5.0 Indicator Reports and Assessments

The following indicator reports have been arranged in numerical order using the indicator I.D. number in order to facilitate the rapid location of any indicator report by the reader.

Salmon and Trout

Indicator #8

Overall Assessment

Status: **Mixed**
Trend: **Improving**
Rationale: **The number of stocked salmonines per year is decreasing due to improvements in suppressing the abundance of the non-native preyfish, alewife. Many of the introduced salmonines are also reproducing successfully in the Great Lakes. The combined effect of a decrease in the number of alewife, as well as the increased health and reproduction of the salmonine population is creating improvement in the Great Lakes ecosystem.**

Lake-by-Lake Assessment

Lake Superior
Status: Fair
Trend: Improving, moving towards Good
Rationale: The number of stocked salmonines per year in Lake Superior is decreasing at a steady rate. Populations of salmon, rainbow trout and brown trout are being stocked at suitable rates to restore and manage indigenous fish species in Lake Superior. Lake trout are considered rehabilitated.

Lake Michigan
Status: Mixed
Trend: Slightly Improving
Rationale: The number of salmonines stocked each year in Lake Michigan is declining. One goal for Lake Michigan is to establish self-sustaining lake trout populations. Currently, more salmon are stocked than lake trout. This lake has the highest stocking rates of all the Great Lakes.

Lake Huron
Status: Fair
Trend: Improving
Rationale: The number of salmonines stocked each year in Lake Huron is declining, largely due to increased natural reproduction, especially of Chinook salmon. This lake now has the third highest number of stocked salmonines, suggesting an improved reproduction rate leading toward a greater balance in the ecosystem. There are recent indications of more widespread natural production of juvenile lake trout.

Lake Erie
Status: Good
Trend: Improving
Rationale: Lake Erie relies least on stocking of the Great Lakes. The objective for Lake Erie is to provide sustainable harvests of valued fish including lake trout, rainbow trout, and other salmonids. Fisheries restoration programs in Ontario and New York State have established regulations to conserve the harvest and increase fish populations for the next five years.

Lake Ontario

Status: Mixed

Trend: Unchanging

Rationale: Lake Ontario now has the second largest stocking rate (after Lake Michigan). The number of stocked salmonines has slightly declined in the last couple decades, but stocking numbers have been fairly constant in the last three years. The main objective for Lake Ontario is to have a diversity of naturally produced salmon and trout, with an abundance of rainbow trout and Chinook salmon as the top predator. There is an abundance of rainbow trout and Chinook salmon, but the salmon and trout are not naturally reproducing sufficiently to reduce the high numbers of stocked fish each year.

Purpose

- To assess trends in populations of introduced salmon and trout species
- To infer trends in species diversity in the Great Lakes basin
- To evaluate the resulting impact of introduced salmonines on native fish populations and the preyfish populations that support them

Ecosystem Objective

In order to manage Great Lakes fisheries, a common fish community goal was developed by management agencies responsible for the Great Lakes fishery. The goal is:

> "To secure fish communities, based on foundations of stable self-sustaining stocks, supplemented by judicious plantings of hatchery-reared fish, and provide from these communities an optimum contribution of fish, fishing opportunities and associated benefits to meet needs identified by society for wholesome food, recreation, cultural heritage, employment and income, and a healthy aquatic environment" (Great Lakes Fishery Commission (GLFC) 1997).

Fish Community Objectives (FCOs) for each lake address introduced salmonines such as the Chinook and coho salmon, and the rainbow and brown trout (see Table 1 for definitions of fish terms). The following objectives are used to establish stocking and harvest targets consistent with FCOs for restoration of native salmonines such as lake trout, brook trout, and, in Lake Ontario, Atlantic salmon:

Term	Definition
Salmonine	Refers to salmon and trout species
Salmonid	Refers to any species of fish with an adipose fin, including trout, salmon, whitefish, graying, and cisco
Pelagic	Living in open water, especially where the water is more than 20 m deep

Table 1. Glossary of various terms used in this report.

Lake Ontario (1999)
Establish a diversity of salmon and trout with an abundant population of rainbow trout and the Chinook salmon as the top predator supported by a diverse preyfish community with the alewife as an important species. Amounts of naturally produced (wild) salmon and trout, especially rainbow trout that are consistent with fishery and watershed plans. Lake trout should be established as the top predator in the offshore benthic community.

Lake Erie and Lake St. Clair (2003)
Manage the eastern basin to provide sustainable harvests of valued fish species, including lake trout, rainbow trout, and other salmonids and non-salmonid species.

