Crawford, S.S. 2001

"A review and ecological evaluation of salmonine introductions to the Great Lakes." (August 1997)

This report, prepared for the Chippewas of Nawash First Nation, was publicly released in August 1997. It presented a history of salmonine (salmon, trouts, and charrs) introductions to the Laurentian Great Lakes from the1870s to the present. I analysed the objectives that fisheries managers attempted to satisfy with these stocking programs, and I concluded that the only major reason for continued salmonine introductions in the modern era is to develop and maintain recreational fisheries.

I used standard ecological theory to categorize the predicted ecological effects of introducing non-native salmonines (e.g. chinook salmon, coho salmon, rainbow trout, brown trout) to the Great Lakes. The report includes a survey of scientific evidence of Great Lakes salmonine ecology published in the primary literature from 1966 to the present. Despite substantial numbers of salmonines introduced to the Great Lakes over the past thirty years (estimates in excess of 1/2 billion), it is truly surprising to learn that NO comprehensive ecological evaluations have been undertaken to determine the ecological consequences of such introduction programs.

I examined the policy of the Ontario Ministry of Natural Resources (OMNR) on salmonine stocking programs that continue to occur under its jurisdiction. I found that, despite explicit recognition of serious negative ecological effects and the absence of comprehensive ecological evaluations, the OMNR has condoned and promoted the ongoing introduction of salmonines to support recreational fisheries. When I applied the OMNR's own protocol for evaluation fish introduction proposals - the OMNR states that this protocol is not to be applied to species that have already been introduced - the protocol rejected the continuation of salmonine introduction to the Great Lakes.

Based on ecological theory and the available evidence, I concluded that introduced salmonines pose an ecologically-signinficant threat to the Great Lakes ecosystem and its native community of organisms. I call for the formation of a politically- and administratively-independent panel of fisheries experts to review the ecological evidence, moderate an open debate, and provide clear direction for the future of salmonine introductions to the Great Lakes.

The historical and ecological sections of the report have been submitted for publication in the primary scientific literature. At the request of the editors, I have removed these sections from the on-line version of the report, while leaving the policy-

oriented sections intact.

To date (April 2000) there has been no response to this report by the OMNR.

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Home
Background
Research
Reports
Opinions
C.V.
Links

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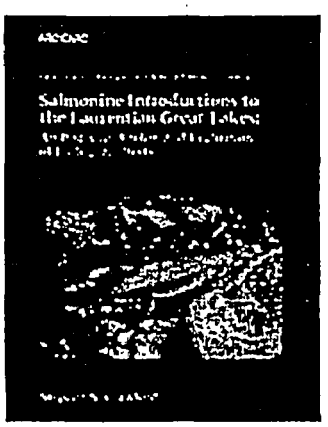
Salmonine Introductions to the Laurentian Great Lakes: An Historical Review and Evaluation of Ecological Effects



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Executive summary

The goal of this report is to provide an historical review and evaluation of documented ecological effects associated with salmonine introductions to the Laurentian Great Lakes. To date, no comprehensive reviews or evaluations have been conducted by any of the Great Lakes fisheries management agencies that participate in, or support, ongoing salmonine introductions. The absence of such a review is noteworthy, especially in light of evidence from the scientific literature that salmonine introductions have had significantly-negative ecological effects on the native members of the Great Lakes community.

History of salmonine introductions

The introduction of salmonines to the Great Lakes dates back to the 1870s, when natural populations of native salmonines in the Great Lakes (e.g. lake charr, brook charr, Atlantic salmon in Lake Ontario) were in severe decline. These declines were largely attributed to human

were in severe decline. These declines were largely attributed to human activities, especially habitat degradation (urbanization, damming, deforestation, agriculture) and overharvesting. Early salmonine introductions in the Great Lakes began with the development of hatchery technology, like the Newcastle facility constructed by Samuel Wilmot for rehabilitation and support of native Atlantic salmon in Lake Ontario. Several non-native salmonines were released by both American and Canadian agencies into the Great Lakes during the early (1870-1960) era of introductions:

Atlantic salmonines:
Atlantic salmon (*Salmo salar*), outside of Lake Ontario
Brown trout (*Salmo trutta*)

