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Technical Papers

OF THE BUREAU OF SPORT FISHERIES AND WILDLIFE

68. History of Salmon in the Great Lakes, 1850-1970

UNITED STATES DEPARTMENT OF THE INTERIOR

FISH AND WILDLIFE SERVICE

BUREAU OF SPORT FISHERIES AND WILDLIFE

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68. History of Salmon in the Great Lakes, 1850-1970

By John W. Parsons

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF SPORT FISHERIES AND WILDLIFE
Washington, D.C. · April 1973

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HISTORY OF SALMON IN THE GREAT LAKES, 1850-1970 [1]

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ABSTRACT.--This history of the salmon in the Great Lakes describes the decline and extinction of the Atlantic salmon (Salmo salar) in Lake Ontario in the 1800's; the failure to establish, by salmon culture, permanent or sizable populations of Atlantic or Pacific salmon in any of the Great Lakes in 1867-1965; and the success of the plantings of coho (Oncorhynchus kisutch) and chinook salmon (O. tshawytsha) in the Great Lakes, in 1966-70 -- particularly in Lake Michigan.

Despite plantings of 5 million fry and fingerlings from Lake Ontario stocks in 1866-84, the native Atlantic salmon in Lake Ontario became extinct in the late 1800's primarily because tributaries in which they spawned were blocked by mill dams. Plantings of 13 million chinook salmon and landlocked and anadromous forms of Atlantic salmon in Lake Ontario and the other Great Lakes in 1873-1947 failed completely. The first species to develop a self-sustaining population was the pink salmon (O. gorbuscha), which was planted in Lake Superior in 1956; however, it has not become abundant.

A salmon fishery finally was established when 15 million coho salmon and 6 million chinook salmon were planted as smolt in the Great Lakes in 1966-70. In 1970, for example, 576,000 coho salmon (12% of those planted in 1969) were caught by anglers in Lake Michigan. Most weighed 5 to 10 pounds (2.3-4.5 kg). Sport fishing for salmon was fair in Lakes Superior and Huron, and poor in Lakes Erie and Ontario.

By 1970, natural reproduction of coho, chinook, pink, and kokanee (O. nerka) salmon had occurred in some tributaries of one or more of the upper three Great Lakes. It is expected, however, that the sport fishery will continue to be supported almost entirely by planted fish.

Introductions of coho (Oncorhynchus kisutch) and chinook salmon (O. tshawytscha) in the Great Lakes in the mid-1960's resulted in an unprecedented, enormously successful put-and-take freshwater salmon fishery. In 1970 alone, for example, an estimated 625,000 salmon were caught by anglers in State of Michigan waters of Lake Michigan. This phenomenal fishery for Pacific salmon is the culmination of a long history of salmon--native and introduced--in the Great Lakes.

Before 1850, the Atlantic salmon (Salmo salar) was the most important fish in Lake Ontario and its tributaries (Niagara Falls barred its entry into the other Great Lakes). Even in the earliest historical records, salmon were referred to as a valuable source of food and their abundance was believed to be an important factor in the early settlement of the Lake Ontario region (Smith, 1892).

The Atlantic salmon in Lake Ontario declined sharply in the mid-1800's and was extinct by 1900. This failure led to a number of publications speculating on the causes, and brought about strong measures by Ontario provincial authorities in the late 1800's to

[1] Contribution 470 of the Great Lakes Fishery Laboratory.

reestablish the species to its former abundance (by salmon culture) and to introduce other species of salmon in Lake Ontario and possibly the other Great Lakes. Most of the Great Lakes states of the United States followed suit. As a consequence, salmon of one species or another have been planted in one or more of the Great Lakes or their tributaries in most years from 1867 to 1970.

This report consists of (Part I) a review of the history of the Atlantic salmon in Lake Ontario (and in the St. Lawrence River, when applicable) and (Part II) a record of exotic salmon plants and results in all the Great Lakes and tributaries through 1970.

Part I may be useful for understanding and solving the problems of reintroducing Atlantic salmon in the Great Lakes, and for anticipating habitat requirements, biological characteristics of the species, and needs for control of newly established populations. Part II documents the plantings of exotic salmons, describes the results in the different lakes, and lays the groundwork for measuring benefits and establishing needs for continued plantings of salmon. Population changes and interrelations of native and introduced species in the Great Lakes since the mid-1800's already have been described in detail by Smith (1972).

PART I--ATLANTIC SALMON IN LAKE ONTARIO

This history of Atlantic salmon in Lake Ontario was gathered from journals and reports written by historians, travelers, naturalists, administrators, biologists and fish culturists. Although a wide range of materials was reviewed, sorted, and culled in an effort to prepare a reasonably accurate and useful documentation, references in the text are restricted to those in which original and objective observations appear to have been recorded; consequently, the bibliography does not include a complete list of publications on the Lake Ontario salmon. Because early writers showed a genuine concern for the predicament of the salmon, their accounts were sufficiently consistent and factual to permit a reasonably detailed description of the loss of a rich natural heritage.

The history of the Atlantic salmon in Lake Ontario is of particular importance because its decline and extinction was the first of a long series of changes in the fish populations of the Great Lakes that have been attributed largely to the direct and indirect influence of man's activities (Smith, 1972).

Although ecologists and conservationists throughout the United States today are writing about ecology, pollution, upsets of the balance of nature, and the destruction of aquatic habitats almost as though they were new subjects, the views being expressed are remarkably similar to those of conservationists who wrote about the disappearance of the Lake Ontario salmon a century ago.

DISTRIBUTION AND ABUNDANCE

Since the Atlantic salmon of Lake Ontario appear to be closely interrelated with those of the Gulf of St. Lawrence and the St. Lawrence River, distribution and abundance are described here for the entire region.

ST. LAWRENCE GULF AND RIVER SYSTEM

Atlantic salmon once were abundant in the Gulf of St. Lawrence and most of its tributaries, westward from Labrador on the north and Nova Scotia on the south, and in the St. Lawrence River and many of its tributaries (Fig. 1) upstream to Lake Ontario and Niagara Falls (Adamson, 1857; King, 1866). Among the St. Lawrence River tributaries in Quebec, salmon apparently were most abundant in the Jacques Cartier River (King, 1866), the St. Francis River (Fox, 1930), and the Au Saumon, St. Anne, and Madeleine Rivers (Follett, 1932). Other principal salmon waters were the Richelieu River and Lake Champlain and its tributaries in New York (Edmunds, 1874a; Watson, 1876), and Lake Ontario and its tributaries in New York and Ontario (DeKay, 1842; Adamson,

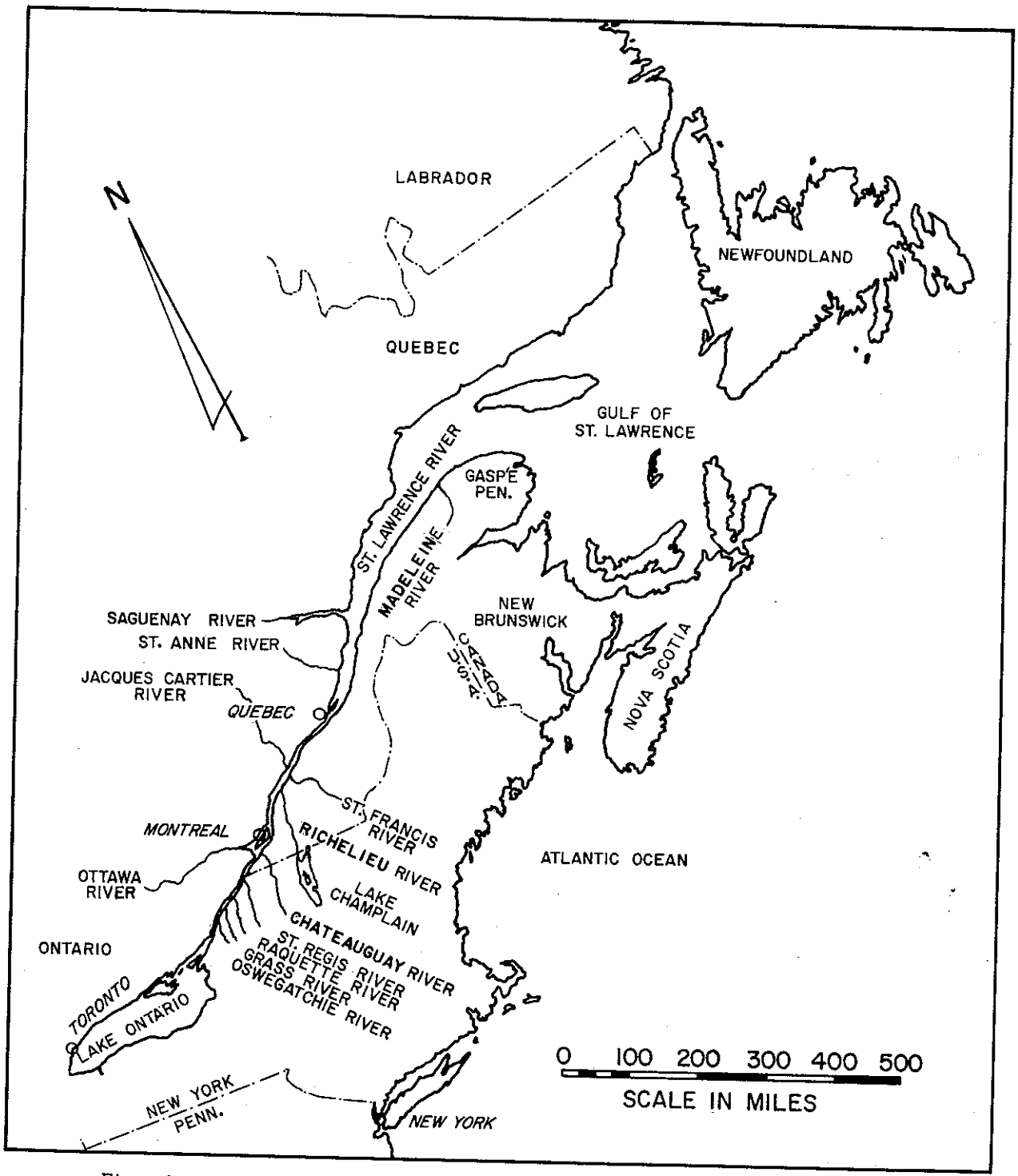


Figure 1.--Major Atlantic salmon waters of the St. Lawrence River system in the early 1800's.

1857). In summary, Fox (1930) applicably wrote, "the wide range of the salmon in the lower St. Lawrence Basin [below Niagara Falls] is striking and significant."[2]

Salmon were reported to be so abundant in the early 1800's that Follett (1932) concluded that the St. Lawrence River and Lake Ontario and their tributaries once supported the greatest freshwater salmon population in the world. Smith (1892) wrote that the history of early abundance of salmon in Lake Ontario "reads like a romance." The frequency with which other authors described the great abundance of salmon firmly supports these views.