Lake Huron (1995)
Establish a diverse salmonine community that can sustain an annual harvest of 2.4 million kg with lake trout the dominant species and stream-spawning species also having a prominent place.

Lake Michigan (1995)
Establish a diverse salmonine community capable of sustaining an annual harvest of 2.7 to 6.8 million kg (6 to 15 million lb), of which 20-25% is lake trout, and establish self-sustaining lake trout populations.

Lake Superior (2003)
Manage populations of Pacific salmon, rainbow trout, and brown trout that are predominantly self-sustaining but may be supplemented by stocking that is compatible with restoration and management goals established for indigenous fish species. Achieve and maintain genetically diverse self-sustaining populations of lake trout that are similar to those found in the lake prior to 1940, with lean lake trout being the dominant form in nearshore waters, siscowet lake trout the dominant form in offshore waters, and humper lake trout a common form in eastern waters and around Isle Royale.

State of the Ecosystem

First introduced to the Great Lakes in the late 1870s, non-native salmonines have emerged as a prominent component of the Great Lakes ecosystem and an important tool for Great Lakes fisheries management. Fish managers stock non-native salmonines to suppress abundance of the non-native preyfish, alewife, thereby reducing alewife predation and competition with native fish, while seeking to avoid large oscillations in salmonine-predator/alewife-prey ratios. In addition, non-native salmonines are stocked to create recreational fishing opportunities with substantial economic benefit (Rand and Stewart 1998).

After decimation of the native top predator (lake trout) by the non-native, predaceous sea lamprey, stocking of non-native salmonines increased dramatically in the 1960s and 1970s. Based on stocking data obtained from the GLFC, approximately 922 million non-native salmonines were stocked in the Great Lakes basin between 1966 and 2005. This estimate excludes the stocking of the Atlantic salmon native to Lake Ontario. Non-native salmonines do reproduce in the Great Lakes. For example, many of the Chinook salmon in Lake Huron are wild and not stocked. Since 2002, 74 million non-native salmonines have been stocked in the Great Lakes, but the number of stocked salmonines has decreased 32% from 2002 to 2004.

Of non-native salmonines, Chinook salmon are the most heavily stocked, accounting for about 45% of all non-native salmonine

