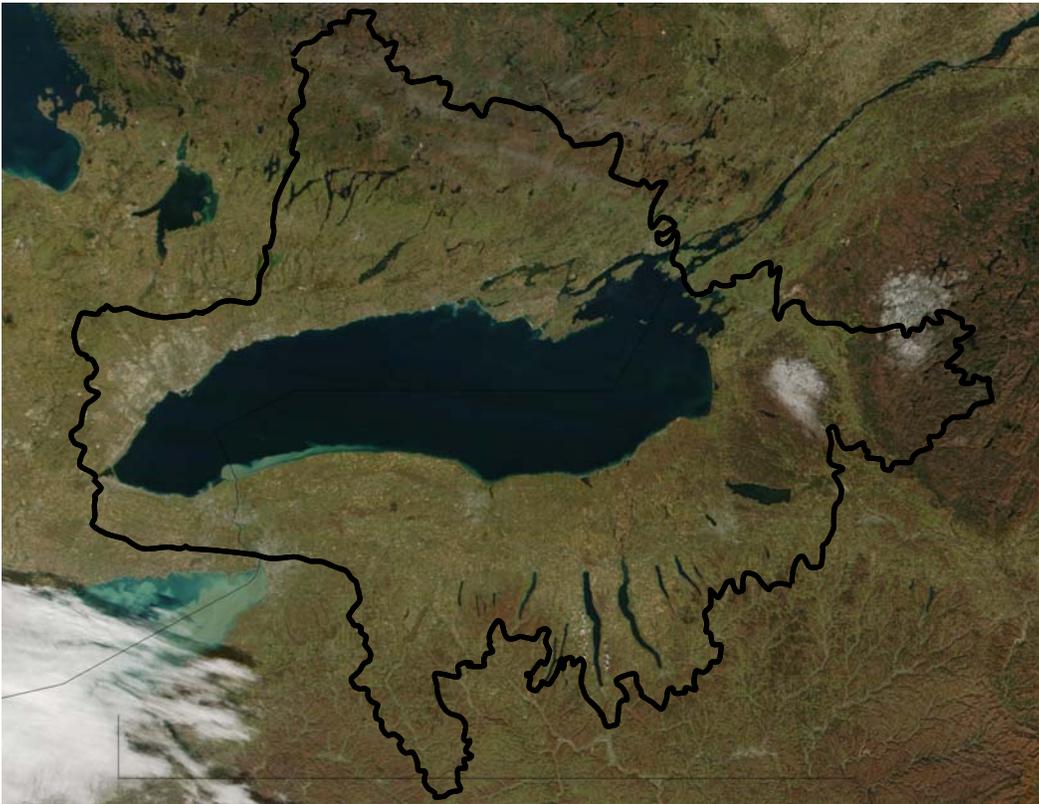


Ecological Indicators and Sustainability of the Lake Ontario Ecosystem



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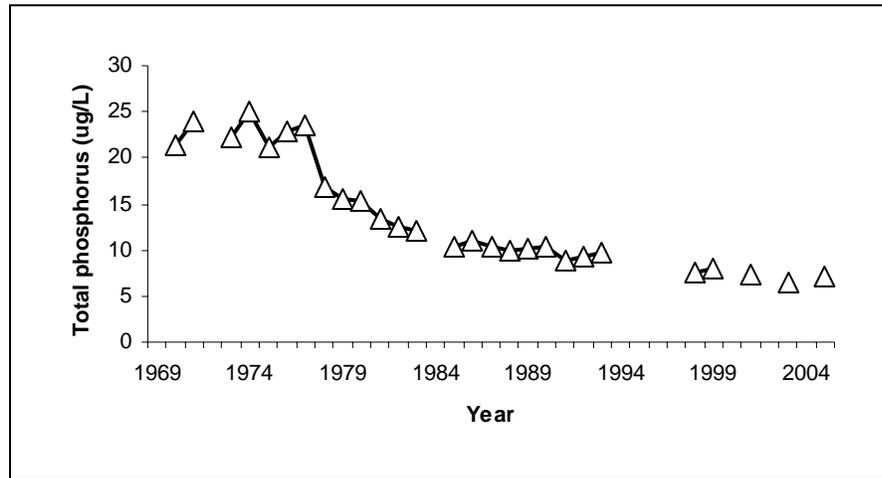
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Lake Ontario: A Brief History of Ecosystem Change

