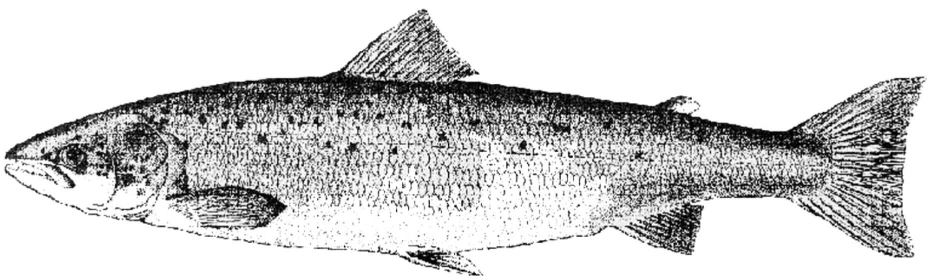
COSEWIC
Assessment and Status Report

on the

Atlantic Salmon
Salmo salar

Lake Ontario population

in Canada



EXTIRPATED
2006

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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Production note:

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Atlantic salmon (Lake Ontario population) — A.H. Leim and W.B. Scott. Fishes of the Atlantic coast of Canada (1966).

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COSEWIC
Assessment Summary

Assessment Summary – April 2006

Common name
Atlantic salmon – Lake Ontario population

Scientific name
Salmo salar

Status
Extirpated

Reason for designation
Once a prolific species throughout the Lake Ontario watershed, there has been no record of a wild Atlantic salmon since 1898. The Lake Ontario Atlantic salmon was extinguished through habitat destruction and through over-exploitation by a food and commercial fishery. Attempts to re-establish Atlantic salmon through stocking have failed, and the original strain is no longer available.

Occurrence
Ontario

Status history
Last reported in 1898. Designated Extirpated in April 2006. Assessment based on a new status report

COSEWIC
Executive Summary

Atlantic Salmon
Salmo salar

Lake Ontario population

Species information

The Atlantic salmon (*Salmo salar*) belongs to the family Salmonidae that includes Atlantic and Pacific salmon, trout, charr, grayling and whitefishes. Adult Atlantic salmon that have been out to sea have trout-like bodies with a blue-green back and silvery sides. The freshwater adults once populating Lake Ontario were reportedly smaller and darker than anadromous strains. This report is concerned with the Lake Ontario population (COSEWIC Designatable Unit).

Distribution

Anadromous Atlantic salmon once occurred in every country with rivers flowing into the North Atlantic Ocean and Baltic Sea. In Canada, nearly every suitable coastal stream within Nova Scotia, New Brunswick, Prince Edward Island, Quebec, Labrador, and Newfoundland supported a spawning run of anadromous salmon. In addition, many inland lakes had freshwater populations that did not migrate to the ocean. Atlantic salmon populations have declined in number throughout much of their global range, as well as in Canada, and self-sustaining populations are no longer found west of Montréal. The Lake Ontario population ceased to exist over 100 years ago.

Habitat

Streams suitable for Atlantic salmon juveniles and adult spawning are characterized by clean water seldom rising above 25°C and naturally graded and stable beds with stony bottoms comprised of particles varying in size from coarse sand and gravel to large boulders. Anadromous Atlantic salmon utilize estuaries and continental margins as well as open seas for growth to the adult stage. Little is known about the specific stream or lake habitat required by the extinct Lake Ontario Atlantic salmon. Usage of streams was probably similar to that for other populations in eastern Canada, and Lake Ontario, because of its large size, likely sustained the adult stage in a manner somewhat similar to that of an ocean environment.

Biology

Atlantic salmon have a complex life history typically described as progressing from egg to alevin to fry to parr to smolt to grilse to adult to kelt. The Lake Ontario Atlantic salmon, unlike those in eastern Canada, probably did not migrate to the Atlantic Ocean but instead completed its life cycle within the Lake Ontario watershed, with egg through parr stage in rivers and smolt through adult and kelt stages within the lake. The life history of Lake Ontario Atlantic salmon was probably similar to that of the species in general, although local adaptations such as in run timing are known.

Population sizes and trends

The Lake Ontario Atlantic salmon is extinct. At one time, Atlantic salmon were so common in Lake Ontario and its tributaries that catches were measured in barrels of fish rather than in numbers of individual fish. The population began to decline by the mid-1800s and continued to decline with various hatchery stocking activities, which began in 1866. The last known Atlantic salmon was removed from the Lake Ontario basin before 1900, by anglers. Today, the Lake Ontario ecosystem contains apparently suitable habitat for Atlantic salmon; however, attempts at stocking non-native populations have continued to be unsuccessful in establishing reproducing populations.

Limiting factors and threats

Lake Ontario Atlantic salmon habitat was degraded by timbering, agriculture, and mills and dams across rivers that prevented access to spawning grounds. Adult Atlantic salmon were also captured as food fish, and harvested in large numbers in a commercial fishery. Lake Ontario fish communities and the aquatic environment have continued to change dramatically over time; presenting new challenges to the introduction of non-native Atlantic salmon. There have been many stocking efforts, but there are no self-reproducing Atlantic salmon in Lake Ontario.

Special significance of the species

Atlantic salmon are said to have encouraged the territorial expansion by Europeans into the interior of Canada. The "king of fish" was valued by aboriginals, provided food for natives and settlers alike, and enabled the creation of a fishery employing thousands of people. The Atlantic salmon was an important species ecologically, functioning in the movement of nutrients from the lake into its tributaries, and as a top predator in both the rivers and the lake. Several recent watershed fisheries management plans have identified the public's interest in restoring naturally sustaining populations of Atlantic salmon.

Existing protection or other status designations

Due to its vast range and collectively large population, the Atlantic salmon has been given a global rank by the Nature Conservancy of G5 (demonstrably widespread, abundant and secure), and a national rank of N4 (apparently secure). At the individual provincial and state levels, however, the designations range from "presumed extirpated" in Ontario, to "secure" in Quebec. Inner Bay of Fundy Atlantic salmon are currently listed as *endangered* by Canada's Species at Risk Act (SARA), and most neighbouring US populations of Atlantic salmon are listed as *endangered* (US Endangered Species Act).

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 5th 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 entities (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 science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2006)

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 category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' 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. Definition of the (DD) category revised in 2006.

Environment Canada / Environnement Canada
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Canada

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

COSEWIC Status Report

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2006

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SPECIES INFORMATION

Name and classification

The Atlantic salmon (*Salmo salar*) or *saumon atlantique* is in the family Salmonidae which includes Atlantic and Pacific salmon, trout, charr, grayling and whitefishes (Mills 1989). Atlantic salmon have several other common names in English and French, many of which refer to the geographical location of a population or a specific life stage. Names such as black salmon, grilse, grilt, kelt, grayling, smolt, slink, fiddler, and parr are all lifestage references (Scott & Crossman 1973). Populations which spend their entire life cycle in freshwater are often referred to as lake Atlantic salmon, non-anadromous salmon, ouananiche, sebago, freshwater salmon or *saumon d'eau douce* (Scott & Crossman 1973, MacCrimmon & Gots 1979). They have been found in lakes in New Brunswick, Quebec, Newfoundland, Ontario (Lake Ontario; and an introduction into Trout Lake, Ontario), and the New England states.