Despite the broad distribution in the St. Lawrence River, salmon were reported (on the basis of commercial catch records) to be much more abundant in the lower reaches of the river (from the City of Quebec upstream to Montreal) than in the upper reaches (from Montreal to Lake Ontario--see Atkins, 1874). This comparison is poor because fishing was far more difficult in the fast-flowing and treacherous upper reaches than in the quieter waters downriver. In fact, salmon apparently were common in the St. Lawrence River above Montreal. Bonnycastle (1842) observed Indians spearing salmon on a shoal of the St. Lawrence River 32 miles (52 km) upstream from Montreal, and Edmunds (1874a) reported that salmon formerly were common along the southeastern shores of the upper St. Lawrence River and often inhabited the adjacent southerly tributaries (Chateauguay River in Quebec, and the St. Regis, Raquette, Grass, and Oswegatchie Rivers in New York; Fig. 1).

LAKE ONTARIO

Province of Ontario.--Approximately 50 tributaries in the Province of Ontario flow into Lake Ontario. Most of these streams are much smaller than those in New York, and few, if any, are obstructed by natural barriers.

According to Follett (1932) most or all of the tributaries in Ontario supported native Atlantic salmon at one time or another. Salmon usually were abundant only in cool, spring-fed streams about 10 to 20 miles (16 to 32 km) long. The Trent River, by far the largest tributary, was rarely inhabited by salmon, and then only near its mouth (Fox, 1930). Because the Trent River was not spring-fed, Fox concluded that it was not favored by the salmon. The Credit River apparently supported the largest salmon runs; Fox described it as a salmon stream "par excellence."

Although Wilmot (1869-82) wrote extensively on the Lake Ontario salmon, he did not publish a list of native salmon streams. He stated or implied, however, that 25 tributaries were once inhabited by native salmon (nos. 1-25, Fig. 2; he used different names for some streams--see footnote 1 of Table 1). He also mentioned two others (Brand and Hawkstone Creeks) which I am unable to locate or identify.

Only rarely were salmon observed in the Niagara River below the falls (King, 1866; Fox, 1930), probably because spawning grounds were lacking there.

New York.--Approximately 50 tributaries in New York flow into Lake Ontario; the four largest are the Black, Salmon, Oswego, and Genesee Rivers. A number of New York tributaries are blocked by high natural falls, which limited the distribution of salmon in some streams. For example, high, impassable falls are located 7 miles (11 km) from the mouth of the Genesee River, and about 25 miles (40 km) from the mouth of the Salmon River.

The Salmon River below the falls was considered to be the best salmon stream in New York (Smith, 1892). Salmon apparently were not particularly abundant in the Oswego River, an extensive tributary system that includes Oneida Lake and the Finger Lakes and is relatively free of natural obstructions.

[2] Approximate distances in statute miles (kilometers in parentheses) in the Lake Ontario and St. Lawrence System are as follows: maximum length of Lake Ontario, 185 (300); eastern Lake Ontario to Montreal, 160 (258); Montreal to Quebec, 135 (217); Quebec to the Gulf of St. Lawrence, 300 (483); western Lake Ontario to mouth of the St. Lawrence River, 840 (1,352); length of the Gulf, 800 (1,288); eastern Lake Ontario to the open sea, 1,500 (2,400).

Ontario

1. Twelve-mile Creek
2. Grindstone Creek
3. Bronte River
4. Oakville Creek
5. Credit River
6. Etobicoke Creek
7. Garrison Creek
8. Humber River
9. Don River
10. Highland Creek
11. Rouge River
12. Duffin Creek
13. Lynde Creek
14. Farewell Creek
15. Bowmanville Creek
16. Soper Branch
17. Wilmot Creek
18. Graham Creek
19. Ganaraska River
20. Gage Creek
21. Cobourg Creek
22. Shelter Valley Creek
23. Trent River
24. Moira River
25. Salmon River

New York

26. Chaumont River
27. Black River
28. Stony Creek
29. Big Sandy Creek
30. Sandy Creek
31. Deer Creek
32. Salmon River
33. Grindstone Creek
34. Little Salmon River
35. Oswego River
36. Three-mile Creek
37. Salmon Creek
38. Genesee River
39. Sandy Creek
40. Twelve-mile Creek

Figure 2.--Tributaries of Lake Ontario in which Atlantic salmon were native; circled numbers indicate tributaries in which native salmon were planted.

According to Green (1874), salmon once inhabited all tributaries of Lake Ontario in New York except the Genesee River. Edmunds (1874a) wrote that salmon were most abundant east of the Genesee River, but the Genesee River (below the falls) and all tributaries to the west also supported salmon. Despite these broad descriptions of distribution, only the following 15 salmon streams (nos. 26-40, Fig. 2) were specifically mentioned in the literature: Chaumont River and Black River (Edmunds, 1874a); Stony Creek, Big Sandy Creek (probably North and South Sandy Creeks in Jefferson County), and Sandy Creek, Oswego County (Smith, 1892); Deer Creek (Goode, 1884); Salmon River, Grindstone Creek, and Little Salmon River (Smith, 1892); Oswego River--including Fish Creek in Lewis County, a tributary to Lake Oneida (Collins, 1885), Lake Oneida (DeKay, 1842), Seneca River (Fox, 1930), and Cayuga and Seneca Lakes (Edmunds, 1874a); Three-mile Creek and Salmon Creek (Smith, 1892); Genesee River (Edmunds, 1874a); and Sandy Creek (Orleans County) and Twelve-mile Creek (Smith, 1892).

BIOLOGY OF LAKE ONTARIO SALMON

Reports in the literature on the biology and habits of native Lake Ontario salmon are scarce because fishery scientists in the 1800's were few, funds for study were lacking, and salmon as a natural resource were taken for granted until they had virtually disappeared. Most of the recorded biological observations on the Lake Ontario salmon were concerned with seasonal abundance, fish size, and migrations. The major exception was the more scientific work and reports by Wilmot (1869-82). Notwithstanding the paucity of knowledge, the combined observations of the early writers provide a useful account of some aspects of the salmon's life history.

GENERAL CHARACTERISTICS OF LAKE ONTARIO SALMON

Apparently there were no measurable differences between salmon in Lake Ontario and those in the St. Lawrence River or along the Atlantic coast. According to Goode (1884) and Atkins (1884), average weights of Lake Ontario salmon were similar to those of coastal salmon. About 200 fish examined in the Salmon River fishery in New York ranged from 1 to 45 pounds (0.5 to 20.4 kg) and averaged nearly 15 pounds or 6.8 kg (the average also was about 15 pounds for salmon of the Penobscot River, Maine). One 40-pound (18.2-kg) fish in Duffin Creek and one 42-pound (19.1-kg) fish in the Salmon River were reported by Smith (1892). Adult salmon in Wilmot Creek usually ranged from 8 to 20 pounds (3.6 to 9.1 kg).

In 1871, Wilmot (1872) sent several smolt, grilse, and adults from Lake Ontario to R.G. Pike, Fishery Commissioner of Connecticut, who compared them with stocks from the Penobscot River in Maine. Pike concluded that fish from the two areas were identical in all respects. None of the authors in the literature suggested that the Lake Ontario salmon had the size, shape, or color characteristics of the true landlocked salmon (commonly called Schoodic salmon in the 1800's; now usually known as Sebago salmon).

MIGRATION AND SPAWNING

According to King (1866) Atlantic salmon started their migration from the Gulf of St. Lawrence up the St. Lawrence River as soon as the ice started breaking up in the spring. According to DeKay (1842) the salmon ascended the St. Lawrence River in April and descended in October and November. Huntsman (1944) held the opinion that the major salmon run up the lower St. Lawrence River was in May. Salmon migrated through the upper St. Lawrence River and many were caught near St. Vincent slightly downstream from Lake Ontario (Goode, 1884; months of the migration were not given).

Upstream migration in some tributaries of Lake Ontario was frequent and occurred in most months of the year (except in winter). Fox (1930) related that salmon were abundant in Lake Ontario in March through November, if not in the other months. He described spring runs up the Salmon River in New York and the Credit River in Ontario, and cited an

1833 account by T.W. Magrath that characterized fish in the Credit River as being "firm and full of curd as if they were within ten miles of the sea instead of five hundred" (the approximate distance to the farthest upstream intrusion of salt water in the St. Lawrence River).

Huntsman (1944) reported that adult salmon migrated up the Humber River in Canada as early as March and April, and in summer whenever freshets occurred. Wilmot (1872) reported that the adults in the spring runs up the Humber and Credit Rivers were silvery and fat--in contrast to the fall migrants which were dark, lean, and in relatively poor condition. Goode (1884) and Collins (1885) reported salmon runs up the Salmon River in New York in June. Smith (1892) wrote that salmon usually moved in along the shoreline of Lake Ontario in June, and migrated upstream if water flow was sufficiently high. The earliest records of salmon in Lake Ontario or its tributaries were reported for the Salmon and Oswego Rivers in 1657-72 (Jesuit Relations and Allied Documents, 1899 a-c). The Jesuits observed Indians on the rivers with boatloads of large salmon in mid-July.

Despite the tendency for salmon to migrate into some Lake Ontario tributaries over a period of many months, various authors fully agreed that most fish migrated upstream in the fall, and that they were intent on spawning. Wilmot (1869-1882), who observed salmon in Canadian tributaries over a span of 17 years, stated that most of the fall migrations up tributaries were in October and November. Although Smith (1892) reported that commercial fishermen believed Atlantic salmon in certain Lake Ontario tributaries spawned in spring as well as in fall, there is no valid evidence that this was the case.

The tributaries of Lake Ontario once provided a wealth of spawning grounds for salmon. Principal spawning areas were characterized by clear, cool water, abundant gravelly shoals, and a relatively sharp stream gradient. In most streams in Ontario and New York, these conditions were most prevalent in the lower reaches near Lake Ontario; consequently upstream penetration of the salmon was limited. The major exception was the Oswego River, where the principal spawning grounds apparently were in the headwaters. Salmon migrated as far as 80 miles upstream to Fish Creek in Lewis County, New York, a tributary to Lake Oneida (Collins, 1885), and nearly the same distance to Cayuga and Seneca Lakes (Edmunds, 1874a). In Ontario the longest upstream migrations were in the Trent River (25 miles or 40 km; Wilmot, 1879) and the Moira River (30 miles or 48 km, to Stoco Lake; Wilmot, 1880).

LAKE ONTARIO SALMON: FRESHWATER RESIDENTS OR ANADROMOUS?

The question most troublesome to early investigators of salmon in Lake Ontario and to many authors since was that of whether the Lake Ontario salmon were freshwater residents or anadromous, or both. Although there may be some question as to the value of a postmortem analysis, the largely circumstantial evidence presented here may be helpful for better understanding the success and failures of salmon plants in the past century.

Opinions expressed in the literature largely supported the view that the Lake Ontario salmon were mostly freshwater residents, but that some also may have been anadromous. The earliest views were expressed by DeKay (1842) and Adamson (1857). They believed that the salmon were freshwater inhabitants, but that some may have migrated to and from the sea. Adamson's view was based on his knowledge of some Atlantic salmon populations in Europe that lived primarily in fresh water. King (1866) thought that Lake Ontario salmon were freshwater stocks because he did not believe that salmon could negotiate the upper St. Lawrence River.