Colonization of the Lake Ontario basin by European settlers initiated a long period of habitat loss and ecosystem degradation. Forest clearing and agricultural development caused gradual water quality deterioration followed by more rapid decay in the mid 1900s from urban runoff and industrial pollutants. Commercial fishing during the period of water quality decline added more stress to an already compromised fish community resulting in further declines in native fish species like Atlantic salmon, lake trout, burbot, lake herring, lake whitefish, deepwater ciscoes, and deepwater sculpin. Since the late 1960s, management actions, socio-political influences, and unplanned events reshaped the Lake Ontario ecosystem. The most notable changes include 1) the stocking of Pacific salmon (late 1960s) to reduce nuisance levels of alewife (sometimes referred to as sawbellies or mooneyes) and to provide recreational fishing opportunities; 2) large scale efforts to reduce phosphorus loading that began with the signing of the U.S. – Canada Great Lakes Water Quality Agreement and a New York ban on high phosphorus detergents (1972); and 3) the establishment of several nonindigenous species (NIS) including the spiny waterflea (1987), zebra mussel (1989), quagga mussel (1991); and fishhook waterflea (1998). These events have had significant impacts on the Lake Ontario food web and have altered the manner in which food energy moves to fish.



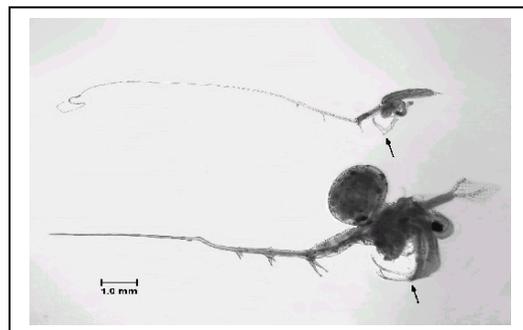
Pacific salmon have flourished and play a critical role in sustaining a multimillion-dollar recreational fishery supported primarily by non-native alewife and secondarily by non-native rainbow smelt. Stocking was so successful that fishery managers shifted from a strategy aimed at



controlling nuisance levels of alewife to concern about whether the salmon fishery could be sustained with a declining alewife population. Mandated phosphorus reductions were also a success. With declining phosphorus loadings (**Figure**), Lake Ontario’s water quality improved and nuisance algal blooms subsided. However, algae and zooplankton (tiny crustaceans) levels also declined, decreasing the lake’s capacity to support fish. The filter-feeding zebra and quagga mussels (**photo**) have also contributed to decreased standing crop of algae and zooplankton, while the non-native waterfleas, *Cercopagis* and *Bythotrephes* (**photo**), feed on zooplankton and therefore compete with fish like the alewife. These pivotal events have forced scientists and managers to think about the Lake Ontario ecosystem as a whole, rather than narrowly focusing on one issue at a time.

The Ecosystem Approach and Ecological Indicators

An ecosystem approach takes into consideration the connections between physical (e.g. water clarity), chemical (e.g. phosphorus), and biological (e.g. zooplankton size) properties to assess the ecological state of the entire ecosystem, recognizing that any management action will have effects that ripple throughout the ecosystem. Unlike earlier management strategies that focused on isolated issues such as remediation of localized pollution or restoration of individual species within Lake Ontario, the ecosystem approach considers effects of and on ecosystem components ranging in scope from land use in the surrounding watershed to quality of algae as food for zooplankton. To better understand effects on the entire ecosystem, scientists are monitoring ecological indicators—ecosystem properties that are easily measured and that can provide information about the status of other ecosystem components. Zooplankton are considered good ecological indicators because of their intermediate position in the food web. This position allows them to



be used to assess the status of both lower (e.g., nutrient levels) and higher (e.g., alewife) food web components. For example, zooplankton mean length can be used to determine if the balance between plankton eating fish (planktivores) and fish predators has been upset. This is because in lakes where planktivores are abundant, large-bodied zooplankton like *Daphnia* are rare. Therefore, smaller species are more prevalent and zooplankton mean length is smaller. When quality-sized piscivores are present in adequate numbers, populations of planktivores are controlled, and larger-bodied zooplankton are more abundant. The dominance of small zooplankton, on the other hand, points to the absence of sufficient number of predators to suppress planktivore abundance. Changes in Lake Ontario's zooplankton community have been monitored in response to both decreased phosphorus levels and the establishment of several non-native species. The response of zooplankton to these stressors allows us to see how the changes have affected the entire food web.