Description

The most complete description of Atlantic salmon can be found in Scott and Crossman (1973) where they are described as having a "trout-like" body with an average length of about 18 inches (457 mm), somewhat compressed laterally, with the greatest body depth usually at the dorsal fin origin or slightly posterior to it (Figure 1). The sea salmon has a blue-green back, silvery sides and a white belly (Carcao 1986). There are several X-shaped and round spots mostly above the lateral line (Carcao 1986). When a marine salmon reenters freshwater it loses the silvery guanine coat replacing it with hues of greenish or reddish brown and large spots that are edged with white (Scott & Crossman1973, Carcao 1986). Juvenile salmon or salmon parr display parr marks or pigmented vertical bands with a single red spot between each parr mark along the lateral line (Scott & Crossman 1973). When parr become smolts and go to sea, the parr marks are lost and the fish become silvery (Scott & Crossman 1973). Adult Lake Ontario salmon and other freshwater salmon were reported to be darker than the "true" salmon found on the east coast and in the British Isles (Dymond 1965).

Designatable units

Approximately 40 tributaries of Lake Ontario were known to support runs of Atlantic salmon (Parsons 1973). The Credit River was "reputed to be the best salmon river in Upper Canada" (Wilmot 1879). Scales obtained from two adult museum specimens indicate an exclusively freshwater growth history, suggesting that the salmon that originally inhabited Lake Ontario was most likely a non-anadromous (freshwater) form (Blair 1938).

Some authors have suggested that prior to the construction of the R.H. Saunders dam in 1958 in the St. Lawrence River, Atlantic salmon would have been able to migrate to the Atlantic Ocean, aside from the distance of 2400 km (Carcao 1986). However, there is compelling evidence that Lake Ontario Atlantic salmon were isolated from the sea and did not mix with other non-anadromous populations. The spring date of runs into Lake Ontario tributaries occurred earlier than possible for adult Atlantic salmon to have returned from the ocean. Two runs occurred, one in spring (March/April) and one in fall (Sep/Oct). Wilmot (1879) reported that salmon appeared in the Humber River in April, and the earliest recorded date in the year for the capture of salmon was March 17. Anadromous individuals are unlikely to have been capable of moving into Lake Ontario so soon after the ice left the St. Lawrence and arrive in the prime condition noted in the Oswego River in New York, and in the Credit and Humber Rivers in Canada (Webster 1982). It is therefore highly likely that the Lake Ontario Atlantic salmon population was geographically and reproductively isolated from other Atlantic salmon populations in North America. Ongoing genetic studies to test this hypothesis are constrained by small sample sizes (historic mounts).

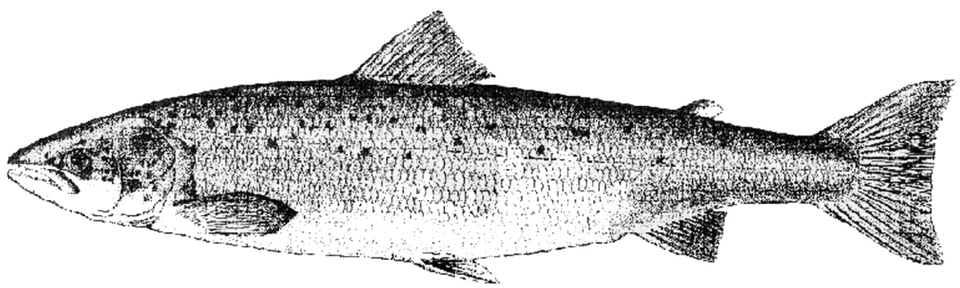

Figure 1. The Atlantic Salmon. Source: A.H. Leim and W.B. Scott. Fishes of the Atlantic coast of Canada. (1966)

DISTRIBUTION

Global range

The Atlantic salmon originally occurred in every country whose rivers flowed into the North Atlantic Ocean and Baltic Sea (Mills 1989) (Figure 2). In Europe the range of the Atlantic salmon extended southward from Iceland along the Atlantic coastal drainage to Northern Portugal including rivers in both France and Spain (MacCrimmon & Gots 1979). In North America, the range of the anadromous Atlantic salmon was northward from the Hudson River drainage in New York State, to outer Ungava Bay in Quebec (MacCrimmon & Gots 1979) (Figure 3). Non-migratory or non-anadromous forms of Atlantic salmon occur in several glaciated areas of Europe, Scandinavia and North America.

The current distribution remains similar to the historical range; however, the number of rivers supporting spawning runs in each country as well as the estimated population densities are much lower than those recorded historically.

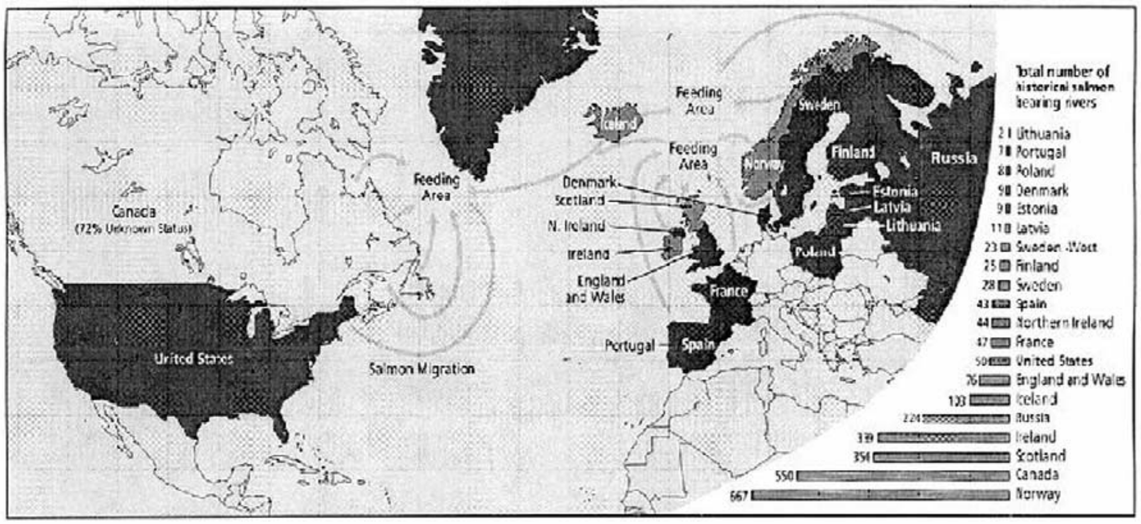

Figure 2. Current Global Distribution of Atlantic salmon (*Salmo Salar*), excluding Canada. Source: World Wildlife Fund website: www.worlwildlife.org/oceans/salmon_handout.pdf. Arrows indicate migration patterns of wild salmon. The total number of historical salmon bearing rivers worldwide is indicated at the right of map.

