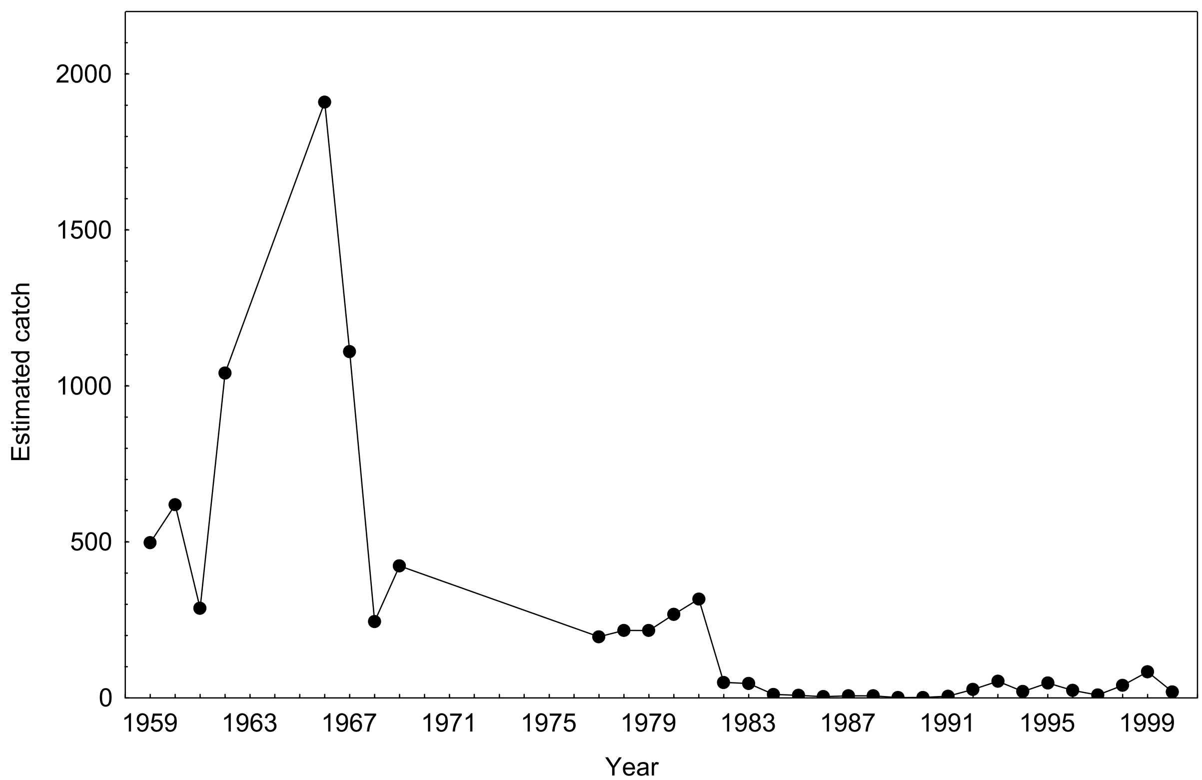

Figure 5. Estimated catch of lake whitefish during fall index trap netting on Lake Simcoe from the period of October 15th to the 26th at Strawberry Island, 1959 to 2000.

Estimated catch of lake whitefish during the winter fishery on Lake Simcoe was high throughout the 1960s and then decreased to its lowest level by 1977 (Figure 6). Since then, estimated catch has increased, but levels are still much lower than those recorded early in the program. The number of hatchery-reared fish in the catch has increased since stocking began in 1982 and the catch of wild fish has remained consistent since the early 1980s. However, it is important to note that the amount of fishing effort exerted during the winter fishery has increased for all anglers as well as for anglers specifically targeting lake whitefish (Figure 7). The catch rate of wild lake whitefish for anglers targeting the species has had a 15 year decline of 60%.

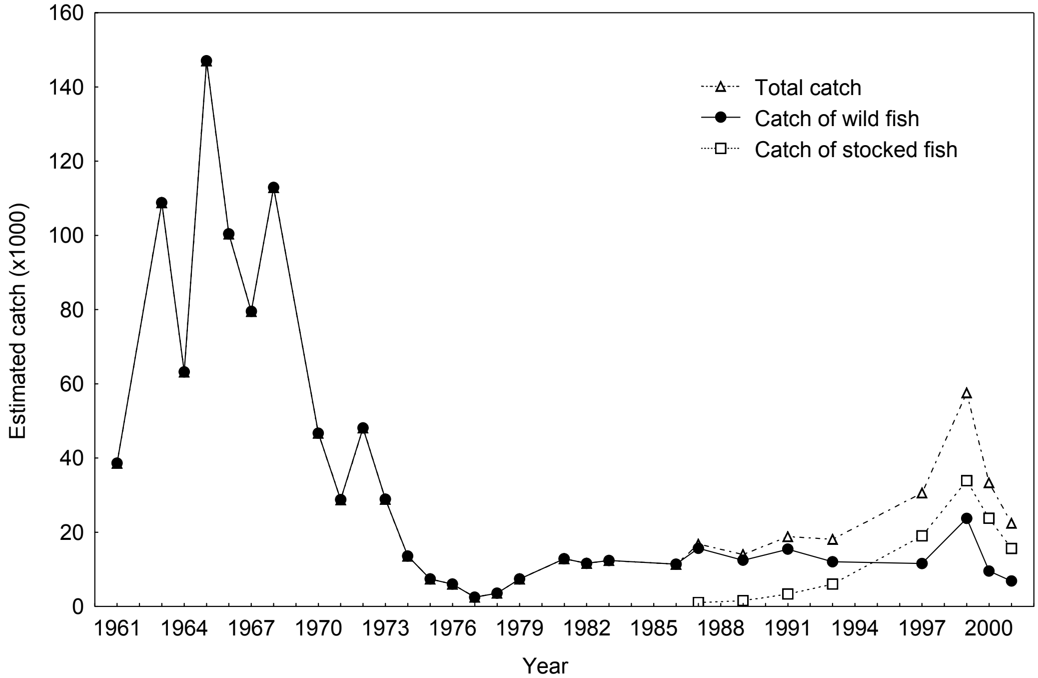

Figure 6. Estimated catch of lake whitefish during the winter fishery on Lake Simcoe adjusted to a 50-day season, 1961 to 2001.