The issue of freshwater residency was reviewed in the discussions of the 1872 meeting of the American Fish-Culturists' Association (now the American Fisheries Society) and the State Commissioners of Fisheries. At that

meeting, Green (1874) and Thaddeus Norris (in Smith, 1892) expressed the strong conviction that the salmon were lake residents. They based their opinion on many years of observation of the seasonal abundance and migration of salmon ranging in size from 1 to 40 pounds (0.5 to 18 kg). Kendall (1924) asserted that the salmon were lake residents because spring migrations in Lake Ontario tributaries (1,500 miles or 2,400 km from the open sea) were concurrent with those of the Penobscot River in Maine, which flows directly into the sea. Blair (1938) gave some evidence that the salmon were freshwater stocks. He examined scales of two adults (museum specimens) collected in Lake Ontario before 1870 and concluded that the scale characteristics (growth pattern and scale erosion) more closely resembled those of landlocked salmon than those of anadromous salmon, and that the fish were therefore freshwater residents.

Huntsman (1944) held the view that the salmon were lake residents because migrant salmon were rare in the upper St. Lawrence River; this observation agrees with that of Atkins (1874), but not with those of Goode (1884) and Edmunds (1874a) given earlier. Huntsman also believed that the salmon migrated into Lake Ontario tributaries much too early (March-April) to have migrated up the St. Lawrence River. Scott (1967) shared the view that the salmon were probably lake residents.

Smith (1892) in his review of the 1872 meeting and of reports of others later, concluded that the salmon probably were lake residents but that some may have been anadromous. J.A. Mathewson (in Goode, 1884) supported this view. He believed that there were several races of salmon in Lake Ontario, based largely on certain physical characteristics and the streams into which they migrated. He stated that an experienced fisherman could readily tell the "home" stream of a particular fish, even though the three streams in New York to which he referred were only a few miles apart. The fish were long and slim in Deer Creek, short and stubby in Grindstone Creek, and large and heavy in the Salmon River. According to Mathewson, the races (which he assumed to be the result of homing instincts) were too clearly defined to be maintained by anadromous stocks. He further suggested that a race of purely anadromous salmon might also be present.

Fox (1930) concluded that some salmon were anadromous and others were lake residents. He suggested that since salmon migrated so far up the St. Lawrence River, some could have easily traveled to Lake Ontario.

Although Wilmot once was convinced that the Lake Ontario salmon were lake residents, he later tended to believe that the population was anadromous. His observations in 1866-81, reviewed in the following section, are strongly convincing that most of the salmon, at least in the 1870's, were lake residents.

I believe that the distribution and migratory habits of the Atlantic salmon in the St. Lawrence River and Lake Ontario, and the decline in abundance through the St. Lawrence River system in the 1800's (described in a later section) strongly indicate that both anadromous and freshwater salmon populations were present, and that they mixed freely. The wide distribution of the salmon (Fig. 1) and the lack of obstructions in the St. Lawrence River rule out the probability that the Lake Ontario salmon were isolated from anadromous populations. Since the Lake Ontario and anadromous salmon were indistinguishable, the variable seasonal migrations of the salmon in Lake Ontario and its tributaries and in the St. Lawrence River, which caused confusion among various authors, may have been a result of differences in the migratory habits of two populations.

Despite the probability of an anadromous Lake Ontario population, there is ample evidence, particularly in Wilmot's reports (1869-82), that some Lake Ontario salmon exhibited characteristics and habits of freshwater inhabitants. This evidence supports the view that Lake Ontario salmon were, indeed, composed of both anadromous and freshwater (residual) residents. This relationship also was reported for kokanee salmon (Oncorhynchus nerka) described by Ricker (1938) in Cultus Lake, British Columbia. Anadromous and resident populations inhabited the lake, the latter undoubtedly the progeny of the former.

WILMOT'S OBSERVATIONS ON THE LIFE HISTORY OF THE LAKE ONTARIO SALMON

Although Wilmot did not set out to describe the life history of the Lake Ontario salmon, he made a number of observations and inferences that appeared to reflect certain aspects of their life characteristics and habits. The following description is from his reports (Wilmot, 1869-82).

The Atlantic salmon in Lake Ontario usually spawned from about mid-October to mid-November; few entered the streams before October and most or all were gone by December. Spawning occurred on gravelly shoals and much of it took place at night, usually within a 2-week period; individual fish rarely remained in the stream more than a week. Most females laid their eggs over a period of 3 to 5 days but late spawners, particularly those that were delayed by low flows, often completed their spawning in one night. Grilse and older adults participated in the spawning.

The eggs usually hatched after about 6 months (late April and early May) and the yolks of the fry were absorbed in 4 to 6 weeks. Wilmot believed that the young remained in the stream about 1 year after hatching, grew to a length of about 5 inches (12.7 cm), smolted, and entered the lake. Wilmot also believed that a few returned to the streams as 2.5- to 3.0-pound (1.1- to 1.4-kg) grilse after one summer in the lake, but that most remained in the lake two summers and returned to spawn in the streams for the first time as 8- to 12-pound (3.6- to 5.4-kg) adults.

The adults spawned more than once. In the fall of 1868, Wilmot fin clipped a number of grilse and older adults in Shelter Valley Creek (actual numbers of fin-clipped fish were not reported except for recaptures in 1873). None were recaptured in 1869, but some of the adults examined in the spawning run of 1870 were fish marked in 1868. A number of salmon from Wilmot Creek were fin clipped in 1871. None were seen in 1872, but in the fall of 1873, 25 of 51 salmon caught in one night were fish marked in 1871. Although from these observations Wilmot suggested a 2-year spawning interval, one female was caught in Wilmot Creek in three consecutive years. According to Wilmot's reports, most of the salmon marked in Shelter Valley and Wilmot Creeks returned to the same streams in later years, which suggests that homing instincts were strong.

Wilmot also suggested that the females lived longer than the males. He formed this opinion in 1881 when the brood population had dropped to low levels and nearly all of the remaining spawners were large females.

The life characteristics of the Lake Ontario salmon described from Wilmot's reports were somewhat different from those described for anadromous salmon from Maine (Cutting, 1966) and for landlocked salmon (Warner, 1966). This difference in characteristics may account for the early maturation of the Lake Ontario salmon reported by Wilmot (1870).

Lake Ontario and landlocked salmon migrate from the lakes into tributaries in the fall and spawn; after the young hatch in the spring, they usually remain in the stream 1 or 2 years before migrating to the lake. The anadromous salmon are different in these respects (Cutting, 1966): most adults migrate from the sea into freshwater tributaries in the spring where they remain until fall to spawn; and the young usually remain in the streams for 2 or 3 years before migrating to the sea.

After smolting and leaving the streams, Lake Ontario and anadromous salmon both grew much faster than landlocked salmon. Cutting (1966) reported that anadromous salmon, after 2 years at sea and spawning for the first time, averaged about 10 pounds (4.5 kg) and Wilmot (1870) reported that first spawners in Lake Ontario weighed 8 to 12 pounds (3.6 to 5.4 kg). According to Warner (1966), spawning landlocked salmon, regardless of age, usually were less than 20 inches (51 cm) long and the largest rarely exceeded 5 pounds (2.3 kg). The observations made by Cutting and Warner generally agree with those of Atkins (1884). Conditions in the sea and Lake Ontario obviously were more favorable for the growth of salmon than those in the relatively small lakes inhabited by landlocked salmon.

The small size of most tributaries of Lake Ontario and their low flow and volume were unfavorable for the extended residency of large salmon; as a consequence, adult salmon usually occupied the streams for only short periods during spawning (Wilmot, 1880). Wilmot observed that young salmon in Wilmot Creek smolted only 1 year after hatching; he did not report any smolt large enough to suggest that the residency was 2 years. Possibly the relatively large spawning runs and the low capacity of such small streams to support large numbers of parr caused early smolting.

Since the Lake Ontario salmon apparently migrated from the streams at least 1 or 2 years earlier than anadromous forms, and grew much faster in the lakes than landlocked forms, they probably matured earlier than the other two forms. This earlier maturity could explain the unexpected early increase in abundance of grilse (after 2 seasons of growth) and older adults (after 3 seasons of growth), if these salmon came from the initial plantings in Wilmot Creek in the late 1860's.

THE DECLINE AND EXTINCTION OF ATLANTIC SALMON IN LAKE ONTARIO

DECLINE IN ABUNDANCE

Notable in the history of the Atlantic salmon were early references to their decline in the 1800's in major areas of abundance in North America other than Lake Ontario[3]. Edmunds (1874a) reported that salmon, once abundant in Lake Champlain and some of its tributaries, were extinct there by 1824; however, Atkins (1874) reported a run of salmon in the Au Sable River, a tributary to the lake, 14 years later, and a few were seen there as late as 1852. Smith (1875) reported serious declines of salmon in Nova Scotia and New Brunswick. C. G. Atkins (in Wilmot, 1873) reported sharp declines in the Saguenay River, a major tributary of the St. Lawrence River; the St. John River in New Brunswick; and in rivers in Nova Scotia and Prince Edward Island. Hamlin (1874) wrote of the decline of salmon in the rivers of Maine. Catastrophic declines of Atlantic salmon occurred in the 1800's along the entire Atlantic Coast where salmon formerly were abundant (Huntsman, 1944).

Huntsman (1931) reported that the decline of salmon in Lake Ontario in the late 1870's occurred almost simultaneously with similar declines in streams of the Atlantic Coast. The decline and extinction of the salmon in Lake Ontario therefore appears to be interrelated with the decline of other populations of Atlantic salmon, and the same factors (described in the following section) appear to have caused the decline throughout most of their range.

DeKay (1842), referring to the tributaries of New York, was the first to mention a decline in the abundance of salmon in Lake Ontario, and Adamson (1857) referred to their scarcity in the 1850's. According to Goode (1884), salmon were abundant in the Salmon River in New York in 1836, but numbers already had been declining for about 20 years.

References to the earliest disappearance of salmon from specific streams were made by J. Smith (in Huntsman, 1944), who observed that the salmon, once abundant in the Don River in Ontario, had disappeared by 1853; and by Fox (1930), who reported their disappearance in the mid-1800's from the Credit River (salmon later reappeared in these streams in the 1870's during Wilmot's propagation attempts). Huntsman (1944) also reported that, by the mid-1860's, salmon were extinct in tributaries west of Toronto and only a few were found in tributaries to the east (principally Wilmot and Shelter Valley Creeks). Witcher and Venning (1870) reported that Wilmot Creek, once crowded with salmon, supported only a few in 1869, and Wilmot (1869) observed that salmon were so scarce in the stream in the fall of 1866 that he had great difficulty in capturing enough parent fish to collect eggs for artificial propagation.

[3]According to Follett (1932), the St. Anne and Madeleine Rivers were the only tributaries of the St. Lawrence River supporting salmon in 1932. Adamson (1857) indicated that the Jacques Cartier River was the only tributary to the St. Lawrence River above Quebec that supported a great abundance of salmon.