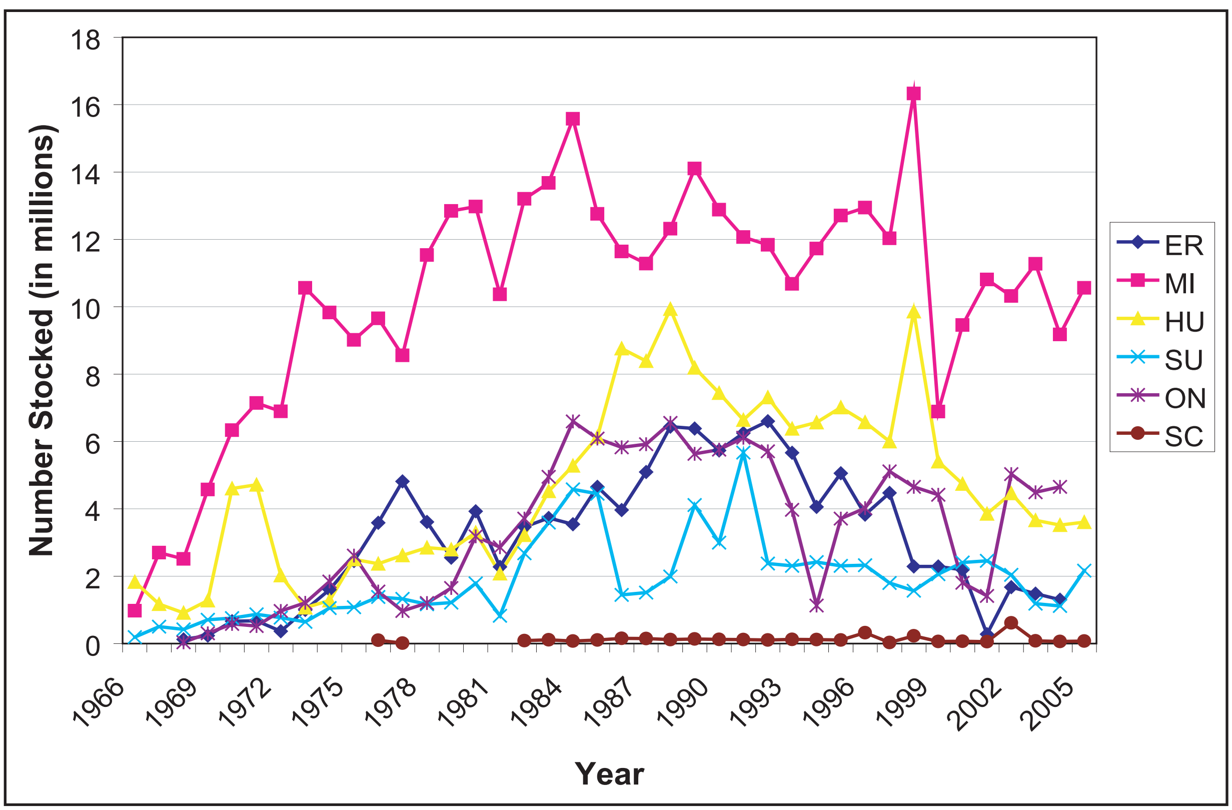

Figure 1. Non-Native salmonine stocking by species in the Great Lakes, 1966-2004 excluding Atlantic salmon in Lake Ontario and brook trout in all Great Lakes.

ER: Lake Erie, MI: Lake Michigan; HU: Lake Huron; SU: Lake Superior; ON: Lake Ontario; SC: Lake St. Clair.

Source: Great Lakes Fishery Commission Fish Stocking Database (www.glfc.org/fishstocking)