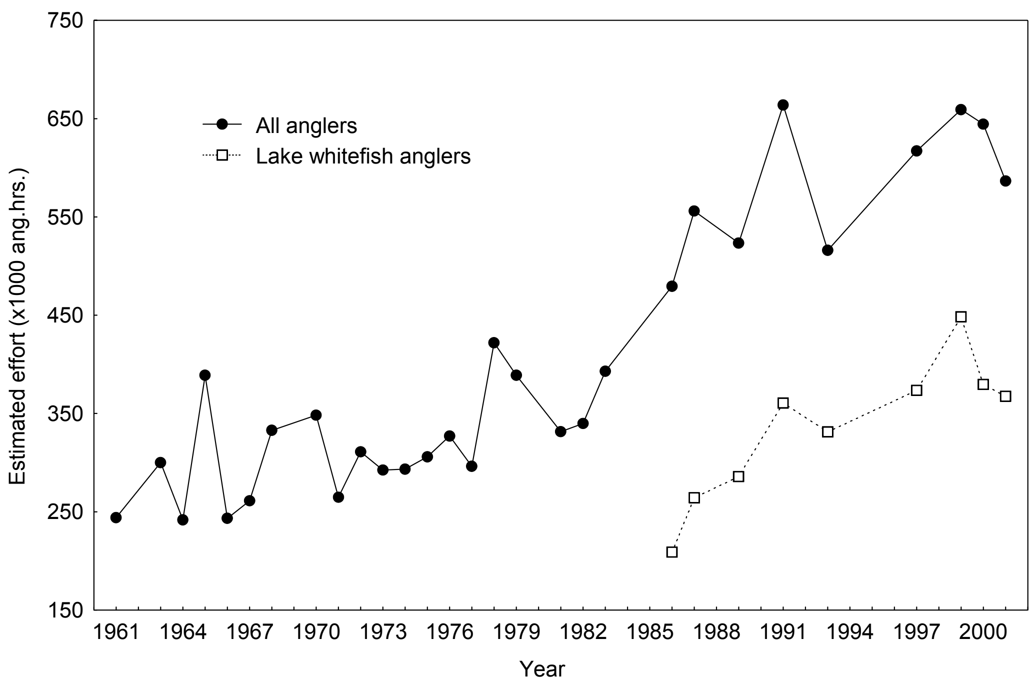

Figure 7. Estimated angling effort during the winter fishery on Lake Simcoe adjusted to a 50-day season, 1961 to 2001.

The estimated catch of lake whitefish during the summer fishery is much lower than that of the winter fishery. The highest estimated catch during the summer for which data are available (1981 to 1998) was close to 3500 fish in 1998 (Figure 8). Due to differences in summer creel survey methodology prior to 1981, including creel survey duration and the type of information collected, comparisons of catch to earlier surveys are difficult. The only comparable statistic throughout the history of the summer creel survey is observed catch per unit effort (CPUE) of all anglers. Comparisons of observed CPUE of all anglers was much higher during the 1960s and decreased sharply by 1970. A gradual decreasing trend continued until 1993 and in 1998, CPUE increased to values recorded in the 1970s (Figure 8). This may have been due in part to an increase in summer angling effort specifically targeting lake whitefish in 1998 (Figure 9). The contribution of hatchery-reared and wild fish to the catch was not recorded, but the presence of stocked fish most certainly contributed to the increase in lake whitefish catch in 1998.

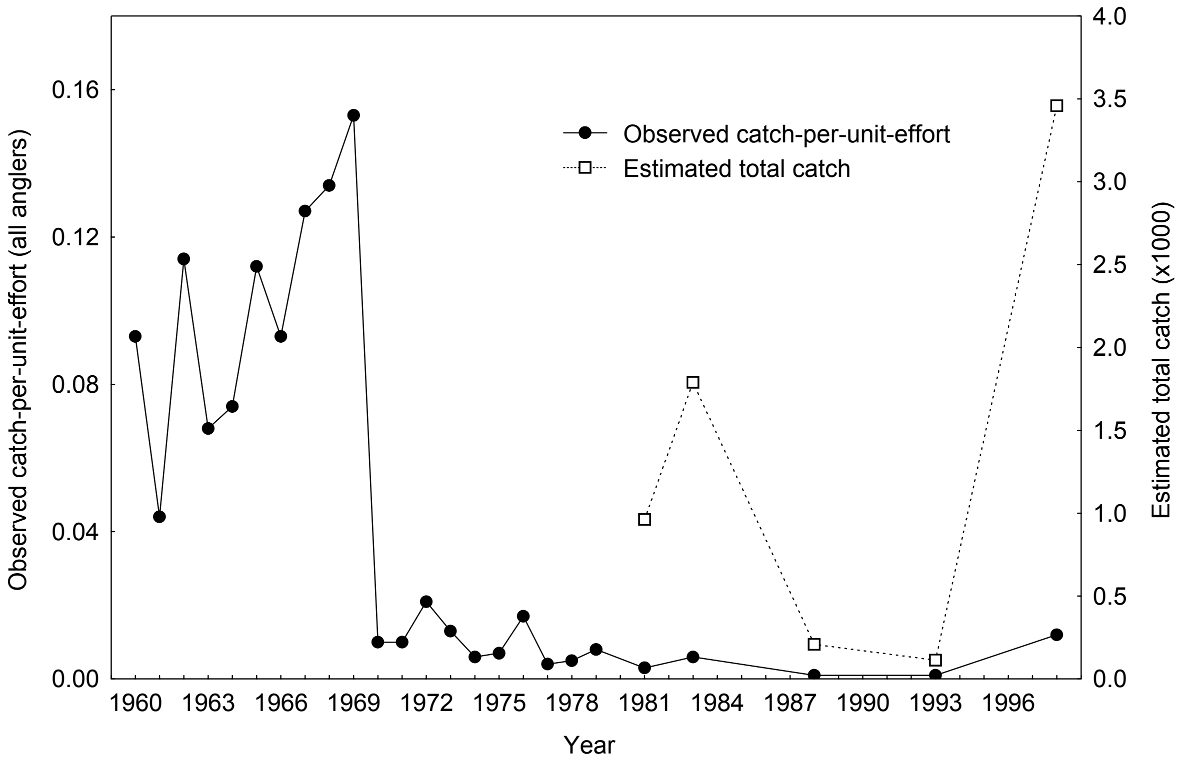

Figure 8. Observed catch per unit effort and estimated catch of lake whitefish during the summer fishery on Lake Simcoe, 1960 to 1998.