Canadian range

Historically, nearly every suitable coastal stream within Nova Scotia, New Brunswick, Prince Edward Island, Quebec, Labrador, and Newfoundland supported a run of salmon (MacCrimmon & Gots 1979) (Figure 3). By the mid-1800s, Atlantic salmon populations on Canada's east coast were in decline, suffering principally from the timber trade that necessitated the damming of major streams and rivers used for spawning by Atlantic salmon and that subsequently destroyed or rendered inaccessible critical spawning and rearing habitat (Dunfield 1985). Atlantic salmon can still be found in much of their northern native range on the Atlantic coast, but populations are currently at very low levels, possibly due to recent reduced marine survival, as well as fishing pressures. A number of populations of non-anadromous salmon still occur in lakes throughout the region, especially in Newfoundland, Labrador and Quebec (MacCrimmon & Gots 1979, Scott & Crossman 1973).

The earliest written records of Atlantic salmon in Lake Ontario were those of Jesuit missionaries, which described catches of eight to ten barrels of salmon in a single night of fishing (Carcao 1986). Fishers were able to catch these fish at all times of the year in Lake Ontario, its tributaries and the interior waters of New York (Clinton 1822) (Figure 4). Runs of salmon were reported to have occurred in most of the north shore tributaries of the St. Lawrence River to the Ottawa River (MacCrimmon & Gots 1979). No salmon runs were known in the Ottawa River itself due perhaps to poor quality spawning and rearing habitat (Dunfield 1985). Lake Ontario salmon had historic isolation from the other Great Lakes to the west, due to the impassable Niagara Falls below Lake Erie.

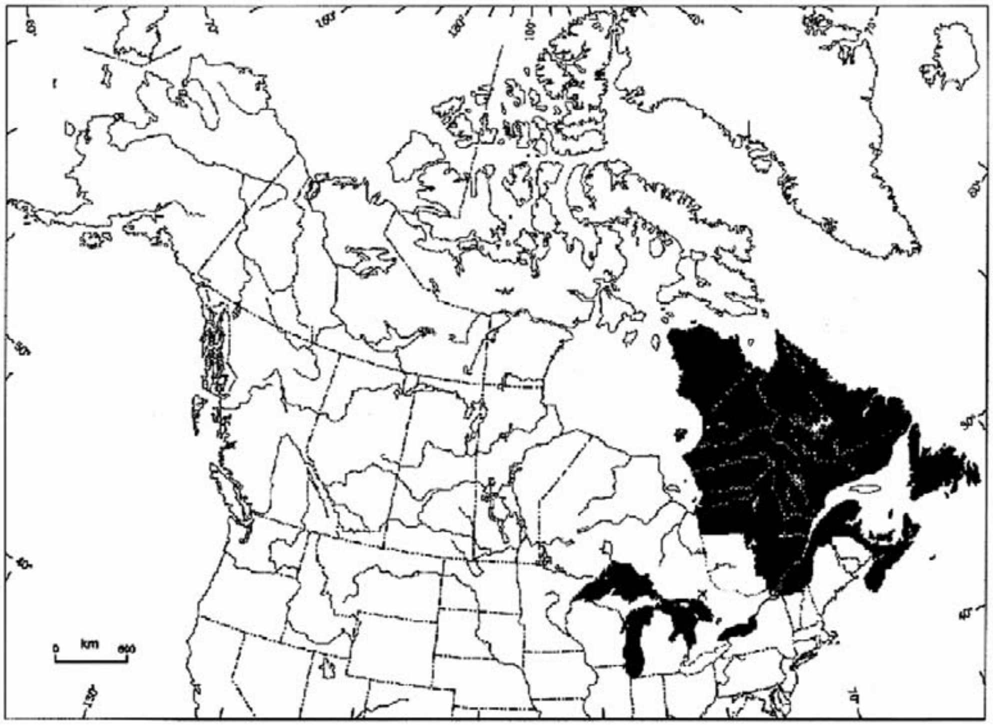

Figure 3. Current Canadian distribution of Atlantic salmon (*Salmo salar*). The shading refers to the general areas where the presence of Atlantic salmon has been confirmed through literature records or through observation; at the scale of this map, these locations are approximations. The X indicates the landlocked Trout Lake, Ontario population. Both the Trout Lake and Great Lakes populations (currently including Ontario) are introduced populations as a direct result of stocking efforts.

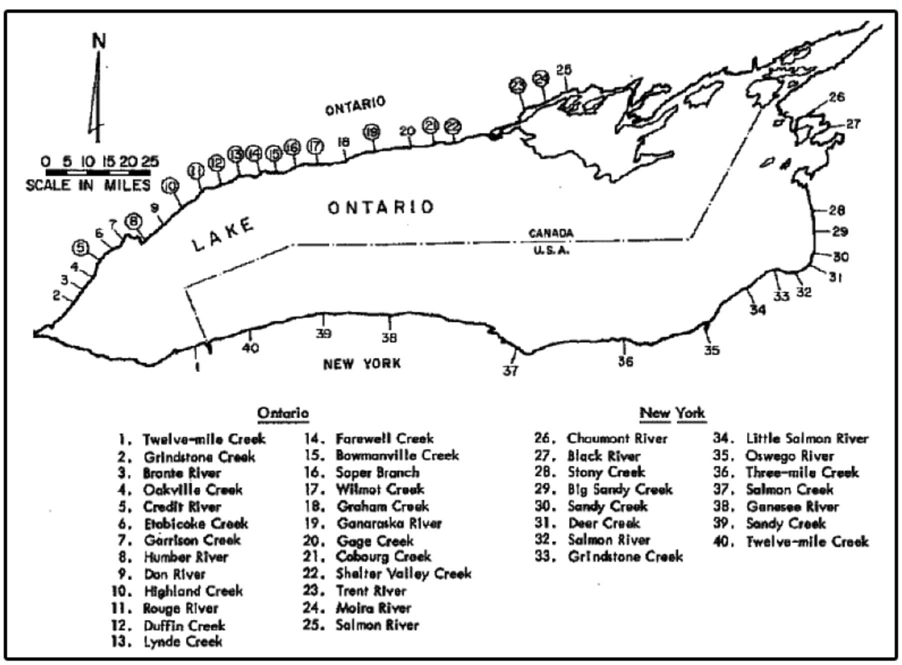

Figure 4. Tributaries of Lake Ontario in which Atlantic salmon were native: circled numbers indicate tributaries in which native salmon were planted (Parsons 1973).

HABITAT

Habitat requirements

Elson (1975) described a good Atlantic salmon river as having clean water seldom rising above about 25°C with a general gradient of about 2-11.5 m/km. The river should have a naturally graded, stable bed with a stony bottom comprised of particles varying in size from coarse sand and gravel to large boulders. However, Atlantic salmon have specific habitat requirements at each stage of their life history.

Adult Atlantic salmon build redds, or nests, and spawn in areas of shallow (20-30 cm) and swift-running water (40-50 $cm \cdot s^{-1}$), mainly located near the banks of the river where the flow of the water is broken (Bardonnet & Baglinière 2000; Moir *et al*. 1998). The substrate is made up of a small proportion of sand and a large proportion of coarse materials ranging from gravel to cobble (Bardonnet & Baglinière, 2000). These areas are also characterized by low (0.2%) to moderate (1%) gradients (Elson 1975).