In 1872, Edmunds (1874a) visited most of the streams in Lake Ontario east of Oswego and concluded that salmon were to be found in New York only in the lower reaches of the Salmon River; however, in the 1870's Smith (1892) reported salmon in several streams and Green (1882) reported salmon in the lower Genesee River--the first observed there in more than 50 years. Despite artificial propagation of salmon by Wilmot in the 1870's, a catastrophic decline in 1880 nearly wiped out the population (Wilmot, 1882). Salmon were extremely rare in Lake Ontario in the 1880's and 1890's; the last one seen in a stream was in Wilmot Creek in 1896 and the last one seen in the lake was reported in 1898 (Huntsman, 1944).

CAUSES OF DECLINE

The decline of salmon in Lake Ontario occurred during the early settlement of the region, and man indisputably was responsible for their loss. The cause of the decline and later extinction was best described by Fox (1930), who wrote: "The Ontario salmon had no longer a home wherein to rear their progeny and all that now remains of them is a name to warn us as a nation against the wanton destruction of a rich inheritance."

The major causes of decline were mill dam construction, deforestation, overfishing, and pollution. These factors, which apply primarily to tributaries and are described here for Lake Ontario, also were held responsible for the serious loss of other populations of salmon in the St. Lawrence River, Maritime Provinces, and Maine (Adamson, 1957; Smith, 1875; C.G. Atkins in Wilmot, 1874; Hamlin, 1874; and Huntsman, 1944).

Mill dams.--Although many factors may have contributed to the decline and ultimate extinction of salmon in Lake Ontario, the consensus among fish culturists and administrators in the late 1800's was that man-made obstructions, usually mill dams, were the principal cause. Passage of migrating salmon to their spawning grounds was not only blocked by the dams, but concentrations of salmon below dams were easy prey for fishermen. Apparently mill dams, many impassable by salmon, were common in Lake Ontario tributaries, particularly in the mid-1800's. For example, Smith (1892) reported a total of about 62 dams on the Salmon, Oswego, and Big Sandy Rivers and MacKay (1963) reported 36 dams on the Don River in 1852. Dams were common on the Little Sandy, Black, and Chaumont Rivers, and Edmunds (1874a) declared that these rivers were impassable for salmon. Wilmot (1875) mentioned that there were mill dams in most Canadian tributaries, many located near the mouths of the smaller streams.[4]

Mill dams as the principal cause for the loss of the salmon were also mentioned by DeKay (1842), Adamson (1857), King (1866), Edmunds (1874b), Goode (1884), Smith (1892), Wright (1892), Follett (1932), and Huntsman (1944). Opinion on the effects of dams on salmon was so strong that Commissioner M. McDonald (in Smith, 1892) reported to the U.S. Senate that "The cause of the disappearance, practically, of salmon from the streams of the St. Lawrence Basin has been chiefly and primarily the erection of obstructions in all rivers, which have prevented the salmon from reaching their spawning grounds, so natural reproduction has been absolutely inhibited."

Deforestation.--Extensive deforestation for agricultural purposes in the watersheds was another factor that apparently reduced the quality of streams for salmon. Although Smith (1892), Wright (1892), and Follett (1932), mentioned deforestation as an indirect cause of the decline of the salmon, Wilmot (1873, 1879, 1882) was the first to describe its most serious

[4] Of the many reports on the Lake Ontario salmon and causes for its decline, none mentioned sea lampreys (Petromyzon marinus) or lamprey attacks on salmon; consequently I assume that lamprey predation was not a serious problem, if it existed at all. If sea lampreys were in Lake Ontario during the decline of the salmon, numbers must have been low; the passage of prespawning lampreys into most tributaries would have been blocked by mill dams, as it was for the salmon, and reproduction would have been severely restricted. The high abundance of sea lampreys in Lake Ontario in the 1900's was probably due, in part, to the abandonment and destruction of many of the mill dams in Lake Ontario tributaries.

effects--accelerated runoff, increased siltation, and, in summer and fall, lowered stream flows and increased water temperatures (up to 24° C. in some streams)[5]. Wilmot warned that, as a result, stream conditions were not only unfavorable for reproduction and the survival of young salmon, but that during low flow the mouths of small streams sometimes were blocked by sand bars that delayed or prevented the passage of spawning salmon in the fall.

Overfishing.--Excessive and ill-timed fishing by various methods was thought to be a major cause of the decline of salmon in Lake Ontario. Most early authors described, with almost monotonous regularity, the taking of salmon with spear and club. For example, Wilmot (1870) blamed fishermen who speared and clubbed spawning salmon in Canadian tributaries and Fox (1930) described wholesale killing of salmon by spear and club in the Don, Humber, and Credit Rivers in Ontario as early as 1793. Kendall (1924) went so far as to calculate that skiff fishermen using spears killed about 10,000 salmon a year in the mid-1800's in the Salmon River in New York.

Conventional commercial fishing also was blamed for the decline. Green (1874) and Edmunds (1874b) thought that pound nets set along the shores and in and near the mouths of salmon streams in New York caught excessive numbers of prespawning salmon (Green reported that pound nets used in Lake Ontario were first imported from Scotland in 1836). J.A. Mathews (in Goode, 1884) reported that gill nets, stretched across the Salmon River in New York seriously depleted salmon there. Smith and Snell (1891) wrote that commercial salmon weirs in the St. Lawrence River were not only destructive to salmon but impeded the migration of salmon to their spawning grounds upstream, including Lake Ontario.

Other references to overfishing with spears, weirs, and nets were made in King (1866), Witcher and Venning (1870), Atkins (1874), Goode (1884), and Follett (1932). In a broader perspective, Huntsman (1944) was strong in his belief that fishing may have contributed to the decline of the salmon, but could not be held for its extinction.

Pollution.--Stream pollution also was described by several authors as a partial cause for the decline of the salmon. Sawdust and mill and factory wastes were most often mentioned as major pollutants by King (1866), Witcher and Venning (1870), Wilmot (1872, 1882), Edmunds (1874b), Goode (1884), and Wright (1892). In Smith (1892) it was reported that the Osewgo River was so polluted that salmon would not enter it. Although sawdust caused the greatest concern, Adamson (1857) ruled it out as a major cause of decline because its effects on salmon were only superficial.

Other factors.--Low flows in tributaries, which adversely affected salmon, may not have been caused entirely by deforestation; Huntsman (1944) believed that low rainfall in 1844-76, which reduced stream flow in salmon spawning streams, accelerated the decline of the salmon but he believed that if Wilmot's observations on stream siltation were valid, natural reproduction in most or all Canadian streams in the late 1800's would have been virtually impossible. Huntsman visited several former salmon streams near Toronto in 1943 and concluded that siltation was severe and that the streams were still unsuited for salmon.

Another factor of decline, unique to the Oswego River, was the construction of canals (as part of the Erie Canal system) among the headwaters of the Oswego River in the early 1800's. According to Edmunds (1874a) the canals ruined the Oswego River as salmon habitat. Still another factor was mentioned by Smith (1892) who suggested that unusually low stream flow in the Oswego River, which was caused partly by the drainage of bogs for agriculture, was detrimental to salmon (bogs acted as reservoirs that contributed to summer and fall flows).

[5]The impounding of streams by mill dams, which almost surely caused a warming of the water in the summer, was not specifically reported in the literature except for casual mention by Wilmot (1879).

Attemped remedies for the decline

The first proposal to save the salmon was made by Adamson (1857), who recommended that fishways be constructed over impassable dams on salmon streams. Atkins (1874) did considerable work in developing and promoting fishways for Atlantic Coast streams, but rarely were fishways constructed over dams in Lake Ontario tributaries.

By implication Green (1874) and Smith (1892) asked that salmon populations be protected by outlawing the use of commercial gear in or near the rivers and stopping the slaughter of migrating or spawning salmon, but by then the salmon in New York were nearly gone. In Ontario, after the fish were declining there, salmon were permitted to be taken by commercial fisheries in July and August only; fishing specifically for salmon in the 1870's was allowed by permit only (Wilmot, 1882).

Earlier, the rapid decline prompted King (1866) to propose that two of the best salmon streams (he chose the Credit and Moira Rivers) should be set aside as nurseries. Wilmot (1870) essentially followed this recommendation and set aside four streams for the natural and artificial breeding of salmon, each of which was protected from fishermen and poachers from about 1870 to 1880.

Before 1880, artificial propagation generally was considered the most likely solution to the decline of the Lake Ontario salmon. Adamson (1857) recommended artificial propagation, should his plan of providing fishways fail. Wilmot (1869) and Edmunds (1874a) strongly supported artificial propagation. Early opinions on the value of artificial propagation rested on the results reported by Wilmot, who practiced salmon culture from 1866 to 1884. By the early 1880's, it was clear that his attempts to restore the Atlantic salmon in Lake Ontario had failed (Wilmot, 1882). (Details of Wilmot's program of artificial and natural salmon restoration are given in later sections.)

Little was written about the salmon in the 1880's, but plans for reestablishing the species in Lake Ontario and the St. Lawrence River were revived in the 1890's. In 1891, in a message to the United States Senate, Commissioner M. McDonald (in Smith, 1892) stated, "It is not only possible, it is entirely practical, to restore and maintain these fisheries [salmon] by adequate recourse to means and agencies entirely within our control." He recommended the construction of facilities for the incubation of one million salmon eggs.

Smith (1892) reviewed the initial steps necessary to obtain a return of the salmon, as proposed by the U.S. Fish and Fisheries Commission. Steps proposed included an examination of the streams to determine the nature and number of obstructions and the extent of pollution. This inventory was to be followed by the removal of unnecessary obstructions, the building of fishways where dams were absolutely necessary, protection of the streams from pollution, and complete protection of salmon for a term of years. Cooperation between the U.S. and Canadian Governments and the development of international fishing regulations on Lake Ontario were advocated. Smith wrote that "having arranged the foregoing preliminaries, the important work of artificial propagation of salmon could be undertaken with every prospect of success."

Since the Lake Ontario salmon were virtually extinct, Commissioner McDonald (in Smith, 1892) recommended that salmon eggs--principally from landlocked forms that had lost their instincts to go to the sea--should be obtained from hatcheries in Maine and that fish should be planted as yearlings rather than fry, in the headwaters of former salmon streams.

Apparently few of the measures proposed by Commissioner McDonald for restoring the Atlantic salmon were initiated. The hatchery was never constructed and only small numbers of salmon fry were planted in the following years.

ATLANTIC SALMON PROPAGATION IN ONTARIO

The fish hatchery at Newcastle, Ontario, on Wilmot Creek, was first operated in 1866 by order of the Council of the Ontario Minister of Marine and Fisheries on the solicitation of Samuel Wilmot, who was appointed fishery officer of pisciculture. The following is an account of the activities of the hatchery, salmon plants, observations, and results extracted from annual reports for 1868-81 submitted by Wilmot and published by the Department of Marine and Fisheries in 1869-82.

CULTURE OF ATLANTIC SALMON BY SAMUEL WILMOT, 1866-81

The records and observations of Wilmot, although valuable and representing by far the best documentary of the salmon in Lake Ontario, lacked continuity because his reports included specific numerical data for only some of the years. Nonetheless, major trends and changes in artificial propagation and the salmon populations were clearly described.