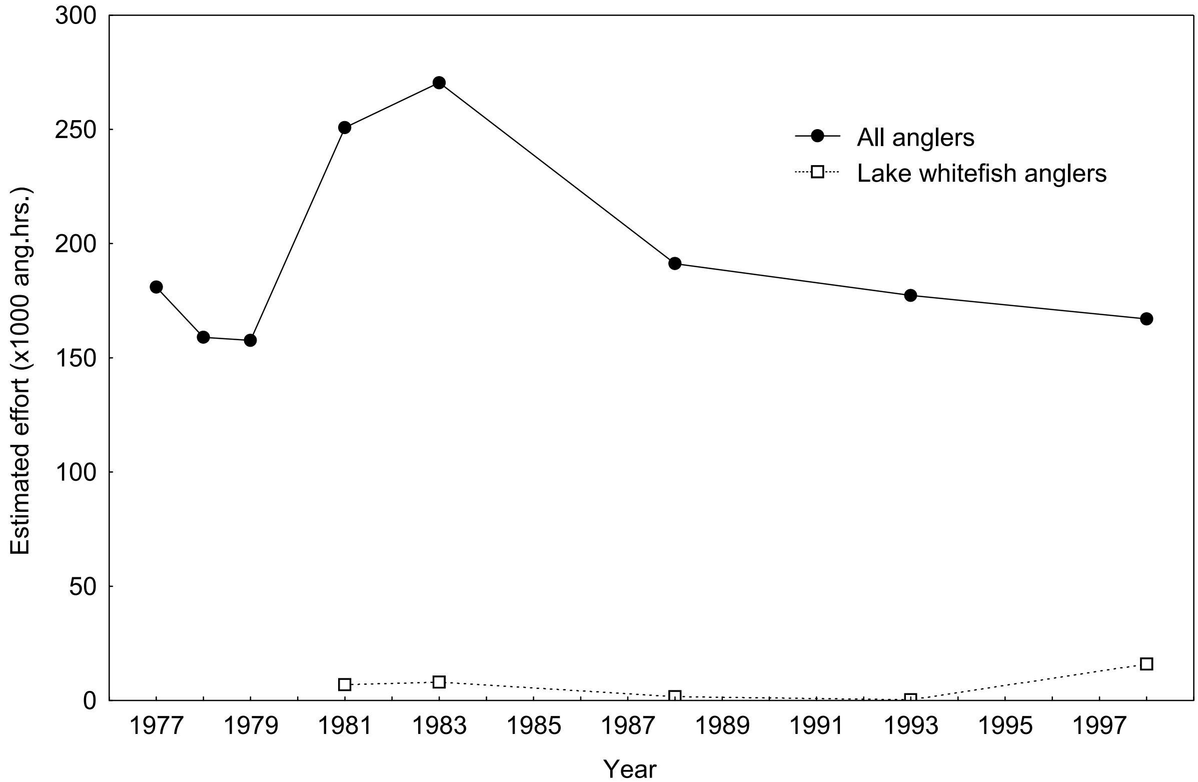

Figure 9. Estimated angling effort during the Lake Simcoe summer fishery, 1977 to 1998.

The mean fork length of Lake Simcoe lake whitefish captured on spawning shoals and during the winter fishery has increased over time (Figures 3 and 10). The mean fork length of wild fish has increased at a relatively consistent rate of 2.5 to 3 mm per year from 1976 to 1997 and at approximately 10 mm per year from the mid-1960s to the mid-1970s. Since 1992, when the first large stocking events (>150,000 fish per year) contributed significantly to the catch, the mean size of hatchery-reared fish has increased at a rate of 7 to 10 mm per year. Total length values measured during the 1960s were converted to fork length using the equation: FLEN=0.951(TLEN)-19.12 mm. This equation was determined using data from the 1969 fall index trap netting program, which included measurements of both fork and total length.