Pacific salmonines:
Chinook salmon (*Oncorhynchus tshawytscha*)
Coho salmon (*Oncorhynchus kisutch*)
Rainbow trout (*Oncorhynchus mykiss*)
Kokanee (*Oncorhynchus nerka*)
Chum salmon (*Oncorhynchus keta*)
Cutthroat trout (*Oncorhynchus clarkii*)
Masu salmon (*Oncorhynchus masou*)
Pink salmon (*Oncorhynchus gorbuscha*)

Arctic salmonines
Arctic charr (*Salvelinus alpinus*)

These early salmonine introductions were intended to develop self-sustaining, wild-reproducing populations to support food, commercial or recreational fisheries. With the exception of brown trout and rainbow trout populations in some Great Lakes tributaries, the early introductions failed to achieve their objectives. Pink salmon, a non-native Pacific salmonine unofficially released to Lake Superior in 1956, quickly established self-sustaining, wild-reproducing populations in the Great Lakes.

Beginning in the mid-1960s, American and Canadian fisheries agencies began an intensive round of salmonine introductions to the Great Lakes that included brown trout, rainbow trout, chinook salmon, coho salmon and kokanee. The objectives for these introductions were (1) to develop self-sustaining, wild-reproducing populations to exert biological control of non-native planktivorous fishes, and/or (2) to develop new recreational fisheries. Alewife and rainbow smelt had become abundant in the Great Lakes, and in some cases were considered to be an aesthetic, economic and ecological nuisance. Both alewife and rainbow smelt had been introduced by humans to the Great Lakes; alewife were released unintentionally, and rainbow smelt were released intentionally as food for introduced Atlantic salmon.

Recently, continued declines in the abundance of alewife in Lake Michigan and Lake Ontario have raised arguments about whether to

decrease stocking of salmonines and prevent a collapse in the alewife populations, or to maintain/increase stocking and support the expanding recreational fisheries. In either case, it has become clear that biological control of alewife and rainbow smelt is no longer a major objective for fisheries managers. Ironically, the alewife and rainbow smelt that were originally considered a novelty, then a nuisance, are now considered by sportsmen and fisheries managers to be a valuable food resource for introduced salmonines. Currently, the only major objective for salmonine introductions in the Great Lakes is the development and maintenance of recreational fisheries.

Despite explicit ecological warnings made in the 1960s about the potential for ecological damage resulting from salmonine introductions, American and Canadian fisheries agencies continued with their Great Lakes salmonine introduction programs. Neither American nor Canadian fisheries agencies conducted comprehensive pre- or post-introduction ecological evaluations of salmonine introductions. Since the 1960s introductions of salmonines to the Great Lakes have increased dramatically, with estimates of total stocking in excess of 745 million fish released during the period 1966-1998, an average of more than 61,000 fish released every day for 33 years. The vast majority (i.e. >91%) of these introduced salmonines have been released by American hatcheries.

Effects of introductions on the introduced salmonines

Introduced salmonines have generally survived and grown well in the Great Lakes ecosystem, especially when feeding on forage fishes such as alewife and rainbow smelt. Recently, concerns have been expressed about the decline observed in growth and survival rates of introduced salmonines in the Great Lakes basin, especially chinook salmon. It has been hypothesized that stocking of the introduced salmonines has led to reductions in the availability of their forage base, especially alewife. Introduced salmonines have developed a reputation for dispersion and migration, especially in the open-lake environments of the Great Lakes basin. These movements have been described at the intra- and inter-basin level, and have been associated with colonisation of habitat where the fish had not previously been stocked.

There is a high degree of uncertainty regarding reproduction of the introduced salmonines in the Great Lakes. For species such as brown trout and rainbow trout, reproduction can reach levels that support wild populations, especially in cases where the population is stream-resident. However, for pelagic species such as chinook and coho salmon, the ability to maintain populations through wild reproduction is highly suspect. Some researchers have argued that the quantity and quality of spawning habitat in Great Lakes tributaries are limiting factors for reproduction. In many cases, populations of introduced salmonines are thought to be heavily stocked beyond levels of reproduction observed in the wild, primarily to support the put-grow-and-take recreational fisheries.