Wilmot Creek was characteristic of most salmon streams along the north shore of Lake Ontario. It was fed by a large spring, was about 10 miles (16 km) long, and consisted of a series of pools and gravel shoals which once were highly suitable for the spawning of salmon. Wilmot Creek, and later Shelter Valley (known by Wilmot as Grafton Creek; see Table 1 for the names of streams used by Wilmot and those now commonly used), Bowmanville, and Duffin Creeks, were set aside for the natural and artificial propagation of salmon and were closed to public fishing and protected from poachers. Weirs were installed on each of these streams for the collection of eggs, but most eggs were taken from Wilmot Creek.

Wilmot first attempted propagation of salmon at Wilmot Creek in 1866 after constructing a weir, retention pool, and a hatchery about 1.5 miles (2.4 km) upstream from Lake Ontario. As the years progressed, he improved methods of propagation and gained fame as a fish culturist; he was the first in Canada or the United States to use the "dry" method of fertilizing eggs.

In the 16 years of egg collecting (1866-81), most eggs were collected from mid-October to mid-November. In 1867-69 all salmon were planted in Wilmot Creek but plants in later years were made in 15 streams that were once known to support spawning runs (see Table 1 for Wilmot's salmon planting records).

Cultural methods differed over the years. In 1867-69, the young were hatched in January; in 1867-68 they were fed pulverized dry beef liver and planted as 1- to 4-inch (2.5- to 10.2-cm) fingerlings in the spring, whereas in January 1869 they were raised to lengths of 2 to 4 inches (measured in December 1869) and released in the early spring of 1870. In all later years (1870-81), most eggs were hatched in April and, with few exceptions, the fish were planted in May or June as swim-up fry. This change was necessary because too few nursery ponds were available to raise large numbers of fingerlings and also because fingerlings were frequently lost from nursery ponds during spring floods. The source and temperature of the water supply was another factor. When egg production was low in the earlier years, spring water (5.6° C) of limited supply was used in the hatchery, rather than creek water (0.6° C). As egg production increased, only creek water supplied the volume necessary for the hatchery operation and, because of the resulting decrease in water temperature, incubation time increased from 65 to 165 days. Nonetheless, for several years after 1869, and in 1873 in particular, a number of salmon were raised to a length of 6 inches (15.2 cm), but were not identified in the planting records.

Trends in the number of brood fish taken in the fall, number of eggs collected, and the number of fish planted each year, were closely similar. For Wilmot Creek, only 15 brood salmon were taken in the weir in 1866, 25 in 1867, and 30 in 1868 (150 grilse also were taken in 1868). For other years when salmon counts (including grilse) in the weir were reported, the numbers were 300 in 1869, 400 in 1870, 800 in 1874, 1,500 in 1875, and 21 in 1881. Although weir catches were not reported

for 1878, 3,000 adults were counted at one time in the stream section below the weir.

The numbers of eggs collected from Wilmot Creek (and from Duffin, Shelter Valley, and Bowmanville Creeks in some of the years after 1867) were 15,000 in 1866, 50,000 in 1867, and 200,000 in 1868. Thereafter the annual take of eggs generally increased to peaks of 1 million in 1875 and 1.5 million in 1876, and declined to 350,000 in 1879 and 250,000 in 1880. Few eggs were collected after 1880. A small percentage of the eggs collected were shipped outside the Great Lakes drainage for hatching and planting.[6]

The numbers of young salmon produced at the Wilmot hatchery and planted in Lake Ontario were 8,000 in 1867, 15,000 in 1868, 62,000 in 1869, and 150,000 in 1870. Numbers planted increased annually to a peak of 1.3 million in 1877, and then declined to 600,000 in 1879 and 140,000 in 1881. In all, about 5.2 million salmon were planted in Lake Ontario and its tributaries in 1867-81 (Table 1). A few apparently were also planted in 1882-84; in 1895, an employee at the Wilmot hatchery collected and incubated eggs from several salmon caught in Wilmot Creek; the 4,000 fry that hatched--the last produced at the hatchery--were planted in the creek in the spring of 1896 (MacKay, 1960).

More than one-half of the Lake Ontario salmon were planted in Wilmot Creek in 1867-81 and, from all indications, the abundance of parr, smolt, grilse, and older adults in Wilmot Creek may have equaled or exceeded that in all other Ontario tributaries combined. Although Wilmot examined most streams planted with salmon in most years, many of the observations on salmon were made by district fishery officers.

Salmon never became even marginally abundant in other streams in the 1870's. In Duffin Creek, 3 adults were observed in 1869, 120 in 1872, 200 in 1876, and 150 in 1877. Most of these fish were observed on spawning redds. In Bowmanville Creek, only a few salmon were seen in 1870 and 1872, but 130 were counted in 1873 and a greater number in 1878. In 1876, 150 spawning redds were counted. In Shelter Valley Creek, catches in the weir increased from several dozen in 1868 to 96 in 1869 (some salmon were seen spawning in 1868-69), and 200 in 1875 (the first sizable run). Although numbers declined in 1877, 200 were observed below the weir at one time in 1878.

In the Trent River, which was reported not to have supported salmon spawning runs in earlier years, brood salmon were observed as far as 25 miles (40 km) upstream from the mouth. A few salmon were observed in 1872-73, and a relatively strong spawning run occurred in 1878.

Although Wilmot reported that salmon could be found in the mid-1870's in most of the streams from Hamilton to Brighton, a shoreline distance of 100 miles (161 km), fall spawning runs were light (compared with those in streams already described). For the first time in years, small runs of salmon and spawning activity were observed in the Rouge, Humber, Credit, Ganaraska, and Moira Rivers, and in Lynde, Highland, Farewell, Brand, Cobourg, and Soper Creeks. Light runs of salmon also were observed occasionally in Twelve-mile Creek, Oakville Creek, Gage Creek, and Bronte River, the only streams supporting salmon runs that were not planted with salmon.

Wilmot, in his annual reports, expressed his views on the results of his attempts to repopulate Lake Ontario with salmon by artificial propagation. After the appearance of 150 grilse in the Wilmot Creek weir in 1868, which seemed to be the first indication of success, Wilmot (1869) wrote that "some special cause must exist for the sudden appearance of young salmon [grilse], which did not exist for the last 15 or 20 years and no probable or reasonable cause can be assigned but the one that leads to the supposition that they are a past product of the first brood which were hatched and set at liberty in the spring of 1867."

[6] Although salmon have never been reported in the Ottawa River, Wilmot planted salmon twice in one tributary to the Ottawa River 45 miles below the City of Ottawa to "restore" the salmon there.

TABLE 1.--Numbers (thousands) of Atlantic salmon from Lake Ontario stocks planted by the Dominion of Canada in tributaries of Lake Ontario in 1867-84; the number of years in which plants were made are given in parentheses

Years	Location[1]	Site number (see Figure 2)	County	Number planted[2]
1873-77	Credit River	5	Peel	100 (5)
1872-77	Humber River	8	York	85 (4)
1871-72	Highland Creek	10	York	40 (2)
1870-77	Rouge River	11	York	70 (4)
1870-77	Duffin Creek	12	Ontario	180 (5)
1870-77	Lynde Creek	13	Ontario	35 (2)
1871	Farewell Creek	14	Ontario	30 (1)
1870-77	Bowmanville Creek	15	Durham	245 (7)
1867-77	Wilmot Creek	17	Durham	2,400 (11)
1871	Cobourg Creek	21	Northumberland	10 (1)
1871-77	Shelter Valley Creek	22	Northumberland	170 (5)
1871-77	Trent River	23	Hastings	230 (5)
1877	Kawartha Lakes[3]	23	Ontario	40 (1)
1872	Moira River	24	Hastings	50 (1)
1877	Lake Ontario	-	-	10 (1)
1867-77 Total				3,695
1878-79	Credit River	5	Peel	- (2)
	Humber River	8	York	- (2)
	Rouge River	11	York	- (2)
	Duffin Creek	12	Ontario	- (2)
	Lynde Creek	13	Ontario	- (2)
	Bowmanville Creek	15	Durham	- (2)
	Soper Branch	16	Durham	- (1)
	Wilmot Creek	17	Durham	- (2)
	Ganaraska River	19	Durham	- (1)
	Shelter Valley Creek	22	Northumberland	- (2)
	Trent River	23	Hastings	- (2)
	Kawartha Lakes	23	Ontario	- (1)
	Moira River	24	Hastings	- (1)
	Lake Ontario	-	Hastings	- (1)
1878-79 Total				1,161
1880	Lake Ontario tributaries	-	-	247
1881	Bowmanville Creek	15	Durham	40 (1)
	Wilmot Creek	17	Durham	100 (1)
1881 Total				140
1867-81 Total				5,243

[1]The names of the streams were taken from maps prepared by the Army Survey Establishment of Canada, 1958-59. Differences in names of streams used by the Survey and those used by Wilmot (in parentheses) are as follows: Bronte River (Twelve Mile Creek); Oakville Creek (Oakville Creek or Sixteen Mile Creek); Lynde Creek (Lynn or Lyons Creek); Farewell Creek (Black Creek); Bowmanville Creek (Barber Creek); Soper Branch (Souche Creek); Wilmot Creek (Wilmot or Baldwin Creek); Ganaraska River (Smith or Port Hope Creek); Cobourg Creek (White Creek); and Shelter Valley Creek (sometimes confused with Grafton Creek).

[2]All fish were fry except for 85,000 1- to 4-inch (25- to 100-mm) fingerlings planted in Wilmot Creek in 1867-69, and unspecified numbers of fingerlings released in Wilmot Creek, in 1870-73.

[3]Kawartha Lakes (reported as Petersborough Lakes by Wilmot) include Balsam, Clear, Sandy, Gull, and Cushog Lakes, all at the headwaters of the Trent River.

He stated further, "It had been ascertained positively that the period intervening between the planting of these young salmon and the appearance of the grilse alluded to, is exactly the time required for the growth in this state of existence." He concluded, "the proof that they were the result of the artificial process commenced by me in the autumn of 1866, is, to my mind and the minds of others, conclusive and almost amounts to a demonstration."

Wilmot's conclusions seemed to be strengthened when some of the salmon hatched in 1867, which he retained in ponds for experimental purposes, smolted in the spring of 1868. He judged that the fingerlings planted in 1867 also smolted in the spring of 1868, and that some returned as grilse in the fall of 1868 and most as older adults in the fall of 1869. Catches in the weirs in those years tended to bear out this judgment.

Wilmot's early propagation attempts appeared to be so successful that Bowles (1872) wrote that "Mr. Wilmot's success in the artificial culture of these salmon is one of the greatest triumphs in the science of fish culture...."

By 1877, the greater abundance of salmon in the fall migrations, as compared with that in earlier years, appeared to be strong evidence that the salmon population was recovering. In 1879, when abundance sharply decreased, Wilmot was inclined to blame low stream flows in the fall for the declines.