Lake Ontario salmon in particular were observed to spawn on gravel shoals in clear, cold streams with rather steep gradients (Parsons 1973). Conditions appropriate for such spawning grounds are typically found at the upstream side of riffles or gravel bars where the concentration of fines is low (10-15% by weight) and permeability is high (>900 $cm \cdot h^{-1}$) and thus dissolved oxygen levels are high (Peterson 1978; cited in Fleming 1998). Spawning runs, in Lake Ontario tributaries, typically began in October (Goodyear *et al*. 1982) and spawning typically began in mid-November; but an April/May run was known to occur in streams west of Toronto (Huntsman 1944).

Alevins emerge from the egg and they usually remain near the incubation area (unless taken downstream as drift) until the absorption of the yolk sac is complete. As fry, the salmon prefer habitat similar to the spawning areas and may remain there or disperse to similar habitat (riffles with coarse substrate) within 200 m downstream of the redd (Beall *et al*. 1994).

<u>Juvenile Habitat</u>

Atlantic salmon parr, ages 1-3 years, settle in riffles characterized by cobble substrate, water velocities of 10-60 $cm \cdot s^{-1}$, and shallow to intermediate water depth (20-70 cm) (Heggenes & Salveit 1990). In Lake Ontario tributaries in particular, juvenile Atlantic salmon have been found to prefer areas above barriers where stream gradients are typically steeper and rock substrate is more abundant (Stanfield and Jones 2003).

Juvenile Atlantic salmon are typically benthic drift feeders and rely on the swift currents to supply a continuous forage base (Wankowski & Thorpe 1979). Rimmer *et al*. (1984) and Cunjak (1996) demonstrated an autumnal shift to deeper stream areas by juveniles. The over-wintering habitats are mainly characterized by suitably sized, unembedded rock shelters (>15-20 cm in diameter) (Rimmer *et al*. 1984). The size of the “home stone” is usually correlated with the size of the parr (Cunjak 1988).

Adult Habitat

'Lake' salmon typically remain in their lake until immediately prior to spawning at which time they ascend into their natal stream and establish a spawning site. The small size of most tributaries of Lake Ontario and their low flow and volume were, in most cases, unfavourable for the extended residency of large salmon (Parsons 1973). Adults rarely remained in the streams longer than 1-week post spawn; none were present in the streams in December (Parsons 1973). Little is known about the preferred lacustrine habitat of Atlantic salmon except that deep, cool, oligotrophic conditions within the host lake, a forage base that includes rainbow smelt (*Osmerus mordax*), and the presence of feeder streams providing suitable spawning and nursery habitat, appear to be the most ecologically suitable (MacCrimmon & Gots 1979, Cuerrier 1983). With a surface area of 18,960 km^2, an average depth of 86 m (Lake Ontario LaMP 2004), and at the time when Atlantic salmon were plentiful, and there were few competitors for food, Lake Ontario may have served the same function for adult and juvenile lake salmon as the ocean did for anadromous populations.

Trends

Recently, there have been significant efforts to restore and enhance the habitat in and around traditional salmon spawning streams, particularly in riparian areas. The removal and failure of numerous dams have increased access to more suitable spawning areas, and improved the potential for stocked Atlantic salmon to survive and breed in Lake Ontario tributaries. It is important to note that the continued increase in urbanization (and associated increase in percent impervious cover) of the Greater Toronto Area is likely to have direct and indirect impacts on the physio-chemical and biological characteristics of streams within associated watersheds (Stanfield and Kilgour 2005, Stanfield *et al*. 2005).

Within the lake itself, there have also been many changes that may impact Atlantic salmon suvival including the introduction of Pacific salmon and other non-native salmonine species (Christie 1973), and the invasion of Lake Ontario by sea lamprey (Christie 1972) and zebra mussels.

BIOLOGY

Reproduction

Lake Ontario Atlantic salmon appeared in the spawning tributaries as early as March and early April; whereas Gulf of St Lawrence salmon do not begin their migration before May, which agrees with the timing of warming of the water there (Huntsman 1944).

The female Atlantic salmon selects a nesting site in a gravel-bottom riffle area and then uses her caudal fin to dig a nesting depression or redd (Fleming 1998). The eggs and sperm are deposited in the redd and then covered with gravel by the female. This activity is repeated, including redd creation, until spawning is completed (Fleming 1998). Atlantic salmon are iteroparous; spawning repeatedly during their lifetime. The number of eggs varies from population to population, but the average female deposits approximately 700 eggs/pound (~1540 eggs/kg) of body weight (Scott and Crossman 1973). Following spawning, any surviving adult fish or kelt, drift downstream. They begin feeding and may return the following or subsequent years to spawn again.

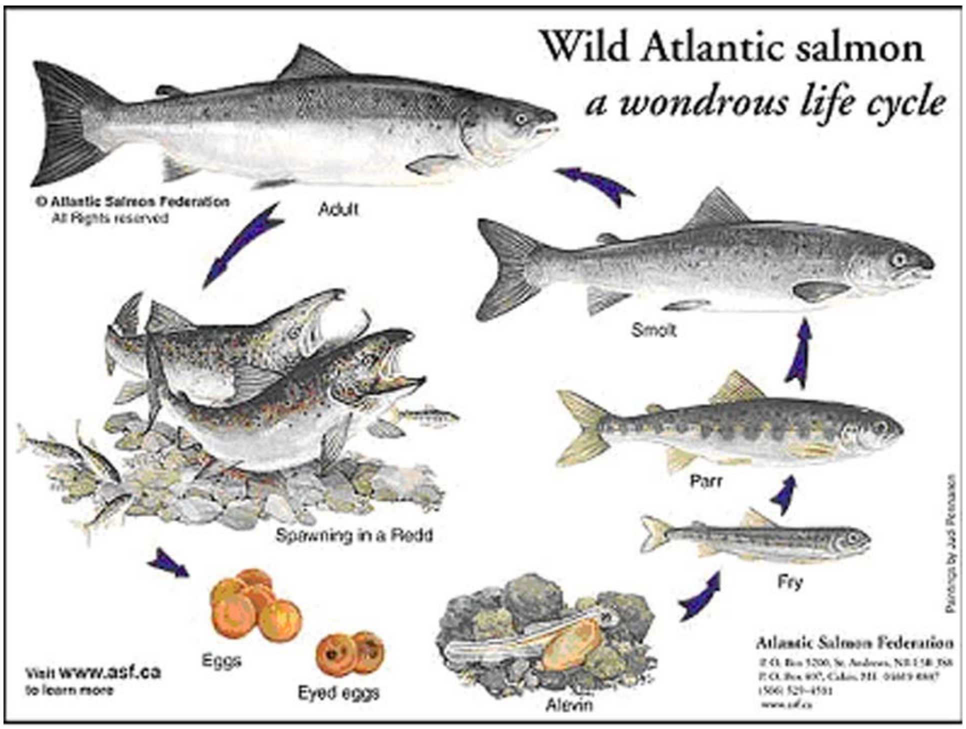

Figure 5. Life cycle of the Atlantic salmon courtesy of the Atlantic Salmon Federation. Original watercolour by J.O. Pennanen.