One of the more alarming effects that introductions have had on the non-native salmonines is the alteration of the life-history characteristics of the introduced species. Shifts from 'normal' patterns have been observed in body form and function, feeding and spawning behaviour. Such life-history shifts can be expected when organisms are transplanted to novel environments, and are subjected to novel ecological and evolutionary pressures.

Effects of introductions on the receiving Great Lakes ecosystem
Non-native diseases (e.g. furunculosis, whirling disease) and parasites (e.g. Philonema oncorhynchi, Ergasilus nerkae) may have been introduced to the Great Lakes along with the introduced salmonines. Of all the Great Lakes species, native salmonines (lake charr, brook charr) are likely the most susceptible to these new diseases and parasites. The intensive culture of hatchery-reared salmonines poses a threat to native fishes by artificially increasing the disease and parasite 'reservoir' that native fishes are exposed to in the wild.

Predation by introduced salmonines on native species in the Great Lakes basin is a serious concern because the stocked fish are 'generalist, vertebrate predators' — they have the ability to feed on a wide variety of prey species. This danger is particularly evident in Great Lakes tributaries where juvenile and stream-resident salmonines forage on a common supply of native species, including a variety of invertebrates and fishes. In the open-lakes, many introduced salmonines forage primarily on alewife and rainbow smelt, however they also feed on native sculpins, bloater, and yellow perch — at levels that may pose a significant threat to the supporting forage populations. It has been predicted that introduced salmonines will switch to alternate, native species as alewife populations decline and/or stocking for the recreational fisheries increases. This switch in behaviour can expose the populations of native forage species to the risk of excessive mortality, especially in situations where stocking programs exceed carrying capacity of the native community.

Competition between introduced salmonines and native species in the Great Lakes basin has been investigated by a limited number of experimental studies. In tributaries, there is evidence that the larger and more aggressive introduced salmonines outcompete smaller native species (e.g. brook charr) for limited food, cover and stream position. In open-lake environments, studies have shown that introduced salmonines forage voraciously on the same species that is dominant in lake charr diets (i.e. the declining alewife populations). Spatial bioenergetic models have shown that lake zones of growth potential for lake charr and chinook salmon have a high degree of overlap. There is also evidence of spawning-phase chinook salmon directly interfering with spawning lake charr in one of the last two self-sustaining populations in Lake Huron.

Genetic alteration of native species by introduced salmonines in the Great Lakes can be either direct or indirect. There is evidence of direct alteration effects, such as hybridization and introgression with native species. Indirect effects, like those associated with declines in population abundance of native species, have occurred as a result of intensive stocking of introduced salmonines.

Environmental alterations by introduced salmonines have been reported in both tributaries and open-lake environments of the Great Lakes basin. In tributaries, spawning salmonines dig up nests or superimpose their redds on the habitat of native species. These physical alterations have been shown to have community-level effects on the abundance and distribution of native fishes and invertebrates in the tributaries. Spawning runs of introduced salmonines have also been shown to transport significant levels of contaminants upriver from the lakes.

Community alteration occurs when the structure or function of a native community is affected by introduced species. In the Great Lakes basin, community structure has been affected by the feeding habits and competitive interactions of the introduced salmonines. In open-lake environments, introduced salmonines have taken on a dominant role as upper-level predators — yet they exist in numbers often more determined by hatchery production capacities than by the characteristics of the ecological community they live in. In Great Lakes tributaries, introduced salmonines have been shown to alter community ecology by increasing the levels of limiting nutrients and toxins picked up in the open-lake environments. A conspicuous example of this kind of community alteration occurs when introduced salmonines embark on massive, and typically lethal, spawning runs into the tributaries. The spawning runs of the introduced salmonines stand in contrast to the typical stream-resident or lake-resident tendencies of the native brook and lake charrs, respectively.

Taken together, this body of evidence supports the conclusion that the ongoing introduction of non-native salmonines poses an ecologically-significant risk to the Great Lakes ecosystem and its native organisms, and that the introductions should be terminated.