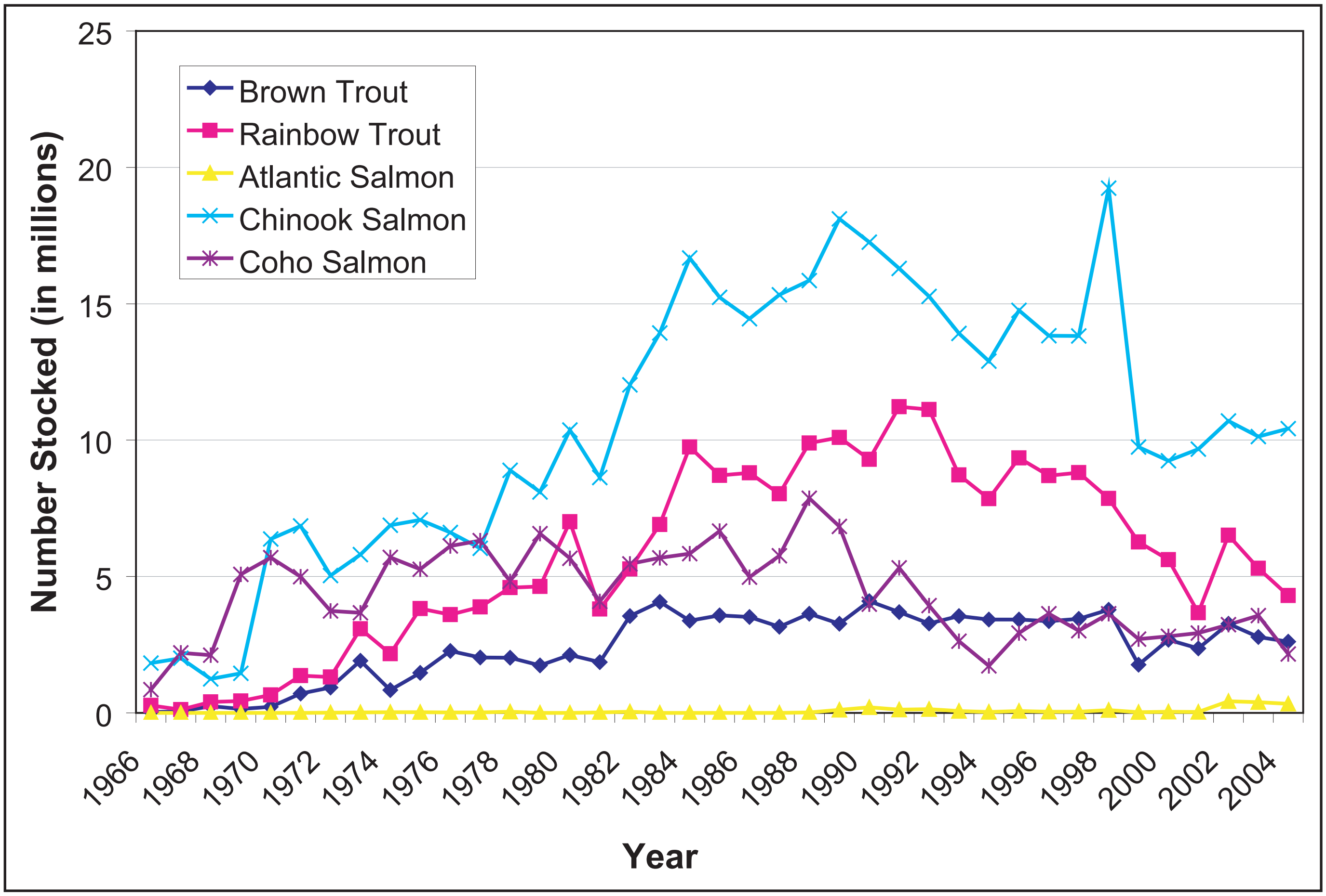

Figure 2. Total number of non-native salmonines stocked in the Great Lakes, 1966-2005 excluding Atlantic salmon in Lake Ontario and brook trout in all Great Lakes.

Source: Great Lakes Fishery Commission Fish Stocking Database (www.glfc.org/fishstocking)

releases (Figure 1). Rainbow trout are the second highest non-native stocked species, accounting for 25% of all non-native salmonine releases. Chinook salmon, which prey almost exclusively on alewife, are the least expensive of all non-native salmonines to rear, thus making them the backbone of stocking programs in Lake Michigan, Lake Huron and Lake Ontario (Bowlby and Daniels 2002). Like other salmonines, Chinook salmon are also stocked in order to provide an economically important sport fishery. While Chinook salmon have the greatest prey demand of all non-native salmonines, an estimated 69,000 metric tons (76,000 tons) of alewife in Lake Michigan alone are consumed annually by all salmonine predators (Kocik and Jones 1999).

Data are available for the total number of non-native salmonines stocked in each of the Great Lakes from 1966 to 2005 (Figure 2). Lake Michigan is the most heavily stocked, with a maximum stocking level in 1998 greater than 16 million non-native salmonines. In contrast, Lake Superior has had the lowest rates of stocking, with a maximum greater than 5 million non-native salmonines in 1991. Lake Huron and Lake Erie both display a similar overall downward trend in stocking, especially in recent years, and Lake Ontario has a slightly declining trend in stocking.

The number of stocked salmonines per year in Lake Superior has been nearly steady since 1992. Populations of salmon, rainbow trout and brown trout are being stocked at suitable rates to restore and manage indigenous fish species in Lake Superior. Stocking rates have decreased in recent years suggesting successful reproduction rates and suitable conditions for an improvement towards a balanced ecosystem in the near future.

The number of salmonines stocked each year in Lake Michigan is declining, although the stocking rates remain the highest of all the Great Lakes. One goal for Lake Michigan is to establish self-sustaining lake trout populations. However, lake trout have not yet re-established naturally reproducing populations. There are currently more salmon than lake trout being stocked.

One goal for Lake Huron is to restore lake trout as the dominant species. Its populations in Lake Huron and Lake Michigan were decimated in the 1950s by over-fishing and predation by the non-native sea lamprey (U.S. Fish and Wildlife Service 2005). The number of lake trout in Lake Huron has increased in the last decade due to the decrease in the numbers of sea lamprey (Madenjian and Desorcie 2004). This lake now has the third highest number of stocked salmonines, suggesting a low reproduction rate, but an improvement in the balance of the ecosystem. since these stocking levels are decreasing.

Lake Erie has low rates of salmonine stocking, similar to those for Lake Superior. The objective for Lake Erie is to provide sustainable harvests of valued fish, including lake trout, rainbow trout, and other salmonids. Fisheries restoration programs in Ontario and New York State have established regulations to conserve the harvest and increase fish populations for the next five years (Lake Erie Lakewide Management Plan 2003). This program is well on its way since there have already been improvements in the fish populations.

Lake Ontario currently has the second highest stocking rate, following Lake Michigan, but the annual rates have been generally declining. This trend can be explained by stocking cuts implemented in 1993 by fisheries managers to lower prey consumption by salmonine species by 50% over two years (Schaner *et al*. 2001). The main objective for Lake Ontario is to have a diversity of naturally produced salmon and trout, with an abundance of rainbow trout, and the top predator to be Chinook salmon. Rainbow trout are stocked at the second highest rate in Lake Ontario, following Chinook salmon. Therefore, part of the goal has been met since the Chinook salmon are readily available as the top predator, and rainbow trout are abundant because of the high stocking levels. However, the objective of having naturally producing salmon and trout has not been met. Salmon and trout are stocked not only to create a balance in the ecosystem, but for a popular recreational activity. Sport fishing is a $3.1 billion annual business, according to a recent industry study (Edgecomb, 2006).