Physiology

Atlantic salmon, like all other bony fishes, are ectothermic and so are dependent upon the surrounding water temperature to cue migratory patterns, to drive metabolic processes, and to determine the rate and success of progression from one life stage to the next (Dymond 1963; Elson 1975; Wilzbach *et al.* 1998). Water temperature is an important factor in river ascent by returning adults, together with river discharge (Banks, 1969). Dependent upon the location of the population, adult salmon ascend spawning streams following afternoon temperature maxima between 16°C and 26°C (Elson 1975). Optimum temperature for egg fertilization and incubation is approximately 6°C (MacCrimmon & Gots 1979). Most juvenile growth has been found to occur at temperatures above 7°C (Elson 1975). The preferred or optimal summer stream temperature for the growth and survivorship of Atlantic salmon is 17°C (Javoid &

Anderson 1967), while the upper incipient lethal temperature for Atlantic salmon is 27.8°C (Garside 1973); however, adult and juvenile salmon may live for short periods above the ultimate lethal temperature (Fry 1947). A sudden increase in incipient temperature of 10°C may bring about the death of resident salmon at temperatures considerably below the upper lethal temperature (MacCrimmon & Gots 1979).

Atlantic salmon juveniles undergo a series of changes at approximately 2-3 years of age and at a critical body length (varies according to location and population) which leads to outmigration (McCormick *et al*. 1998). Behavioural changes include: loss of positive rheotactic behaviour and territoriality, adoption of a downstream orientation, and schooling tendencies (McCormick *et al*. 1998). The outmigrating period is a critical stage for imprinting to odours used for homing (McCormick *et al*. 1998). The transition is cued by photoperiod and temperature, while temperature and water flow appear to be key factors regulating the timing of downstream movements (McCormick *et al*. 1998).

Movements/dispersal

When juvenile Atlantic salmon reach a certain size-related developmental stage in freshwater, they leave their rearing tributaries in spring and head downriver, to marine or lacustrine feeding areas (McCormick *et al*. 1998). Although growth opportunities are generally better at sea than in fresh water, and mortality may be higher in the marine environment, the "decision" as to whether greater advantage is gained from migration or residence depends on the balance of these two factors (Gross *et al.* 1988). For Lake Ontario salmon, the availability of prey in the lake may have rendered the need to travel the approximately 2400 kilometres back to the Atlantic Ocean unnecessary.

Historically, there was controversy as to whether Lake Ontario Atlantic salmon made the lengthy migration to the sea or whether they were permanent freshwater residents. Wilmot alluded to the fact that there might be both an anadromous form and a lake-resident form of Atlantic salmon in Lake Ontario (in Parsons 1973). In 1938, A. A. Blair published results of a comparison of scales from museum specimens of Lake Ontario Atlantic salmon with those of i) an ouananiche specimen form Lake St. John and ii) a sea salmon from Miramichi Bay, N.B. Based on the character of the growth of these fish (measured average widths of 10 scale ridges formed during the first summer), Blair concluded that: " the difference between the ouananiche salmon from Lake St. John and the Lake Ontario salmon is not significant but the difference between Lake Ontario salmon and the sea salmon from Miramichi Bay is significant." This study provided evidence that some individual Lake Ontario Atlantic salmon were non-anadromous forms.

Atlantic salmon remain in their natal stream for 2 to 3 years post hatch at which time they migrate to the sea or lake (depending upon whether the population is anadromous or non-anadromous). The fish mature in the larger body of water and migrate back to their natal stream to spawn following 1 or 2 years of feeding and growth at sea or in the lake. The Lake Ontario population was thought to ascend the streams in preparation for spawning in two separate runs, one in early spring (almost immediately following ice out) and another in September and October (Dymond 1965). East of Toronto, salmon entered streams in the fall during the spawning season in October and November with exceptionally few entering in late September; both the Humber and the Credit rivers are stated to have had both spring and fall runs (Huntsman 1944). Atlantic salmon in Lake Ontario may have dispersed throughout the lake. Regardless of the locations, mature adults could be expected to have returned to their natal streams to spawn.

Nutrition and feeding behaviour

Stream-dwelling juvenile salmonids are visual predators that forage by holding station in the water current within a defended territory and darting out to intercept prey (Wankowski 1981, Tucker and Rasmussen 1999). Juvenile Atlantic salmon feed mainly upon aquatic insect larvae including chironomids, mayflies, caddisflies, blackflies and stoneflies that are supplied by the current (Scott & Crossman 1973). Upon entry to the marine or lake environment, smolts feed opportunistically, primarily near the surface. Their diet includes invertebrates, amphipods, euphausiids and fish (Hislop & Youngson 1984). As post-smolts grow to adulthood in a marine environment, fish such as capelin (*Mallotus villosus*) and herring (*Clupea harengus*) become an increasingly dominant component of their diet (Mills 1989). In Lake Ontario, the primary forage fish currently available to the Atlantic salmon are two non-native species: alewife (*Alosa pseudoharengus*) and rainbow smelt (*Osmerus mordax*). Adults cease feeding when they begin their migration to the spawning grounds and consequently are in declining physiological condition at the time of spawning.

Lake Ontario salmon were known to have growth rates more similar to anadromous salmon than to non-anadromous salmon (Parsons 1973). Rather than indicating that the Lake Ontario form was anadromous, however, this suggests that the conditions in the sea and Lake Ontario were more favourable for growth than those in relatively small lakes inhabited by non-anadromous salmon.

Of some concern to the re-establishment of Atlantic salmon in Lake Ontario is a condition of thiamine deficiency that has been linked to a diet rich in alewife and smelt. Both of these species contain high levels of thiaminase, an enzyme that catalyzes the destruction of thiamine (Ketola *et al.* 2000). Results of several studies demonstrated that recruitment in non-anadromous populations in New York has been compromised by severe thiamine deficiency (Fisher *et al*. 1996, Ketola *et al*. 2000). Thiamine deficiency can result in high mortality rates of eyed eggs (Ketola *et al*. 2000) and swim-up fry during yolk absorption (Fisher *et al*. 1996, Fynn-Aikins *et al.* 1998). This condition has been called "Cayuga syndrome", "early mortality syndrome" (EMS) or "swim-up syndrome" (Fynn-Aikins *et al.* 1998). Alewife and smelt colonized Lake Ontario in the late 1800s and early 1900s, respectively (Christie 1972). These non-native species are the primary prey fish for salmon and trout in the lake today. The dependence of Atlantic salmon on a diet of alewife and smelt lends support to the concern that thiamine deficiency may be affecting natural reproduction. Research about early mortality syndrome is ongoing.

Interspecific interactions and survival

Factors affecting the survival of Atlantic salmon change with each life stage. Survival from the egg to alevin stage is dependent upon stream temperature at incubation and hatch, the amount of oxygen permeating the spawning gravel, the degree of siltation and the stability of the nest (i.e., whether it is re-excavated by another spawning female) (Mills 1989).