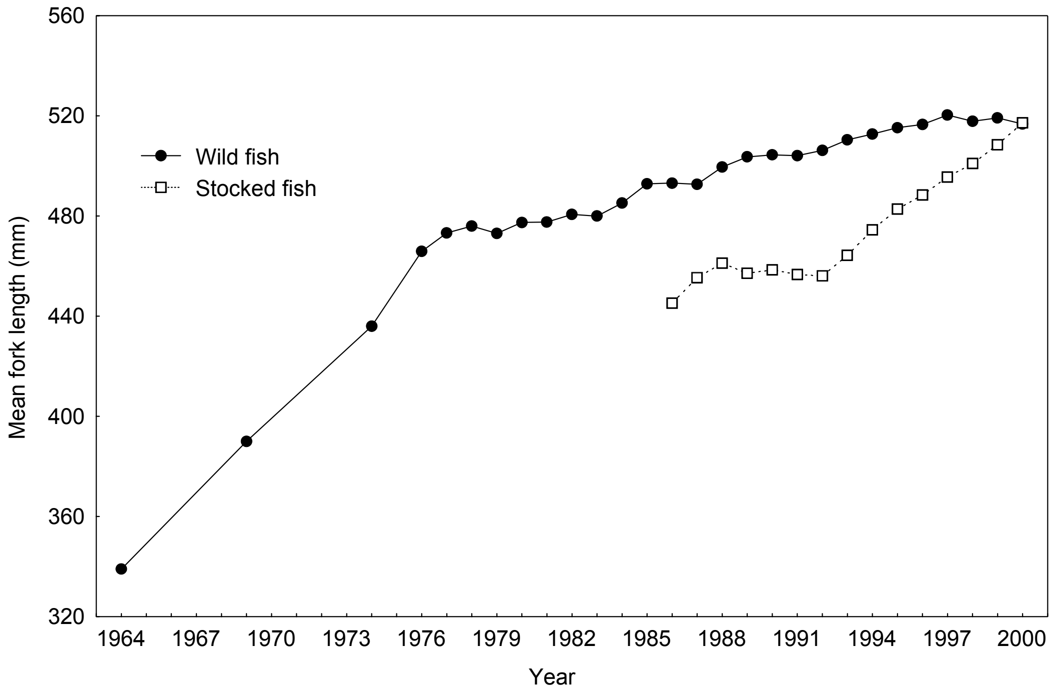

Figure 10. Mean fork length of Lake Simcoe lake whitefish captured during fall index trap netting. Data from 1976 to 2000 include fish captured at the North Georgina and Strawberry Island spawning shoals. Data from 1964, 1969, and 1974 include fish captured from all sites.

The mean weight of lake whitefish captured during the winter fishery on Lake Simcoe in recent years was much greater than historical records (Figure 11). Mean weight of wild fish has increased by 35 g per year since 1978 and the mean weight of hatchery-reared fish has increased by 105 g per year since 1992. MacCrimmon and Skobe (1970) reported the mean weight of fish captured during the winter fishery was between 340 and 570 g. It is interesting to note that Rawson (1930) reported the mean weight of several thousand lake whitefish harvested in 1928 was 510 g. The mean weight recorded in 2001 was more than four times the historical measure. Furthermore, fish greater than 910 g were considered rare in historical catches and during the 2001 winter fishery, the smallest fish measured was 975 g.

There are several possible explanations for the increase in the size of Lake Simcoe lake whitefish since the mid-1960s. These possibilities include an increase in the predominance of old individuals in the population and decreased intra-specific competition. As a result of recruitment problems in the 1960s, the predominance of older and larger lake whitefish in the lake increased. Although an increase in the mean size of the fish in the population would be expected as a result of an older population, it does not explain the observed increase in growth rates (Amtstaetter 2002). Many studies have noted an inverse relationship between whitefish growth and population size (Healy 1980; Jensen 1981; Salojärvi 1992a; Salonen *et al*. 1998). Rawson (1930)

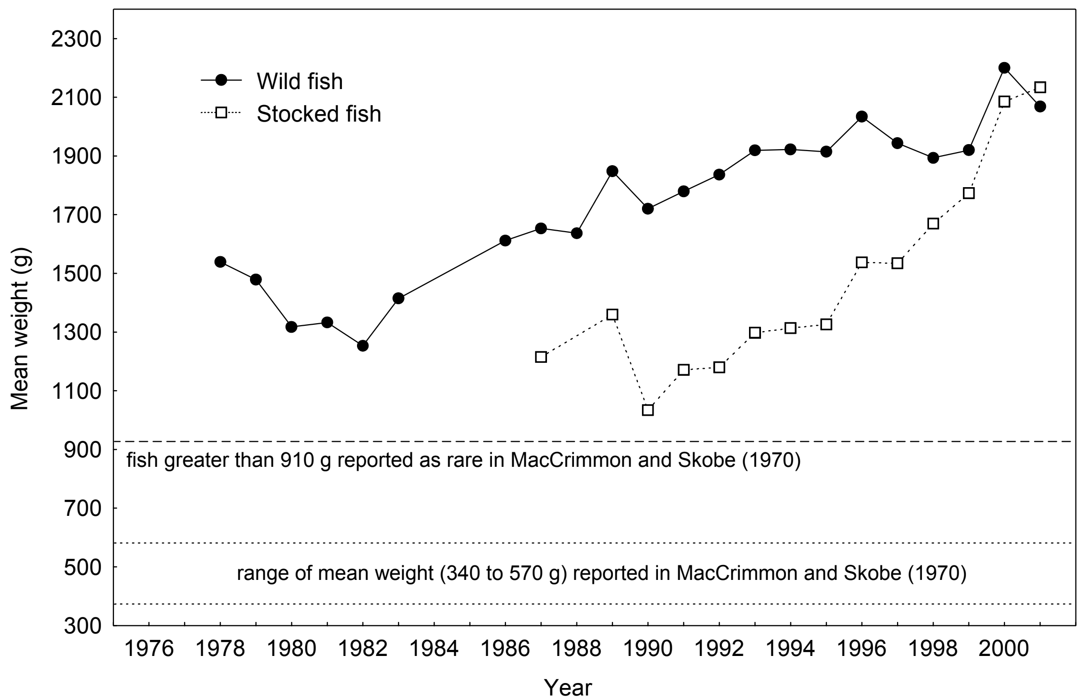

Figure 11. Mean weight of lake whitefish captured during the winter fishery on Lake Simcoe, 1978 to 2001.

noted the relatively small size of Lake Simcoe lake whitefish and suggested that it was likely the result of overcrowding and a resultant competition for food. Colby *et al*. (1972) reported that salmonid communities may exhibit an increase in growth rates as a result of eutrophication in oligotrophic lakes.

The dramatic decrease in the abundance of lake whitefish in the early 1970s was the result of recruitment failure. However, wild (unclipped) fish continue to be captured in Lake Simcoe three decades later. There are several possible explanations for their continued presence including: some successful natural recruitment still takes place, hatchery-reared fish being mistaken for wild fish, or the fish are extremely long lived. Determining the age of these unclipped fish, and whether they are of hatchery origin, is important in determining the status of the wild lake whitefish population.