Although the decline of salmon in 1879 may not have appeared to be serious, evidence in 1880 confirmed that the salmon population was in trouble; eggs were collected only after an unprecedentedly intensive search for mature adults, and only 140,000 fry were produced (as compared to 1.3 million in 1877).

By 1881, Lake Ontario salmon had virtually disappeared. The weir catch in Wilmot Creek consisted primarily of a few large females. Only three males were captured during the entire season (their milt was used to fertilize the few eggs that were collected). None of 18 salmon seined from spawning redds in Wilmot Creek below the weir were males.

Not until he wrote the 1881 report did Wilmot (1882) indicate that he had observed a serious decrease in the abundance of parr and smolt in Wilmot Creek from 1875-78, and that few parr, smolt, or grilse were seen thereafter; although the decline in abundance of adults should therefore not have been entirely unexpected, Wilmot was astounded. He stated that "the falling off of these fish [salmon] is beyond all comprehension...." and "This fact [scarcity of salmon] . . .will not allow me to disguise from myself the conviction that the time is gone by forever, for the growth of the salmonoid family in this [Wilmot Creek] or any other of the frontier streams in Ontario."

Despite Wilmot's emphasis on artificial propagation, he placed great importance on protecting spawning fish from poachers to develop greater potential for natural reproduction. His observations bore out that there was rather extensive natural spawning in several streams, principally Wilmot, Duffin, and Shelter Valley Creeks, and some natural spawning in a total of 20 streams.

From all indications, stream conditions were poor for the natural reproduction of salmon in the period when Wilmot carried out artificial propagation. In most years rainfall was unusually low (see Huntsman, 1944) and, according to Wilmot (1873), low stream flows in the summer and fall were becoming serious and seemed to worsen every year. Wilmot identified intensive timber cutting and increased agriculture as major contributors to low flow. Stream flow was so low in 1871 that salmon were observed, for the first time, attempting to spawn along the shoreline adjacent to the mouths of several streams (Shelter Valley Creek in particular). At the mouths of these streams, sand bars, coupled with low flow, interfered with the upstream passage of salmon. Wilmot reported this condition in several other years, the last in 1879.

Wilmot conducted experimental fishing for salmon in some years to help establish commercial fishing potentials. In 1871, several trap nets set in the summer in Lake Ontario near Wilmot Creek caught 200 salmon weighing 6 to 15 pounds (2.7 to 6.8 km) each and in July 1875, traps set near the mouth of Wilmot

Creek caught 120 salmon. In July 1876, 100 salmon were caught in several trap nets set near Coburg, and 240 (8 to 18 pounds or 3.6 to 8.2 kg) near the mouth of Wilmot Creek. Experimental nets took another 143 salmon in 1877. Wilmot (1875) blamed the low catches on poorly rigged gear, inexperienced hands, and the failure of salmon to inhabit shallow waters in the summer. His explanations were prompted by claims of the Minister of Fisheries that the propagation program had not developed a fishery of any consequence.

Analysis of Wilmot's reports

In summary, Wilmot initiated artificial propagation of salmon in Lake Ontario in 1866, and because of poor results, discontinued it in 1884. Before propagation, the Lake Ontario salmon were nearly extinct; small spawning runs remained only in Wilmot and Shelter Valley Creeks in Ontario and in the Salmon River in New York. During the years of propagation, the numbers of parr and grilse increased substantially from 1868 to 1874, and the numbers of adults increased remarkably from 1869 to 1877. By 1878, spawning runs were observed in 20 Canadian tributaries, and a few salmon appeared in several New York tributaries where salmon had not been seen for years.

The subsequent decline was demonstrated by sharp decreases in abundance of parr and smolt in 1875-76, of grilse in 1876-77, and of adults in 1879-80.

Wilmot's plan to reestablish salmon to their former abundance in Lake Ontario and the work that followed appear to have been sound. Commercial fishing, except on an experimental basis, generally was banned; four of the principal spawning streams were protected from poachers by Wilmot's staff; salmon in most other streams were protected (but rather weakly) by law; swim-up fry (and fingerlings up to 6 inches (15.2 cm) long in the early years) were planted in 15 tributaries of Lake Ontario over a period of 18 years; and adults were seen to spawn in relatively large numbers in streams that formerly were highly productive of young salmon.

Circumstantial evidence suggests that Wilmot's artificial propagation attemps were responsible for the temporary revival of the Lake Ontario salmon. The increase in abundance of parr, then grilse, and then older adults in successive years after the first plant in 1867 indicates a successful first plant. The increase in the numbers of fish planted in the following years and the increase in abundance of salmon in a number of tributaries by the mid-1870's suggest a successful program of artificial propagation. The unusually low flows, increased water temperatures, and siltation in the salmon streams during the period of propagation would hardly favor a natural recovery, however temporary, of a population near extinction. Furthermore, most of the fry and all or most of the fingerlings were planted in Wilmot Creek, and it was here that parr, smolt, grilse, and older adults appeared in by far the greatest numbers. It may have been more than a coincidence that spawning runs developed in nearly all the streams planted, including the Trent River (until salmon were planted in the Trent River, spawning runs were not known there).

Conceivably, the abundance of grilse and older adults in the 1870's could have been caused by a temporary influx of migrants from the sea. If so, it would be difficult to explain why they selected Wilmot Creek in particular, and why few or none were reported in the upper St. Lawrence River and its tributaries or in New York waters of Lake Ontario and its tributaries.

Assuming that Wilmot's artificial propagation was the cause of the temporary increase in abundance of the salmon in the 1870's, there is evidence for speculation on the causes of his success and ultimate failure. I postulate that the fingerlings planted in 1867-69, and others up to 6 inches (15.2 cm) long in 1870-73 made up the bulk of the adults in later years. Dependence on the survival (perhaps extremely low) of fry planted after 1873 may have been accountable for the failure of artificial propagation.

Wilmot's propagation program could have been a temporary reprieve of a population that

had severely dwindled over the years because dams and stream habitat deterioration destroyed natural reproduction. If Wilmot and others had continued to plant fingerlings through the years, they might have saved the Lake Ontario salmon from extinction.

PART II--EXOTIC SALMON IN THE GREAT LAKES

In this part a chronological review of the history of exotic salmon and their artificial propagation in the Great Lakes from 1850 to 1970 is followed by descriptions of the plantings and results from 1873 to 1947 (when all plants were failures) and from 1950 to 1970 (when new salmon fisheries developed).

ARTIFICIAL PROPAGATION OF EXOTIC SPECIES OF SALMON IN THE GREAT LAKES

The decline of the Atlantic salmon and several other species of fish in northeastern North America in the 1800's led to a strong conviction among fishery authorities that artificial propagation was the solution for reestablishing declining populations, as well as for introducing new species to enhance the fisheries.

In the period when the Atlantic salmon population exhibited its greatest decline (in the 1860's) and when Wilmot's artificial propagation of salmon for planting in Lake Ontario seemed to show great promise (in the 1870's), various federal and state fish commissions were established, primarily to initiate fish culture. The commissions that were involved in the early introductions of salmon in the Great Lakes, and the year that they were founded are as follows: Department of Marine and Fisheries of Canada - 1866; U.S. Fish and Fishery Commission - 1871; and state fish commissions in New York - 1868, Pennsylvania - 1870, Ohio - 1873, Michigan - 1873, Wisconsin - 1874, and Minnesota - 1875 (Goode, 1881).

These commissions gave top priority to the propagation of salmon, and egg collecting stations and hatcheries were promptly constructed. In Canada, the Newcastle Station on Wilmot Creek was constructed in 1866 to propagate Atlantic salmon (from Lake Ontario) and later, chinook salmon. The U.S. Fish and Fishery Commission built egg collecting and hatchery facilities in 1872 for anadromous Atlantic salmon on the Penobscot River in Maine and for chinook salmon on the Sacramento River in California, and in 1873 for landlocked Atlantic salmon at Grand Lake Stream in Maine. All of these stations supplied eggs to federal and state hatcheries, for hatching and distribution. For many years, all or most salmon planted in the Great Lakes were apparently supplied from these stations (except for the Newcastle station, which stopped hatching salmon eggs in 1884), or from new stations that propagated the same stocks of salmon. It was not until about 1950 that the bulk of the salmon eggs were obtained from new sources. New strains or species were sought and some states and Ontario initiated new salmon stocking projects. Sources of eggs, when known, are identified with the plantings in the text.

The relatively intensive introduction of exotic salmon in the Great Lakes in 1873-80 was characterized by the planting of large numbers of small lots of fry in a wide range of habitats. Few salmon were planted in 1881-1919 (except in New York waters of Lake Ontario), partly because of past failures and partly because the U.S. Fish and Fishery Commission gave high priority to supplying salmon for coastal streams. From 1920 to 1949 only a few plants of salmon were made but some of the individual plants were large, and the fish, mostly fingerlings, were planted in streams that provided the best chance for survival. In 1950, the trend began toward planned, long-term introductions of salmon.

Until 1966 nearly all salmon were planted in Great Lakes waters with the primary objective of establishing self-sustaining populations, either in the Great Lakes or in inland tributary lakes and streams. (Except for the plantings of pink salmon, Oncorhynchus gorbuscha,

in Lake Superior, all failed.) This practice was greatly altered when the conservation departments of Michigan and other Great Lakes states planted millions of coho and chinook salmon smolts in the Great Lakes in 1966-70 to provide a put-and-take sport fishery. Not only was a sizable sport fishery established in Lake Michigan and to a lesser extent in the other lakes, but coho salmon reproduced in several Michigan streams in 1968-70. A chronological review of the history of salmon in the Great Lakes in 1850-1970 follows:

1850-67 - Sharp decline in abundance of Lake Ontario Atlantic salmon.

1866 - Canadian Department of Marine and Fisheries founded. Newcastle salmon hatchery constructed on Wilmot Creek, Ontario.

1867 - First Lake Ontario Atlantic salmon planted in Lake Ontario.

1871 - United States Fish and Fishery Commission founded.

1872 - Chinook salmon egg collecting station (The Baird Station) constructed by the U.S. Fish and Fishery Commission on the McCloud River, a tributary to the Sacramento River in California. Egg collecting station for anadromous Atlantic salmon (the Bucksport Station, now known as the Craig Brook hatchery), constructed on the Penobscot River, Maine, by the U.S. Fish and Fisheries Commission. Lake Ontario Atlantic salmon first planted in Lake Huron tributaries by the Canadian Department of Marine and Fisheries.

1873 - Station for collecting eggs of landlocked Atlantic salmon constructed at Grand Lake Stream, Maine, by the U.S. Fish and Fishery Commission. Anadromous Atlantic salmon and chinook salmon first planted in the Great Lakes.

1874 - Landlocked Atlantic salmon first planted in the Great Lakes.

1881 - Lake Ontario tributaries declared unfit for salmon by Samuel Wilmot.

1884 - Newcastle breeding station discontinued for the artificial propagation of salmon.

1890 - Introductions of Atlantic and chinook salmon in the Great Lakes declared failures by the U.S. Commissioner of Fish and Fisheries.

1896 - The last few thousand Lake Ontario Atlantic salmon planted in Lake Ontario.