Survival from the fry to parr stage is primarily dependant upon optimal stream temperature which facilitates growth, and the nature and degree of competition with other salmonids for both food and territory (Gibson 1981, Mills 1989, Scott *et al*. 2003). Juvenile rainbow trout are typically more aggressive than Atlantic salmon of the same age; however, this does not automatically translate to superior competitive ability (Hearn & Kynard 1986, Volpe *et al*. 2001). While the two species demonstrate some degree of habitat overlap, and thus potentially engage in inter-specific competition, juvenile Atlantic salmon are more associated with positions close to the substrate (riffle areas) and rainbow trout with the water column (or pool habitats) (Hearn & Kynard 1986, Volpe *et al*. 2001). Recent research conducted in Lake Ontario streams also suggests that Atlantic salmon and rainbow trout juveniles can coexist successfully in streams where the habitat is suitable for both species (Stanfield & Jones, 2003). Coho salmon is another non-native salmonid species that through stocking has established a large, self-sustaining population in Lake Ontario (Scott *et al*. 2003). The presence of chinook in the Lake Ontario system at very high densities has the potential to negatively affect Atlantic salmon behaviour and restoration efforts (Scott *et al*. 2003). Yet another limiting factor for the survival of young-of-the-year fish is the threat of predation by larger Atlantic salmon, other resident fish species and piscivorous birds (Mills 1989). The possibility for negative interactions between Atlantic salmon and other salmonine species such as rainbow trout (*Onchorhynchus mykiss*) poses a key concern to Atlantic salmon restoration (Stanfield and Jones 2003).

Adaptability

There is a recognized association between ‘healthy’ Atlantic salmon populations and pristine or stable natural environments. This species has demonstrated a low tolerance to environmental degradation and thus has been considered by many researchers as a potential indicator of environmental decline (Wilzbach *et al*. 1998). It is important to note, however, that it is the changes wrought by disturbances that cause Atlantic salmon to suffer; once the rate of change has slowed; the salmon can adapt and potentially flourish in the new environmental steady state.

The life cycle of the Atlantic salmon is very complex (Figure 5), involving many different habitats and physio-chemical requirements. Increases in stream temperature above the optimal range can compromise the incubation of eggs, the emergence of fry, the growth of juveniles, and the timing of smoltification. Increased sediment loads and siltation can smother eggs in the nest by filling in the interstitial spaces in the gravel and can also restrict the ability of the visual feeding juveniles to capture prey items. Natural disturbances can be equally as catastrophic as human-induced disturbance to Atlantic salmon populations. A mid-winter ice breakup and subsequent flood in Catamaran Brook, N.B. scoured salmon nests, causing significant egg mortality (Cunjak *et al*. 1998).

Atlantic salmon have been raised in hatcheries since approximately 1866 when the federal Newcastle Hatchery was first established on Wilmot Creek (McCrimmon 1950). The resulting fry and smolts have been stocked in many tributaries of Lake Ontario. Traditionally Lake Ontario was stocked with non-native Atlantic salmon, but recently, researchers have been searching for remnant specimens of the original Lake Ontario stock. One possibility had been that some fish of the Lake Ontario basin (NY side) were stocked into waters of Argentina; however, further investigation has suggested that the Argentinian fish originated from the Grand Lake stream hatchery identified in McCrimmon & Gotts (1979) (pers. comm., Gerry Smitka). Comparisons of DNA samples from Argentina, Maine (West Grand Lake, Sebago Lake), and Lake Ontario (wall mounts and vertebrae samples from the 15th century from an archeological dig along the north shore of Lake Ontario) will be conducted to confirm their relatedness.

POPULATION SIZES AND TRENDS

Observations of the historical population levels of Atlantic salmon in Lake Ontario have been largely based on anecdotal information rather than discrete population estimates. However, the large numbers of Atlantic salmon in Lake Ontario began to show marked decline in number in the mid-1800s and were no longer present before 1900 (Parsons 1973, Scott & Crossman 1973). The colonization of Upper Canada in the late 1700s led to the demise of the Atlantic salmon in Lake Ontario. As recounted by Lady Simcoe, prior to 1800, the rivers and creeks abounded with salmon; however, during the ensuing years settlers fished heavily with nets and spears and erected dams at the mouths of rivers to support growing industry, all to the detriment of the salmon (Dunfield 1985). Although there are no early population estimates, anecdotal accounts suggest that, prior to its extirpation, the Atlantic salmon abounded in the tributaries of Lake Ontario. One resident of the Credit River area stated that around 1810 “salmon…swarmed the rivers so thickly that they were thrown out with a shovel and even with the hand" (Simcoe, *Diary*). There seems, however, to be no evidence that when salmon were abundant in streams discharging into Lake Ontario, they were also abundant in the upper part of the St. Lawrence River (Huntsman 1944).

Samuel Wilmot reported in 1879 that for some years previous to 1868, scarcely any Atlantic salmon could be found in the streams tributary to Lake Ontario (Wilmot 1879). The last native salmon was thought to have been caught in 1898 (Dymond 1965, Carcao 1986, Scott & Crossman 1973).

There have been several attempts to strengthen, and now to re-establish, a population of Atlantic salmon in Lake Ontario since the 1866 when Samuel Wilmot established his hatchery in Newcastle, Ontario (Dunfield 1985, Dymond 1965). At first, the stocking effort had a distinct effect on the salmon population, as population increases were recorded in many Lake Ontario tributaries. By 1879, however, the number of salmon observed in the streams was falling to the point that, in1881, Wilmot is reported as stating that "only a half dozen adult fish and a few dirty discoloured grilse" were seen (Dymond 1965).

In the 1940s, the Ontario Department of Lands and Forests attempted to re-establish Atlantic salmon in Duffin Creek using eggs from Miramichi River stock (Bisset *et al*. 1993). However, mortalities due to high summer stream temperatures and predation shortly after stocking dampened the effect of this stocking attempt as juveniles were only observed in the stream for two years (McCrimmon 1950).

In 1987, the Ontario Ministry of Natural Resources (OMNR) initiated an experimental stocking program. The objective of the program was to re-establish Atlantic salmon in one or more tributaries of Lake Ontario and to provide a sport fishery based on naturally reproducing populations and supplemented by stockings of hatchery-reared fish (Bisset *et al*. 1993). Returns of stocked fish were much lower than expected. In 1995, OMNR established a formal plan to investigate the feasibility of restoring self-sustaining populations of Atlantic salmon to the Lake Ontario basin (Bisset *et al*. 1995). The plan was designed to systematically explore the factors considered to be most important to the successful restoration of self-sustaining populations. Benchmarks for each life stage were set in order to measure progress towards meeting the goals and objectives of the plan. Current stocking by OMNR (see Appendix A) is in support of scientific studies to evaluate stream habitat suitability and species interactions.

In 1983, the New York State Department of Environmental Conservation (NYSDEC) launched an Atlantic salmon restoration program with the objective to restore a self-sustaining spawning stock in New York tributaries yielding at least 2 smolts/100 yd^2 of suitable rearing habitat by 1990 (Abraham 1983). During the late 1980s, Atlantic salmon became a small but consistent component of the lake fishery. Although growth of the adult salmon returning to the study streams was excellent, natural reproduction was non-existent (Eckert 2003). In 1990 the Atlantic salmon program changed from a small-scale experimental project with a stocking target of 50,000 yearlings/year to a larger put-grow-take program (target of 200,000 yearlings/year) that would support a trophy sport fishery (Eckert 2003). Returns of Atlantic salmon failed to meet the expectations of the expanded stocking program. Due to continuing poor returns of stocked fish, NYSDEC has further reduced its Atlantic salmon stocking program (Eckert 2003).