Non-native Species and the Lake Ontario Food Web

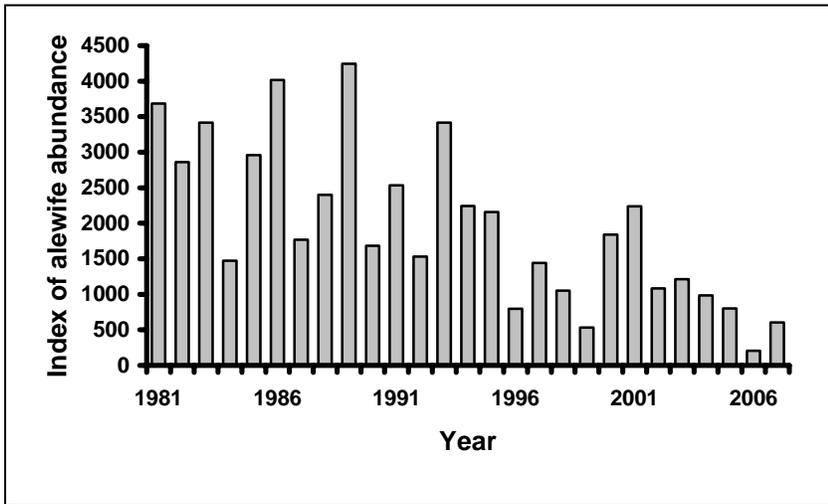
The Lake Ontario food web is a complex network of organisms through which energy is transferred. Algae (phytoplankton) are the foundation of the food web. They use sunlight and nutrients like phosphorus and nitrogen to provide food for zooplankton and bottom-dwelling organisms such as amphipods (tiny freshwater shrimp or “scuds”). Zooplankton are the primary food source for small fish such as alewife (**Figure**) and rainbow smelt. Small fish are consumed by the lake's top predators—Pacific salmon (**Figure**). Lake Ontario's food web has changed drastically in the last 40 years, due primarily to the establishment of several non-native species introduced via transoceanic shipping. The zebra mussel, quagga mussel, spiny waterflea, and fish hook waterflea have each impacted the food web, altering the way in which energy is transferred to fish.

The establishment of zebra and quagga mussels in Lake Ontario occurred simultaneously with phosphorus reductions, making it difficult to determine the degree to which each of those events affected the ecosystem individually. Lower phosphorus levels combined with filtration of the water by zebra and quagga mussels resulted in reduced algal biomass, increased water clarity, and changes in the types of algae present. The high filtration capability of zebra and quagga mussels has greatly decreased algal standing stocks and increased light penetration. When light increases and nutrients are held constant, algae increase their carbon content relative to nitrogen and phosphorus, making them less nutritious for zooplankton. In addition, higher light levels combined with selective filtration by dreissenids may have the counterintuitive effect of promoting nuisance algal blooms, despite lower water column nutrient availability. This is because mussels reject (spit out) the less palatable algae species that are responsible for those



blooms. Therefore, both the *amount* and *quality* of food available to zooplankton and fish in Lake Ontario have been reduced.

Juvenile and adult alewife are the dominant planktivores in Lake Ontario, and these fish account for most of the predation on zooplankton. Alewife abundance declined since the early 1980s (**Figure**), and larger zooplankton species became more abundant. However, with the arrival of *Bythotrephes* in 1987 and *Cercopagis* in 1998, the relationship between zooplankton average size and alewife abundance became more complicated. *Cercopagis* prey on small zooplankton such as *Bosmina*, so declines in *Bosmina* could contribute to a shift in the mean size of zooplankton toward larger organisms, giving the false impression that alewife are suppressed.



However, *Cercopagis* is a moderately large sized zooplankton and adult alewife are known to feed on it. So, a high abundance of *Cercopagis* provides some circumstantial evidence that adult alewife numbers are low. Alewife also feed on *Bythotrephes* in Lake Ontario. *Bythotrephes* is occurring more frequently in recent years providing yet one more line of evidence that adult alewife abundance is currently suppressed in Lake Ontario.

The Future of Lake Ontario: Challenges

In the coming years, the Lake Ontario ecosystem will continue to experience stress caused by the watershed's growing human population and from other anthropogenic forces such as invasive species and contaminants. Important questions to be addressed include:

- Can the fishery be sustained?
- What non-native species will arrive next?
- What effect will the loss of key players (e.g. *Diporiea*) in the food web have?
- What new chemicals will be discovered and what will the impacts be on fish and human health?

Great Lakes scientists and managers must continue to work diligently to assess ecosystem status and to evaluate indicators of ecological change. The success of efforts to maintain recreational fisheries and to restore self-sustaining populations of native species depends on the condition of the lower food web. Long-term assessment of the lower food web is critical to measure the effectiveness of remedial actions, to better understand how stressors manifest themselves across habitats and impact fish communities, and to make recommendations for future actions.

Figure 1. Lake Ontario and its watershed (black outline).

Figure 2. Total phosphorus concentrations in Lake Ontario, 1969 – 2005. Source: Environment Canada Surveillance Program

Figure 3. Quagga mussel (left) and zebra mussel (right)

Figure 4. Fish hook waterflea (top) and spiny waterflea (bottom). Source: Hugh MacIsaac, University of Windsor

Figure 5. Alewife

Figure 6. Chinook salmon

Figure 7. Index of alewife abundance in Lake Ontario, 1981 – 2007. Source: United States Geological Survey

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