The age of wild lake whitefish is a key factor in determining whether successful natural recruitment has taken place during the last three decades. Most age assessment of Lake Simcoe lake whitefish has depended on scales. Typically, scale age assessment underestimates the age of fish, especially with slow growing individuals (Mills and Beamish 1980; Casselman 1983). Scale age assessment for hatchery-reared lake whitefish in Lake Simcoe has been more accurate than for wild fish because fin clip information was used to identify possible year classes to which the fish could belong. Difficulties in assessing the age of hatchery-reared lake whitefish begin when the fish reach an age of seven years and increase as the fish increase in age. There is no validation of scale age assessment of wild Lake Simcoe lake whitefish less than seven years of age. However, given the relatively young age and the success of age assessment of hatchery-reared fish, scale age assessment should identify unclipped fish less than seven years of age. To investigate whether successful natural recruitment has taken place, the proportion of unclipped fish, less than seven years of age in the catch was examined.

The proportion of wild fish assessed as less than seven years of age in the catch on spawning shoals and during the winter fishery has been very low (Figures 12 and 13). There were several peaks indicating the potential for occasional successful year classes of wild fish (1976 and 1999 fall index trap netting and 1982, 1987, 1990, and 1992 winter fishery). However, none of the peaks were observed in both programs or in successive years, indicating that they were probably not the result of sporadic successful recruitment of wild year classes. The possibility remains that some of these fish assessed as young may actually be older individuals whose ages were underestimated. During periods of successful natural recruitment (1960s), age frequency distributions indicate that 44 to 50% of the wild fish were assessed as less than seven years of age. There is little doubt that a shift in the age structure of wild Lake Simcoe lake whitefish has occurred.

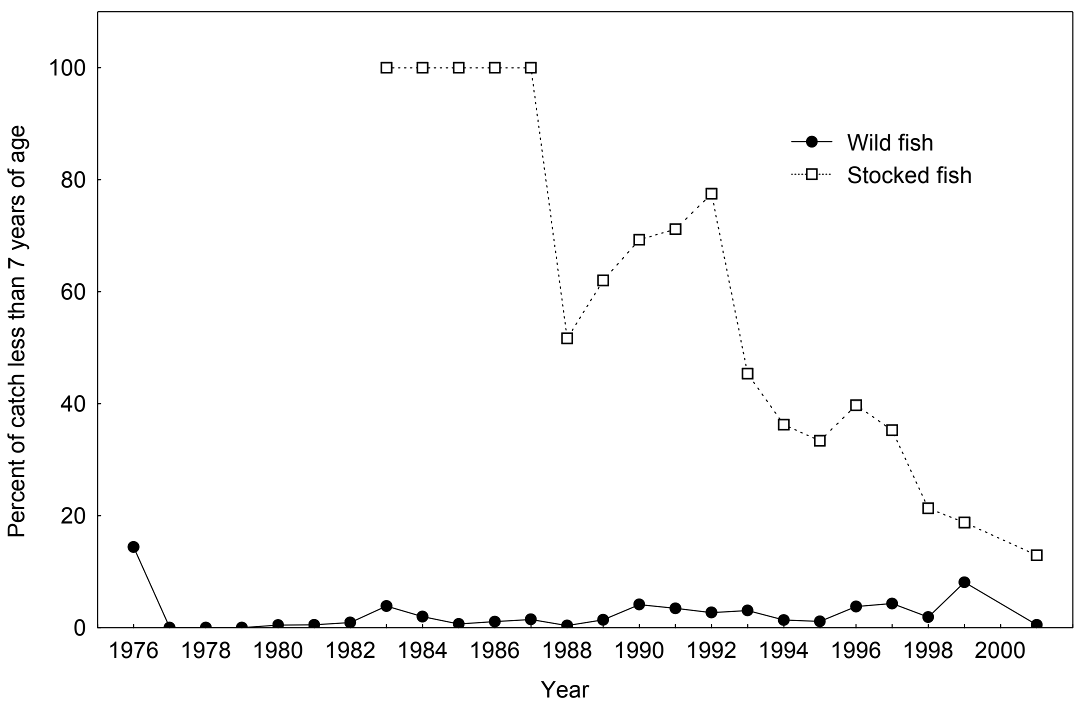

Figure 12. Proportion of lake whitefish assessed as less than seven years of age in the catch at the North Georgina and Strawberry Island spawning shoals during fall index trap netting, 1976 to 2001.

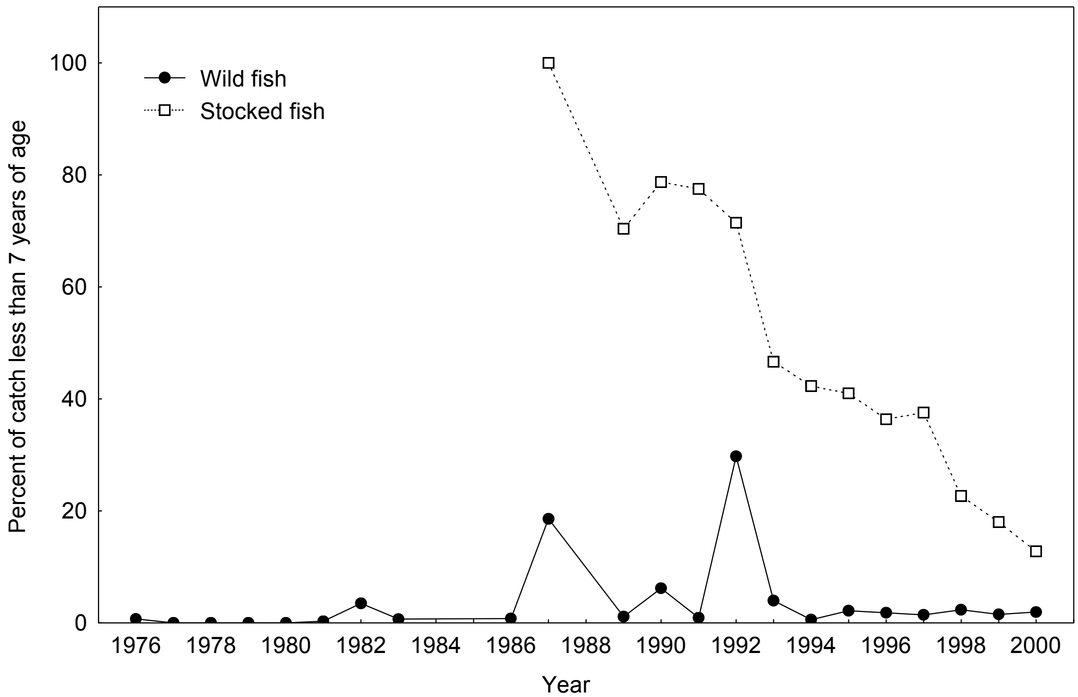

Figure 13. Proportion of lake whitefish assessed as less than seven years of age in the catch during the winter fishery, 1976 to 2000.