1898 - Lake Ontario Atlantic salmon became extinct.

1919 - Tendency began for planting salmon fingerlings in a few selected waters rather than planting fry in a wide range of habitats.

1929 - The masu salmon (Oncorhynchus masu), from Japan, planted in a tributary of Lake Michigan by the Michigan Department of Conservation (the only plant of this species).

1933 - Coho salmon first planted in the Great Lakes (as fingerlings in Lake Erie by the Ohio Division of Conservation).

1938 - Tendency began for introducing salmon for sport fishing, rather than for commercial fishing.

1944-47 - The first scientific study of the results of planting salmon (anadromous Atlantic salmon) in the Great Lakes (Duffin Creek, Lake Ontario), conducted by the Ontario Department of Lands and Forests.

1950 - First kokanee salmon (lacustrine stocks of sockeye salmon, Oncorhynchus nerka) planted in the Great Lakes (in Lake Ontario tributaries by the New York Conservation Department).

1950-53 - First long-range plan (still in progress in 1970) of introducing exotic salmon (kokanee in 1950 and anadromous Atlantic salmon in 1953) in Great Lakes waters (in Lake Ontario tributaries by the New York Conservation Department).

1956 - Pink salmon first planted in the Great Lakes (in Lake Superior by the Ontario Department of Lands and Forests).

1958 - First known natural reproduction of an exotic salmon in the Great Lakes (pink salmon in Lake Superior).

1964 - Long-range plan (still in progress in 1970 in Lake Huron) for establishing kokanee salmon in Lakes Huron and Ontario initiated by the Ontario Department of Lands and Forests.

1966 - Coho salmon first planted in the Great Lakes in large numbers, as smolt (in Lakes Superior and Michigan by the Michigan Department of Conservation).

1967 - Coho salmon sport fishery in Lake Michigan showed first promise of success. Chinook salmon first introduced in the Great Lakes in large numbers, as smolt (in Lakes Superior and Michigan, by the Michigan Department of Conservation).

1968-70 - Coho and chinook salmon smolts planted in all the Great Lakes (all of the Great Lakes states and the Province of Ontario participating).

1968 - Natural reproduction of kokanee salmon discovered in a tributary of Lake Huron by the Ontario Department of Lands and Forests (the first for the Great Lakes). Natural reproduction of coho salmon discovered in several tributaries of Lakes Michigan and Superior by the Michigan Department of Conservation.

1969 - Pink salmon first discovered in a tributary of northern Lake Huron. Pink salmon in Lake Superior had sustained, by natural reproduction, six successive complete generations.

1969-70 - Sport fishery for coho and chinook salmon very successful in Lake Michigan, but only fair to poor in the other Great Lakes.

Table 2 shows the number and percentage of the grand total of Atlantic, chinook, coho, and kokanee salmon planted in each of the Great Lakes and their tributaries in different periods in 1873-1970, and for each form or species, the number of plants, average number of fish per plant, and percentage of fish of different life stages planted. More detailed descriptions of the planting records and results are given in the following sections. Stream locations and species planted for each lake for different periods in 1873-1970 are given in Figures 3 (Lake Ontario), 4 (Erie), 5 (Huron), 6 (Michigan), and 7 (Superior).

SALMON PLANTING RECORDS AND RESULTS, 1873-1947

Since plants of salmon in this period were failures (none of the species planted established a fishery or permanent population), the following is largely a record of the plants by species, lake, and state or province.

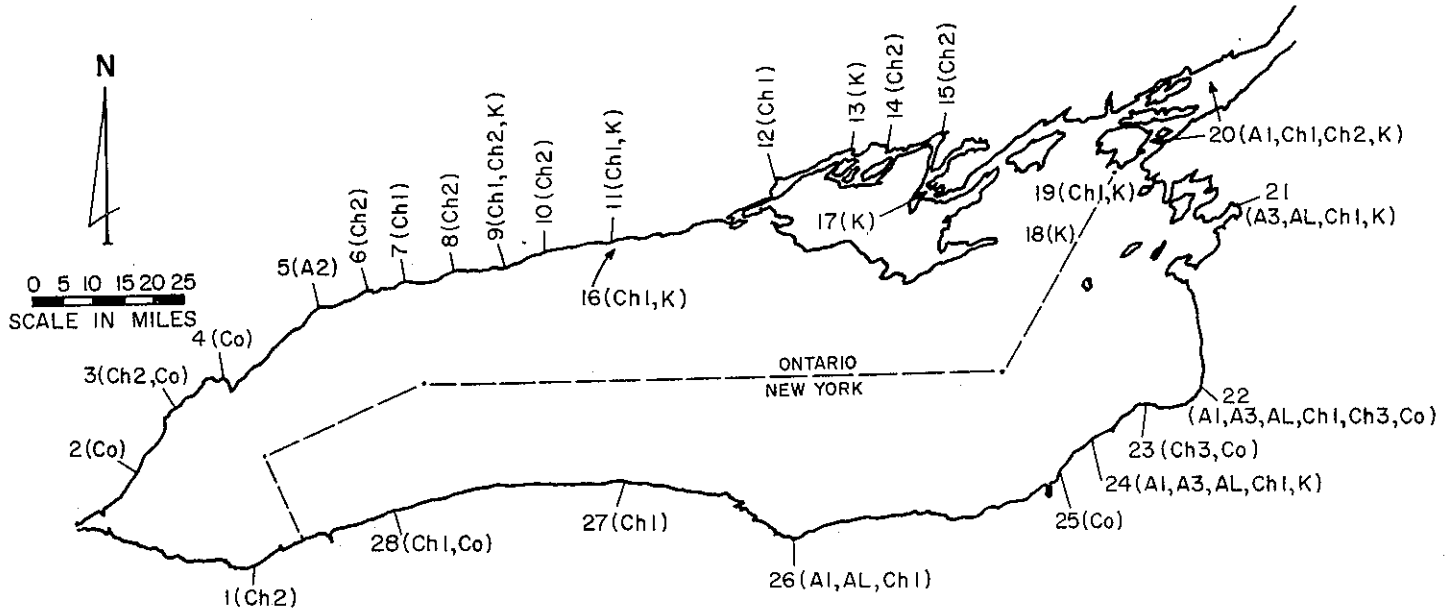
CHINOOK SALMON

In 1873-1933, about 11 million chinook salmon were planted in the Great Lakes, Lake St. Clair, and their tributaries (Table 3). Percentages of the total planted in the various lakes or their tributaries were: Lake Ontario, 82; Lake Michigan, 7; Lake Erie, 6; Lake Huron, 3; Lake Superior, 1; and Lake St. Clair, 1.

Table 2.--Number (thousands) and percentages of the grand total (in parentheses) of Atlantic, chinook, coho, and kokanee salmon planted in each of the Great Lakes and their tributaries; and for each form or species, the number of plants, average number per plant, and percentages planted at different life stages, 1873-1970

Lake or item	Atlantic salmon				Chinook salmon				Coho salmon	Kokanee salmon	Grand total
	Anadromous			Landlocked							
	1873-1947	1953-70	1853-1970	1873-1933	1873-98	1919-33	1967-70	1873-1970	1966-70	1950-70	
Ontario	329(44)	410(100)	739(64)	42(4)	6,854(77)	2,338(98)	211(4)	9,403(55)	726(4)	5,387(30)	16,297(30)
Erie	53(7)	-	53(5)	192(10)	566(6)	79(2)	150(3)	795(5)	881(6)	326(1)	2,147(4)
Huron	27(4)	-	27(2)	215(20)	337(4)	-	1,127(19)	1,464(9)	1,640(10)	8,956(47)	12,302(22)
Michigan	130(17)	-	130(11)	499(49)	842(9)	-	4,110(69)	4,952(28)	10,196(65)	3,936(20)	19,713(37)
Superior	200(28)	-	200(18)	188(17)	64(1)	-	318(5)	382(2)	2,394(15)	366(2)	3,530(6)
Lakes combined	[1]743	410	[1]1,153	[2]1,064	[3]8,794	2,417	5,916	[3]17,127	[4]15,878	18,971	54,193
Number of plants	48	137	-	118	237	40	34	-	178	139	
Average number per plant	16	3	-	9	37	60	174	-	89	137	
Percentage planted at different life stages[5]											
Fry	85	-	-	97	99	89	-	-	-	75	
Fingerlings[6]	15	100	-	3	1	11	-	-	1	16	
Smolts	-	-	-	-	-	-	100	-	99	-	

[1]Total includes 4,000 fish planted in Lake St. Clair.
[2]Total includes 28,000 fish planted in unspecified waters of the State of Michigan.
[3]Total includes 131,000 fish planted in unspecified waters of the State of Michigan and 74,000 fish planted in Lake St. Clair.
[4]Total includes 41,000 fish planted in 1933 in Lake Erie waters.
[5]Not shown are plants of kokanee salmon eggs (9% of total) in 1950-70.
[6]Fingerlings usually were less than 1 year old, but some were older.



SPECIES INDEX

Atlantic Salmon
- Anadromous
  - A1 : 1873-1919
  - A2 : 1944-47
  - A3 : 1953-70
- Landlocked
  - AL : 1878-1917