Although the stocking efforts in Lake Ontario to date have been successful in securing a limited number of Atlantic salmon in Lake Ontario and its tributaries, self-sustaining populations have not been established, and there is no discernable evidence of natural reproduction.

Although Atlantic salmon are not native to the other Great Lakes, stocking programs have been initiated by both the U.S. government and non-governmental agencies in Lakes Huron, Michigan and Superior (Appendix B). There has been no evidence of natural reproduction in any of these lakes (pers. comm., OMNR Lake Biologists: J. Bowlby, D. Reid). Although spawning activity has been observed in the St. Marys River population, no definitive evidence of natural reproduction or subsequent recruitment has been documented (Roger Greil, Aquatic Research Laboratory, Lake Superior State University, Sault Ste. Marie, MI).

There is a non-anadromous population in Trout Lake, near North Bay, Ontario that is naturally reproducing (Maraldo *et al*. 1997). Atlantic salmon were first introduced to this lake in 1935 through stocking of fish from the Lac St-Jean area of Quebec (Maraldo *et al*. 1997). Following a significant spill of zinc into Four Mile Creek in 1967, the principal spawning creek of the system, Atlantic salmon were extirpated from Trout Lake. Salmon fingerlings from the Ontario Ministry of Natural Resources, North Bay hatchery were re-introduced to the lake in 1989, and by 1995, low but viable numbers of naturally reproduced Atlantic salmon were captured during electro-fishing surveys (Maraldo *et al*. 1997).

LIMITING FACTORS AND THREATS

The Atlantic salmon, a member of the original aquatic community of Lake Ontario, is no longer a naturally occurring or reproducing entity within the lake. Many conditions contributed to the decline and ultimate disappearance of the salmon in Lake Ontario; however, most are attributable to the settlement of the basin and the alteration of habitat by timbering, agriculture, dams for mills, and the fishing industries (Dymond 1965).

In clearing the land for timber harvest and agriculture, destruction of the salmon's natural environment occurred, since land clearance caused greater and more frequent fluctuation in water levels and periodically produced drought conditions in tributary streams in the summer months (Dunfield 1985). Total land clearance also resulted in soil erosion and silting which degraded critical spawning habitat and is reported to have "suffocated" eggs and fry; hydrochemical changes which altered pH and shifted the balance and concentration of chemicals and nutrients within the stream; and the elevation of water temperature beyond the optimal range for Atlantic salmon (Dunfield 1985).

Atlantic salmon were extensively harvested by early settlers (~ 1792). The species was popular due to the size of the fish, its abundance in all of the major tributaries to Lake Ontario, and the variability it provided to the settlers' diet (Dunfield 1985). By 1840, salmon fishing emerged as a commercial venture in Lake Ontario; by 1866, the fisheries on both the American and Canadian sides of the lake had largely collapsed (Dunfield 1985). Dymond (1965) suggested that while overfishing contributed to the demise of the Atlantic salmon, its influence was in addition to the habitat impacts and was not the sole cause.

Perhaps of greatest consequence to Atlantic salmon populations over their global range has been the construction of mill and driving dams for the timber trade, as well as dams for tanneries, carding mills and gristmills (Dymond 1965, Dunfield 1985). These dams were typically built with no provision for fish passage so salmon were prevented from reaching their native spawning grounds. The fish congregating at the base of the dams were vulnerable and more easily captured by fishermen. In many instances, this resulted in complete elimination of runs of Lake Ontario Atlantic salmon.

It is not possible to determine the date that the last native salmon was caught in Lake Ontario. The last salmon generally believed to be from Lake Ontario, was a 7 lb (3.2 kg) fish reported by the *Globe and Mail* to have been caught off Scarborough Beach in April 1898 (Carcao 1986).

Several challenges to the re-establishment of the Atlantic salmon in Lake Ontario have been mentioned within this document and include: significant changes in the fish community, stream habitat quality, availability of a suitable genetic strain for stocking, possible effects of thiamine deficiency on reproduction and fitness of adults, and interspecific competition, especially in the streams.

SPECIAL SIGNIFICANCE OF THE SPECIES

Few fish have attracted the attention given to the Atlantic salmon, known as the “King of Fish”.

> "Prized by the Gauls, then by the Romans, an abundant commercial fish in the British Isles, mentioned in the Magna Carta, revered by sportsman and esteemed by gourmets, its relation with man has been truly unique" (Scott & Crossman,1973).

Dunfield (1985) suggests that it was the Atlantic salmon that encouraged the territorial expansion and European settlement of the interior of Canada. The availability, in great abundance, of such a fish varied the diet of native North Americans, settlers and military personnel alike. An entire fishing industry was developed in the early 1800s in North America, supporting thousands of commercial fishermen (Dunfield 1985). Atlantic salmon continue to be highly valued by anglers. However, commercial harvesting of North American wild Atlantic salmon has ceased due to the continental-wide decline in harvestable numbers and efforts by conservation organizations (e.g., Atlantic Salmon Federation) to protect remaining numbers.

Atlantic salmon are an ecologically important species that once contributed significantly to the offshore pelagic fish community in Lake Ontario. They also bring nutrients from the lake into the rivers of the watershed and thus enrich the biotic life forms that can exist there. While the Atlantic salmon is important ecologically it has and continues to be a highly prized species worldwide for its cultural and economic significance. The restoration efforts currently being undertaken for Atlantic salmon in Lake Ontario are also consistent with a recent Biodiversity Strategy for Ontario.

Although the original Lake Ontario Atlantic salmon DU is extinct, the species still exists, although at reduced numbers, in its global range.

EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS

The Nature Conservancy has assigned Atlantic salmon an overall Global Heritage Status Rank of G5 (demonstrably widespread, abundant, and secure) and a National Heritage Status Rank of N4 (apparently secure) for both Canada and the United States (NatureServe2001). However, on a local level, a number of populations are at risk: the Gulf of Maine population is listed by the NatureServe as G5T1Q (critically imperiled), Canada's SARA lists the Inner Bay of Fundy Atlantic salmon as Endangered (2003), and the US ESA has listed a Distinct Population Segment of the Atlantic salmon in Maine as Endangered (2000).

The habitat of the Atlantic salmon could in theory be protected under the habitat provisions of the federal Fisheries Act. As of 2000, there are no commercial Atlantic salmon fisheries in Canada or the United States. In Ontario, the season for stocked Atlantic salmon is open from January 1 to September 30, with an allowable harvest of one salmon per day. In Lake Ontario, anglers may take one fish, 63 cm or greater, per day. With the exception of some stream mouths, the tributaries of Lake Ontario in Ontario waters are closed to Atlantic salmon fishing, year-round.