Not all of the unclipped lake whitefish captured and assessed as less than seven years of age can be explained by underestimation of the age of fish. There were nine fish captured during the past five years that were less than 430 mm in fork length. Comparisons with growth rates of hatchery-reared lake whitefish suggest that these unclipped fish were truly less than seven years of age. However, the extent of the age assessment difficulties for larger fish can still not be determined. Therefore, our best estimation must rely on scale age assessment which indicates that since 1976, young (< seven years of age) unclipped fish contribute an average of 2.5% and 3.6% of the catch of unclipped fish during the spawning run and winter fishery, respectively.

The possibility remains that young, unclipped Lake Simcoe lake whitefish may actually be hatchery-reared fish. There are several factors that could contribute to this result including fin clips not being applied to all hatchery-reared fish, regeneration of fin clips, and fin clips not being identified at time of recapture. Fin clip assessment of hatchery-reared fish prior to stocking indicates that missed or poor fin clips existed. Since the 1987 year class, approximately 0.78% of the fish stocked had no fin clip applied and 0.99% of the fish stocked had poor clips applied. Poor fin clips were defined as less than 50% complete. The presence of these young, unclipped hatchery-reared fish could artificially inflate the calculated value of the proportion of young, wild fish in the catch.

Although fin clipping error and scale age assessment difficulties can explain the presence of young, unclipped fish in the catch, it does not prove the complete absence of natural recruitment to maturity. In fact, a few small, young individuals were captured during both the spawning run and the winter fishery before juveniles were stocked into Lake Simcoe. If a small number of wild fish survived to be captured during the early 1980s, then it is possible that some wild individuals currently survive to maturity.

Since natural recruitment problems of lake whitefish in Lake Simcoe began in the late 1960s and only a small proportion of unclipped fish captured can be attributed to clipping error or recent natural recruitment to maturity, most of the unclipped fish must be very old. There are several pieces of evidence that suggest this could be the case. Firstly, a lake whitefish tag recapture shows that an individual tagged as a mature adult was recaptured 28 years later. There is no doubt that this fish was greater than 33 years of age at time of recapture. Secondly, otolith samples from 56 unclipped Lake Simcoe lake whitefish collected in 1990, 1999 and 2000 were prepared using an acid etching technique and assessed for age. Results indicated that 54 of the 56 fish were from the 1969 year class or earlier, these fish ranged in age from 30 to 48 years. Finally, it appears that some lake whitefish which had their adipose fin removed as part of a mark recapture study in 1972 (N>10,000) and 1975 (N unknown) still exist in Lake Simcoe (Amtstaetter 2002).

It is interesting to note that if most of the wild fish in Lake Simcoe are very old fish, that such a large number were captured during the fall spawning run when hatchery-reared lake whitefish were first captured in large numbers (1990 and 1991). This was probably not the result of high catch due to one or two years of favourable spawning conditions (e.g., weather) attracting more fish to the shoals because the decline in catch over the following years was gradual. It appears that the presence of hatchery-reared fish on the spawning shoals may have affected the magnitude of the catch of wild fish.

Summary

Strong corroboration relating to adult lake whitefish abundance and size in Lake Simcoe exist between all programs. Generally, catches were high during the 1960s and decreased sharply by the early 1970s. Since then, catch has remained relatively low compared to catches during the 1960s, but has increased somewhat as a result of the annual stocking of hatchery-reared fish. Wild lake whitefish continue to contribute to the recreational fisheries as well as to trap net catches on spawning shoals during the fall. However, catch rates of wild fish during the winter fishery have decreased since 1986 and catch has decreased during the fall index trap netting program since 1992. The size of Lake Simcoe lake whitefish is much larger than historical values. Since the early 1960s the mean weight and mean length of wild fish has increased by approximately 360% and 60%, respectively. Possible explanations of the increase in size include an increase in the predominance of old individuals in the population and decreased intra-specific competition. The mean size of wild and hatchery-reared fish are currently very similar.

Currently, the Lake Simcoe lake whitefish population is made up largely of hatchery-reared fish along with a smaller population of wild fish. Catch rates of wild fish are extremely low compared with data from the 1960s. Evidence suggests that, currently, the wild lake whitefish population is made up mostly of old individuals that were the result of successful recruitment in the 1960s. While it is possible that some successful natural recruitment to maturity still takes place, the magnitude of such events appears to be small and has little bearing on the size and age structure of the population.

LIMITING FACTORS AND THREATS

The decline of lake whitefish, lake trout (*Salvelinus namaycush*) and cisco (*C. artedi*) has been attributed to nutrient loading and accelerated eutrophication and its impacts on spawning and hypolimnetic habitat in Lake Simcoe (Evans 1978; Evans *et al*. 1988; Evans *et al*. 1996). There has been a threefold increase in phosphorus loading from pre-settlement rates (Johnson and Nicholls 1989) which has affected water quality. Several species of zooplankton indicative of eutrophic states are now common in Lake Simcoe. The scarcity of one oligotrophic indicator coupled with the absence of another, suggest the impairment of the deep cold-water habitat of Lake Simcoe (Nicholls and Tudorancea 2001). Evans *et al*. (1996) reported that the volume-weighted temperature-corrected hypolimnetic dissolved oxygen concentration from August 30th to September 19th declined from approximately 4.5 mg/L in 1975 to 2.0 mg/L by 1993. Recruitment failure of lake trout, lake whitefish and cisco occurred in the 1960s, 1970s and 1980s, respectively. More recently, declines in the abundance of burbot (*Lota lota*) have also been observed. This order is the same as the order in which these fish spawn in Lake Simcoe. Lake trout, lake whitefish, cisco and burbot spawn in October, November, December and January, respectively. Smith (1972) reported a similar sequence in which cultural eutrophication adversely affected groups of fish in the Great Lakes. However, he indicated that declines in cisco took place before declines in lake whitefish.