Pressures

The introduction of non-native salmonines into the Great Lakes basin, beginning in the late 1870s, has placed pressures on both the introduced species and the Great Lakes ecosystem. The effects of introduction on the non-native salmonine species include changes in rate of survival, growth and development, dispersion and migration, reproduction, and alteration of life-history characteristics (Crawford 2001).

The effects of non-native salmonine introductions on the Great Lakes ecosystem are numerous. Some of the effects on native species are; 1) the risk of introducing and transferring pathogens and parasites (e.g., furunculosis, whirling disease, bacterial kidney disease, and infectious pancreatic necrosis), 2) the possibility of local decimation or extinction of native preyfish populations through predation, 3) competition between introduced and native species for food, stream position, and spawning habitat, and 4) genetic alteration due to the creation of sterile hybrids (Crawford 2001). The introduction of non-native salmonines to the Great Lakes basin is a significant departure from lake trout's historic dominance as key predator.

Most introduced salmonines are now reproducing successfully in portions of the basin, and they are considered naturalized components of the Great Lakes ecosystem. Therefore, the question is no longer whether non-native salmonines should be introduced, but rather how to determine the appropriate abundance of salmonine species in the lakes.

Within any natural system there are limits to the level of stocking that can be maintained. The limits to stocking are determined by the balance between lower and higher trophic level populations (Kocik and Jones 1999). Rand and Stewart (1998) suggest that predatory salmonines have the potential to create a situation where prey (alewife) is limiting and ultimately predator survival is reduced. For example, during the 1990s, Chinook salmon in Lake Michigan suffered dramatic declines due to high mortality and high prevalence of bacterial kidney disease when alewife were no longer as abundant in the preyfish community (Hansen and Holey 2002). Salmonine predators could have been consuming as much as 53% of alewife biomass in Lake Michigan annually (Brown *et al*. 1999). While suppressing alewife populations, managers seek to avoid extreme "boom and bust" predator and prey populations, a condition not conducive to biological integrity. Currently managers seek to produce a predator/prey balance by adhering to stocking ceilings based on assessment of forage species and naturally produced salmonines.

Because of its importance as a forage base for the salmonine sport fishery, alewife is no longer viewed as a nuisance by some managers (Kocik and Jones 1999). However, alewife preys on the young of a variety of native fishes, including yellow perch and lake trout, and it competes with native fishes for zooplankton. In addition, the enzyme thiaminase causes early mortality syndrome in salmonines. Alewife contains high levels of thiaminase, possibly threatening lake trout rehabilitation in the lower four lakes and Atlantic salmon restoration in Lake Ontario.

Management Implications

In Lake Michigan, Lake Huron and Lake Ontario, many salmonine species are stocked to maintain an adequate population to suppress non-native prey species (such as alewife) as well as to support recreational fisheries. Determining stocking levels that will avoid oscillations in the forage base of the ecosystem is an ongoing challenge. Alewife populations, in terms of an adequate forage base for introduced salmonines, are difficult to estimate because there is a delay before stocked salmon become significant consumers of alewife. Meanwhile, alewife can suffer severe die-offs in particularly harsh winters.

Fisheries managers seek to improve their means of predicting appropriate stocking levels in the Great Lakes basin based on the alewife population. Long-term data sets and models track the population of salmonines and species with which they interact. However, more research is needed to determine the optimal number of non-native salmonines, to estimate abundance of naturally produced salmonines, to assess the abundance of forage species, and to better understand the role of non-native salmonines and non-native prey species in the Great Lakes ecosystem. Chinook salmon will likely continue to be the most abundantly stocked salmonine species in Lake Michigan, Lake Huron, and Lake Ontario because they are inexpensive to rear, feed heavily on alewife, and are highly valued by recreational fishers. Fisheries managers should continue to model, assess, and practice adaptive management with the ultimate objective being to support fish community goals and objectives that GLFC lake committees established for each of the Great Lakes.

Comments from the author(s)

This indicator should be reported frequently as salmonine stocking is a complex and dynamic management intervention in the Great Lakes ecosystem.

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