SUMMARY OF STATUS REPORT

Atlantic salmon were once so plentiful in Lake Ontario that they formed a staple in the diet of aboriginal peoples and of early European settlers of the Lake Ontario watershed. The Lake Ontario Atlantic salmon was likely reproductively isolated from its marine conspecifics; further, the population had observably unique phenotypic and behavioural traits providing evidence of adaptation to the freshwater environment of Lake Ontario and its tributaries. It is accepted that many conditions contributed to the decline and ultimate disappearance of the Atlantic salmon in Lake Ontario; however,most are attributable to the human impacts on habitat as well as fishing. There has not been a native Atlantic salmon taken from Lake Ontario since before 1900. Although several stocking programs have been attempted with non-native stocks, to date there has not been success in establishing a self-sustaining population. Providing that habitat restoration efforts continue and that a suitable stocking strain is found, Atlantic salmon might be re-established in Lake Ontario. However, the native Atlantic salmon DU, with a likely history of thousands of years, is extinct in Lake Ontario.

TECHNICAL SUMMARY

Salmo salar
Common name: Atlantic salmon — Saumon atlantique population de lac Ontario
Population name: Lake Ontario population
Range of Occurrence in Canada: Ontario: historically throughout Lake Ontario basin

Extent and Area information	
• *extent of occurrence (EO)(km²) (freshwater phase)*	Formerly Lake Ontario basin, now zero km²
• *specify trend (decline, stable, increasing, unknown)*	Now extirpated
• *are there extreme fluctuations in EO (> 1 order of magnitude)?*	N/A
• *area of occupancy (AO) (km²) (freshwater phase)*	Now zero km²
• *specify trend (decline, stable, increasing, unknown)*	N/A
• *are there extreme fluctuations in AO (> 1 order magnitude)?*	N/A
• *number of extant locations*	None
• *specify trend in # locations (decline, stable, increasing, unknown)*	N/A
• *are there extreme fluctuations in # locations (>1 order of magnitude)?*	N/A
• *habitat trend: specify declining, stable, increasing or unknown trend in area, extent or quality of habitat*	Improving in rivers; possibly declining in lake
Population information	
• *generation time (average age of parents in the population) (indicate years, months, days, etc.)*	Unknown (3-5 years in eastern Canada)
• *number of mature individuals (capable of reproduction) in the Canadian population (or, specify a range of plausible values)*	None
• *total population trend: specify declining, stable, increasing or unknown trend in number of mature individuals*	N/A
• *if decline, % decline over the last/next 10 years or 3 generations, whichever is greater (or specify if for shorter time period)*	N/A
• *are there extreme fluctuations in number of mature individuals (> 1 order of magnitude)?*	N/A
• *is the total population severely fragmented (most individuals found within small and relatively isolated (geographically or otherwise) populations between which there is little exchange, i.e., ≤ 1 successful migrant / year)?*	N/A
• *list each population and the number of mature individuals in each*	N/A
• *specify trend in number of populations (decline, stable, increasing, unknown)*	N/A
• *are there extreme fluctuations in number of populations (>1 order of magnitude)?*	N/A
Threats (actual or imminent threats to populations or habitats)	
Causes of extirpation include deterioration in spawning habitat due to timbering, agriculture, and mills and dams across rivers that prevented access to spawning grounds, in addition to extensive commercial and food fisheries.	

Rescue Effect (immigration from an outside source)	Unknown
• *does species exist elsewhere (in Canada or outside)?*	Atlantic salmon are found in eastern Canada; however, these populations are likely to be genetically distinct from the Lake Ontario Atlantic salmon DU. Stocking of North American strains into Lake Ontario has not produced a self-sustaining population.
• *status of the outside population(s)?*	Generally declining or stable at reduced numbers; Inner Bay of Fundy Atlantic salmon designated Endangered (COSEWIC 2001; SARA 2003). Most US populations designated Endangered (ESA 2000).
• *is immigration known or possible?*	No
• *would immigrants be adapted to survive here?*	Unknown
• *is there sufficient habitat for immigrants here?*	Unknown
Quantitative Analysis	

Status and Reasons for Designation

Status: Extirpated	**Alpha-numeric code**: Not Applicable

Reasons for Designation:

Once a prolific species throughout the Lake Ontario watershed, there has been no record of a wild Atlantic salmon since 1898. The Lake Ontario Atlantic salmon was extinguished through habitat destruction and through over-exploitation by a food and commercial fishery. Attempts to re-establish Atlantic salmon through stocking have failed, and the original strain is no longer available.

Applicability of Criteria

Criterion A: (Declining Total Population): Not applicable.

Criterion B: (Small Distribution, and Decline or Fluctuation): Not applicable.

Criterion C: (Small Total Population Size and Decline): Not applicable.

Criterion D: (Very Small Population or Restricted Distribution): Not applicable.

Criterion E: (Quantitative Analysis): Not available.

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Appendix A. Partial stocking history of Atlantic salmon in Lake Ontario. Numbers indicate all fry, fall and spring fingerling, yearling and adult fish stocked. Sources: Lake Ontario Management Unit (LOMU) Annual Reports, Great Lakes Fishery Commission (GLFC) stocking database 2001, and the United States Fish & Wildlife Service (USFWS). Blank spaces indicate that no information was available for that year.

Year	OMNR	NYSDEC	USFWS	USGS-TUN	Total
1940	40,000				40,000
1945	40,000				40,000
1946	84,710				84,710
1947	40,000				40,000
1948	98,400				98,400
1949	212,000				212,000
1952	20,800				20,800
1955	225,725				225,725
1957	10,800				10,800
1962	39,960				39,960
1963	5,770				5,770
1964	15,400				15,400
1965-1984					
1985		68,000			68,000
1986		55,400			55,400
1987	1,009	65,329			66,338
1988	48,995	55,430	25,000		129,425
1989	88,032	64,200			152,232
1990	66,847	33,320			100,167
1991	59,145	178,000			237,145
1992	34,758	169,305			204,063
1993	57,366	169,000			226,366
1994	66,812	188,000			254,812
1995	135,038	226,150	6,870		368,058
1996	131,128	119,000	178,117		428,245
1997	138,069	75,000	59,174	1,831	272,243
1998	167,763	75,000	31,882		274,645
1999	174,340	271,500	89,728		535,568
2000	270,874	187,594			458,468
2001	204,709	161,757			366,466
2002	249,627	92,236			341,863
2003	212,049	82,604			294,653

Appendix B. Partial stocking history by U.S. agencies of Atlantic salmon in Lakes Huron, Michigan and Superior as obtained from the GLFC stocking database 2001. Numbers indicated include all fry, fall and spring fingerling, yearling and adult fish stocked. Blank spaces indicate that no information was available for that year.

Year	Huron	Michigan	Superior
1972		10,000	
1973		15,000	
1974		21,863	
1975		22,172	
1976		20,590	
1977		18,589	
1978		46,212	
1979			
1980			
1981		19,558	
1982		45,030	
1983			
1984			
1985			
1986			
1987			
1988		17,340	
1989	18,596	42,871	31,251
1990	33,253		173,702
1991	32,804		88,576
1992	20,703		98,248
1993	70,164		
1994	33,275		
1995	66,695		
1996	43,725		
1997	43,568		
1998	52,174		