Rainbow smelt (*Osmerus mordax*) was first documented in Lake Simcoe in 1961 and by the early 1970s had become very well established. The timing of rainbow smelt expansion in the late 1960s coincided very closely with recruitment failure of lake whitefish. Evans and Waring (1987) suspected that the decline in lake whitefish recruitment in Lake Simcoe was probably caused by competition between young rainbow smelt and lake whitefish or predation by adult rainbow smelt on young lake whitefish, and that predation appeared to be of lesser importance. It has been documented that rainbow smelt prey upon larval lake whitefish and cisco (Loftus and Hulsman 1986; Evans and Loftus 1987). However, rainbow smelt piscivory on lake whitefish has not been observed in Lake Simcoe (Day and DesJardine 1975; MacCrimmon and Pugsley 1979). Evans and Loftus (1987) found that in 13 of 24 case studies of rainbow smelt introduction to Ontario lakes that there was a reduction in lake whitefish recruitment documented (Lake Simcoe was included in their study). Reckahn (1970) found that intra-specific competition between young lake whitefish in South Bay, Lake Huron was likely much more significant than competition with other species including rainbow smelt. The role that rainbow smelt may have played in lake whitefish recruitment failure in Lake Simcoe is unclear. However, there is little doubt that any potential effect would have acted only on juvenile fish less than six months of age given the high survival of hatchery-reared lake whitefish in the presence of a large rainbow smelt population throughout the 1980s and early 1990s.

The continued success of cisco recruitment during the rapid expansion of rainbow smelt provides insight into the potential effects of the introduction of rainbow smelt on lake whitefish. Given the overlap in distribution of larval cisco and lake whitefish (DesJardine 1979; Cucin and Faber 1985), any effects of rainbow smelt on lake whitefish would also be expected on cisco at this life stage. There is also a large degree of overlap in the diet items of young lake whitefish including copepods and cladocerans. As a result, any competitive effect that could affect lake whitefish and not cisco would be the result of spatial segregation between the two species. Post-larval lake whitefish and cisco do occupy different habitat types, benthic and pelagic, respectively. However, given the diel behaviour exhibited by rainbow smelt during the summer period, they share habitat with both lake whitefish and cisco. For example, at night, adult rainbow smelt disperse from the lake bottom into the water column and often into the epilimnion (Ferguson 1965; Heist and Swenson 1983) while young-of-year rainbow smelt appear to move from the epilimnion to the hypolimnion at night (Brandt *et al*. 1980).

The catch of rainbow smelt during the winter fishery on Lake Simcoe has declined since 1989. By 1999, catch decreased to levels observed during the mid-1960s and has remained low through to 2001. To date, a response in the success of lake whitefish recruitment to the decrease in rainbow smelt abundance has not been detected.

However, Lake Simcoe fish monitoring programs rarely capture juvenile fish and, as a result, a lag time of several years exists between a potential change in the success of natural recruitment and observations of results. Continued sampling over the next few years may provide more evidence relating to the potential interactions between rainbow smelt and lake whitefish.

Zebra mussels (*Dreissena polymorpha*) and spiny waterflea (*Bythotrephes* sp.) were first observed in Lake Simcoe in 1992 and 1994, respectively. Given their recent introduction, these species could not have affected lake whitefish recruitment failure in the late 1960s. There is no evidence that these species have negatively affected growth or survival of hatchery-reared Lake Simcoe lake whitefish. However, the effect, if any, that zebra mussels or spiny waterflea would have on juvenile lake whitefish less than six months of age is unknown. Since the introduction of these species has the potential to alter the structure of the zooplankton community (MacIsaac 1996; Yan and Pawson 1997), it could possibly alter prey availability for juvenile lake whitefish. Evans (pers. comm.) has also suggested these species along with lake trout predation may have contributed to recruitment failure in cisco, which is now evident and the decline in smelt by altering their prey abundance. He recently hypothesized that a decline in smelt abundance and the relatively low numbers of young-of-the-year smelt occupying early juvenile whitefish habitat may help explain the continuation of low levels of lake whitefish recruitment and the resurgence of slimy and spoonhead sculpins.

SPECIAL SIGNIFICANCE OF THE SPECIES

As reported in Evans *et al*. (1985), the Lake Simcoe whitefish was considered to be a genetically discrete stock of the lake whitefish (Ihssen *et al*. 1981), having been separated from nearby stocks in the Great Lakes region for about 7,000 to 10,000 years by geographic and man-made barriers. Given the low probability that an environment similar to that in Lake Simcoe exists elsewhere in Canada and that the Lake Simcoe whitefish has diverged genetically from nearby stocks as a result of its local habitat, Evans *et al*. (1985) suggested providing special protection for the Lake Simcoe lake whitefish.

Along with other cold-water fish species in Lake Simcoe, the decline in lake whitefish abundance in the lake has indicated deteriorating habitat quality. As indicators of habitat quality, these species fulfill an important ecological role. Successful rehabilitation of the lake whitefish could also result in rehabilitation of other cold-water species in Lake Simcoe.

The Lake Simcoe lake whitefish remains the species most targeted by recreational anglers. During the 2001 winter fishery on Lake Simcoe, 63% of the total estimated effort was targeted, in part (i.e., many anglers target more than one species), toward lake whitefish. The recreational winter fishery on Lake Simcoe provides anglers with over one million angler hours of fishing each year. This fishery increases tourism to the area and provides an influx of money to the local economy.

EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS

The federal *Fisheries Act* serves as the primary legislation for the protection of fish and fish habitat in Canada. Two of the more commonly applied sections relate to the protection of fish habitat and the control of deleterious substances. Section 35(1) stipulates that no person shall undertake work that results in the harmful alteration, disruption or destruction of fish habitat. Section 36(3) prohibits the deposition of deleterious substances into water frequented by fish. There are also numerous other pieces of legislation that relate to the preservation of fish habitat in Ontario such as the *Environmental Protection Act*, *Ontario Water Resources Act*, *Conservation Authorities Act* and the *Lakes and Rivers Improvement Act*.

The Ontario Fishery Regulations, pursuant to the federal *Fisheries Act*, sets out closed seasons for lake whitefish in Lake Simcoe from March 16th to the day before the 2nd Saturday in May and from October 1st to December 31st and limits angler catch to two fish per day and a possession limit of two fish. There is no commercial fishery for lake whitefish in Lake Simcoe.

To maintain the genetic strain of the Lake Simcoe lake whitefish, approximately 140,000 lake whitefish are stocked into Lake Simcoe annually. These fish are the progeny of fish captured in Lake Simcoe. In the early 1980s, Lake Simcoe strain lake whitefish were stocked into Upper Roslyn Lake to serve as a refuge population. The status of this population is unknown.

In response to declining water quality and the impacts of eutrophication on the Lake Simcoe ecosystem, the Lake Simcoe Environmental Strategy (LSEMS) was initiated in the 1970s. The current goal of this multi-agency partnership is: to improve and protect the health of the Lake Simcoe watershed ecosystem and improve associated recreational opportunities by restoring a self-sustaining coldwater fishery, improving water quality, reducing phosphorus loads to Lake Simcoe and protecting natural heritage features and functions.

The Chippewas of Georgina Island First Nations are involved in conservation management of Lake Simcoe Lake Whitefish in their capacity as members of the Lake Simcoe Environmental Strategy (LSEMS - *see*: http://www.lsrca.on.ca/ar2002.html).

TECHNICAL SUMMARY

Coregonus clupeaformis
Lake whitefish, Lake Simcoe population — Grand corégone, population du lac Simcoe
Ontario

Extent and Area information	
• *extent of occurrence (EO)* [*see* Distribution]	725 km^2
• *trend*	Stable
• *are there extreme fluctuations in EO?*	No
• *area of occupancy (AO)* [less than EO as the species is not found throughout the lake]	<725 km^2
• *trend*	Stable
• *are there extreme fluctuations in AO?*	No
• *number of extant locations*	1
• *trend in # locations*	Stable
• *are there extreme fluctuations in # locations?*	No
• *habitat trend*	Decline
Population Information	
• *generation time (average age of parents in the population)*	Wild fish - <30 years Stocked fish - 10 years
• *number of mature individuals (capable of reproduction) in the Canadian population* Estimated to be in the area of 200,000 including stocked fish, which probably represent 90% of whitefish in the lake.	Unknown
• *total population trend*	Wild fish declining
• *if decline, % decline over the last/next 10 years or 3 generations, whichever is*	15 year decline of 60% for wild fish
• *are there extreme fluctuations in number of mature individuals?*	No
• *is the total population severely fragmented?*	No
• *list each population and the number of mature individuals in each*	Not Applicable
• *trend in number of populations*	Not Applicable
• *are there extreme fluctuations in number of populations?*	Not Applicable
Threats (actual or imminent threats to populations or habitats)	
- Lack of natural reproduction resulting from habitat loss due to cultural eutrophication and its effects on spawning and hypolimnetic habitat - Inter-specific competition with introduced exotics i.e., rainbow smelt - Potential of negative impact from introduction of zebra mussels and spiny waterfleas	
Rescue Effect (immigration from an outside source)	Nil
• *does species exist elsewhere (in Canada or outside)?*	Not the Lake Simcoe strain
• *status of the outside population(s)?*	Good
• *is immigration known or possible?*	No
• *Would immigrants be adapted to survive here?*	Probably
• *is there sufficient habitat for immigrants here?*	No
Quantitative Analysis	Not Done

Existing Status

Nature Conservancy Ranks (Natureserve 2004)
Global – T2
National
US – N/A
Canada NNR
Regional
US – N/A
Canada – ON SNR

Wild Species 2000 (Canadian Endangered Species Council 2001**)**
NR

COSEWIC
Data Deficient (May 2005)

Status and Reasons for Designation*

Status: Data Deficient	**Alpha-numeric code**: Not Applicable
Reasons for Designation: Although this population is on its way to extirpation, there is inconclusive evidence regarding its distinctiveness and the best evidence available at this time is insufficient to resolve the species' eligibility for assessment.	
Applicability of Criteria	
Criterion A (Declining Total Population): The wild component of the population has severely declined and remains depressed (A2b), habitat quality and quantity generally is degraded (A2c), exploitation continues and appears to be increasing (A2d), and exotics continue to threaten the integrity of both the ecosystem and the population (A2e); recovery may be further impacted by hatchery propagation procedures. The wild component qualifies for Endangered; the total population (wild+stocked) qualifies for Threatened; however, there is insufficient evidence to establish eligibility.	
Criterion B (Small Distribution, and Decline or Fluctuation): One lake containing one population with a limited or unknown number of stocks present in a continued depressed state. The number of mature wild individuals has declined, appears to consist mostly of very old fish from recruitment events >30 years ago, thus will decline in future as these individuals die from either natural or fishing causes (B2a,b(v)). Although attempts at reversing habitat degradation have occurred and some success has been realized, rehabilitation to levels necessary for population recovery is unlikely; however, there is insufficient evidence to establish eligibility.	
Criterion C (Small Total Population Size and Decline): No information regarding actual abundance is available for wild fish, but it is likely quite low relative to what should be present in a lake this size.	
Criterion D (Very Small Population or Restricted Distribution): Criterion not met; however, there is insufficient evidence to establish eligibility.	
Criterion E (Quantitative Analysis): Data not available; however, there is insufficient evidence to establish eligibility.	

*Since there are ongoing studies relative to the discreteness of this, and other whitefish populations, an update will be tabled within 5 years, or whenever such information becomes available.

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