Chinook Salmon
- Ch1 : 1873-98
- Ch2 : 1919-25
- Ch3 : 1969-70

Coho Salmon
- Co : 1968-70

Kokanee Salmon
- K : 1950-70

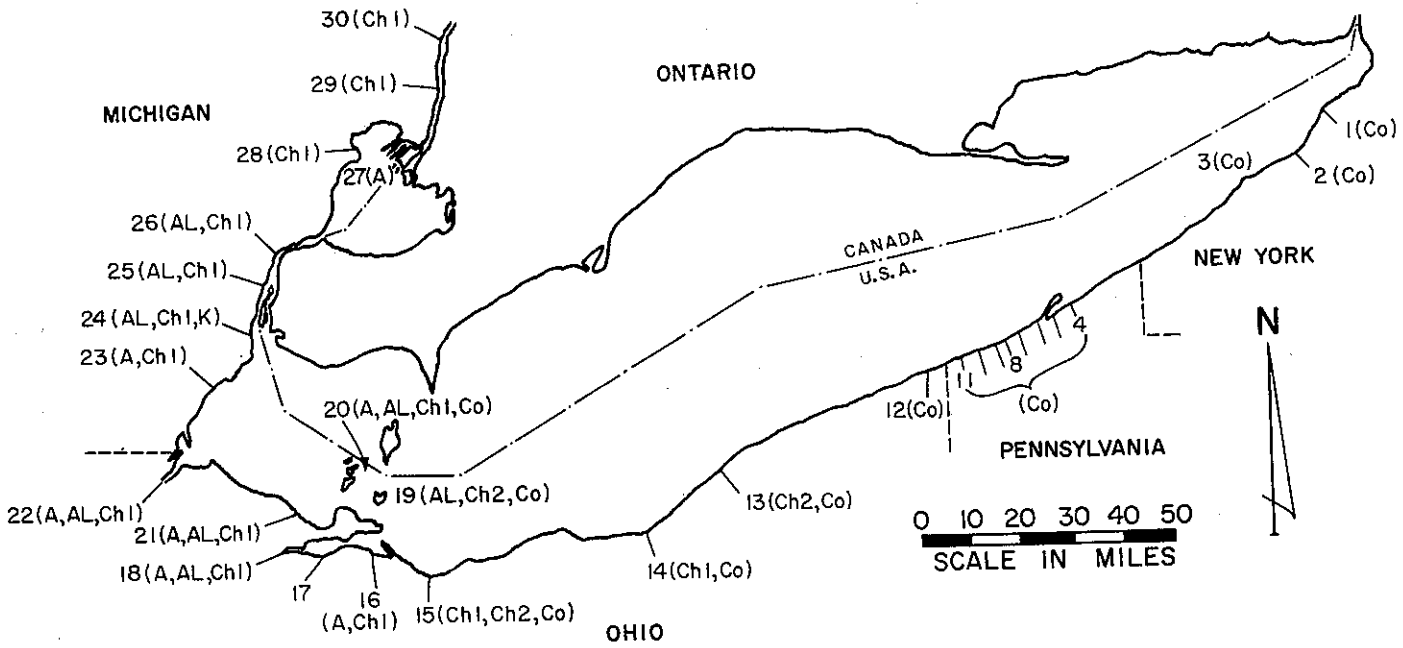
Ontario

1. Twelve-mile Creek
2. Bronte River
3. Credit River
4. Humber River
5. Duffin Creek
6. Lynde Creek
7. Bowmanville Creek
8. Soper Branch
9. Wilmot Creek
10. Graham Creek
11. Shelter Valley Creek
12. Trent River
13. Salmon River
14. Clark Creek
15. Napanee River
16. Lake shoreline
17. Lake shoreline
18. Main Duck Island
19. Charity Shoals
20. St. Lawrence River

New York

19. Charity Shoals
20. St. Lawrence River
21. Black River
22. Salmon River
23. Little Salmon River
24. Oswego River
25. Sterling Creek
26. Genesee River
27. Sandy Creek
28. Oak Orchard Creek

Figure 3.--Lake Ontario, showing sites (indicated by numbers) and (in parentheses) species planted at those sites in different periods in 1873-1970 (indicated by species index code).



New York
1. Eighteen-mile Creek
2. Cattaraugus Creek
3. Dunkirk Harbor

Pennsylvania
4. Orchard Beach Run
5. Six-mile Creek
6. Walnut Creek
7. Trout Run
8. Unnamed Creek
9. Godfrey Run
10. Grimshaw Run
11. Elk Creek

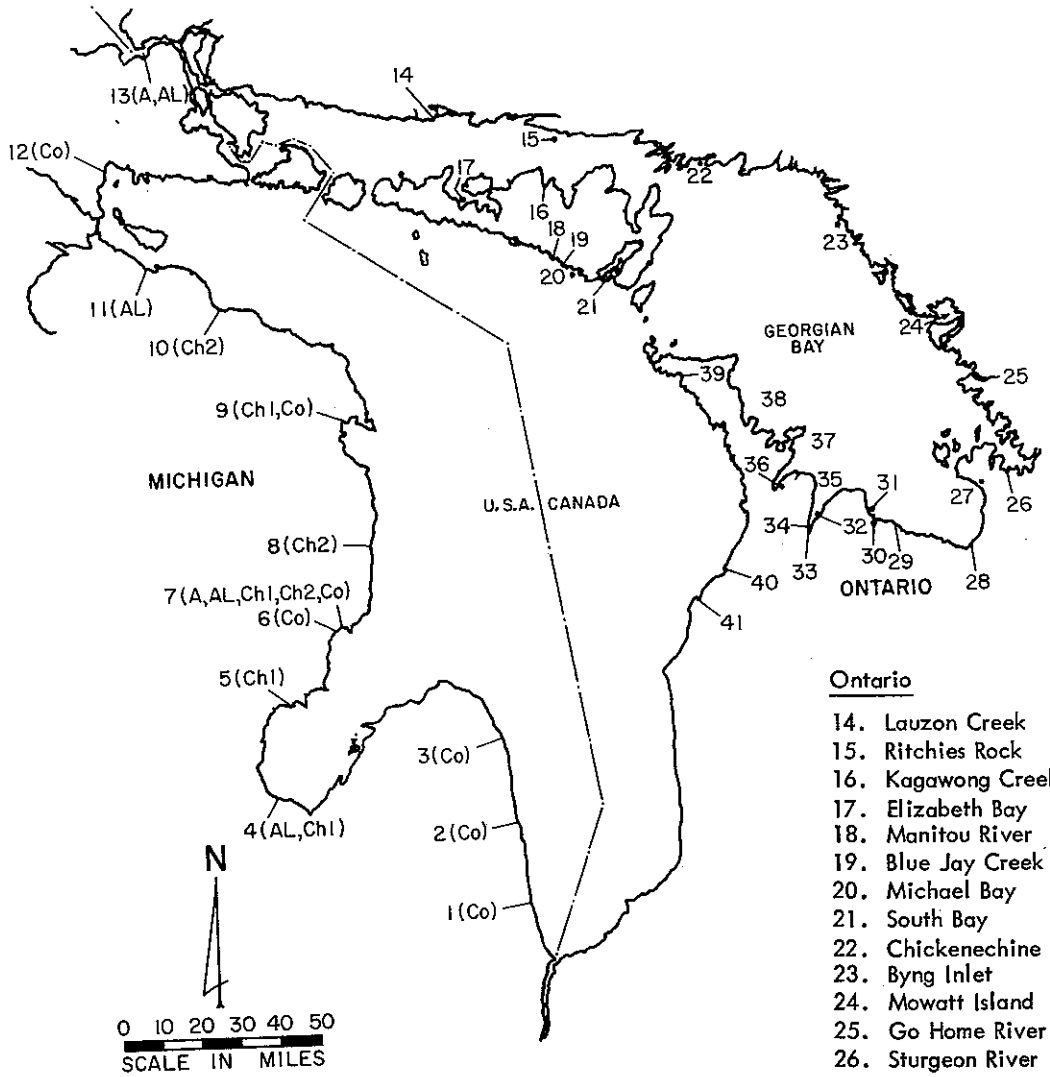
Ohio
12. Conneaut Creek
13. Chagrin River
14. Cuyahoga River
15. Huron River
16. Cold Creek
17. Pickerel Creek
18. Sandusky River
19. Kelley Island
20. Bass Islands
21. Portage River
22. Maumee River

Michigan
23. Raisin River
24. Huron River
25. Detroit River
26. Rouge River
27. Lake St. Clair
28. Clinton River
29. St. Clair River
30. Black River

SPECIES INDEX

Atlantic Salmon
Anadromous
A : 1873-75
Landlocked
AL : 1874-1932
Chinook Salmon
Ch1 : 1873-80
Ch2 : 1968-70
Coho Salmon
Co : 1968-70
Kokanee Salmon
K : 1969-70

Figure 4.—Lake Erie, Lake St. Clair, and Detroit and St. Clair Rivers, showing sites (indicated by numbers) and (in parentheses) species planted at those sites in different periods in 1873–1970 (indicated by species index code); not shown are plantings of coho and chinook salmon in Cold and Pickerel Creeks (site numbers 16 and 17) in 1933.



SPECIES INDEX

Atlantic Salmon
- Anadromous
  - A : 1873-75
- Landlocked
  - AL : 1874-1919

Chinook Salmon
- Ch1 : 1873-82
- Ch2 : 1967-70

Coho Salmon
- Co : 1967-70

Michigan

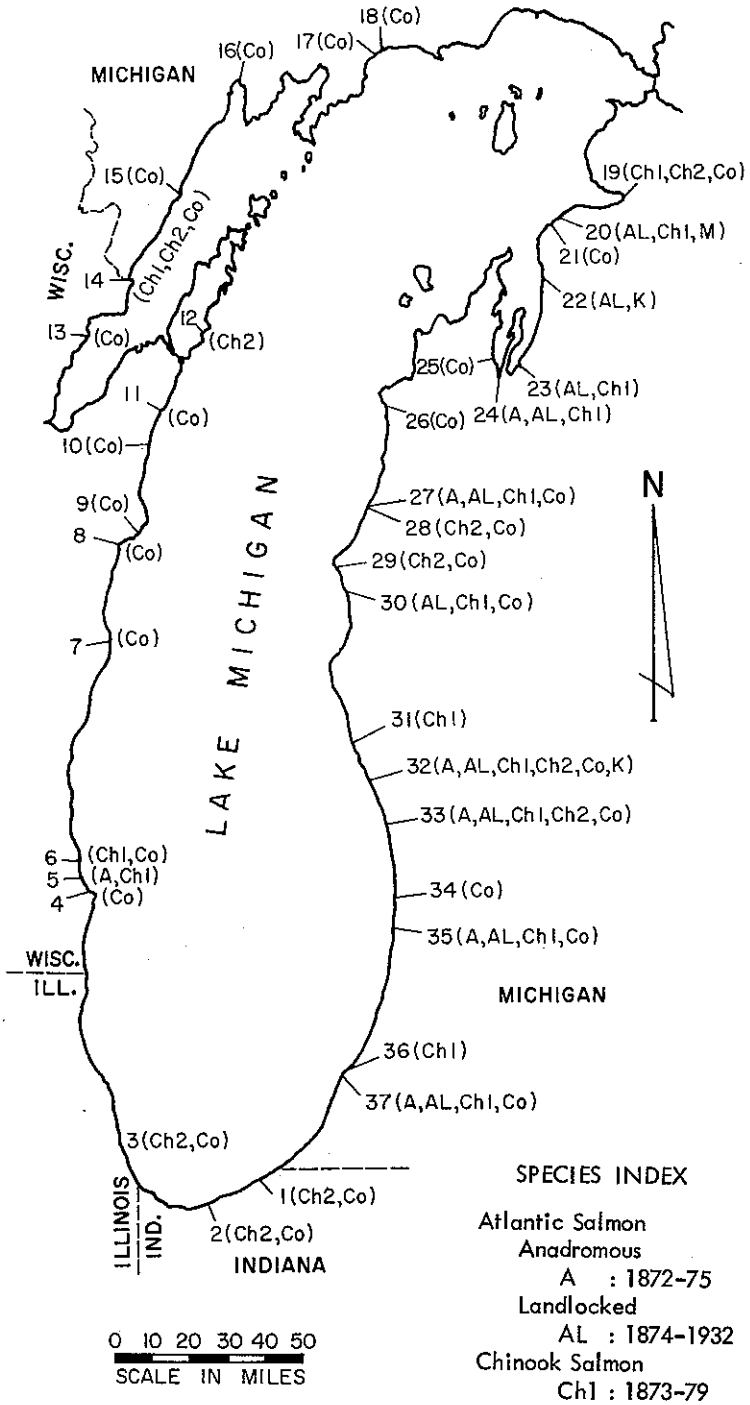
1. Lakeport Creek
2. Elk Creek
3. Diamond Creek
4. Saginaw River
5. Rifle River
6. Tawas River
7. Au Sable River
8. Mill Creek
9. Thunder Bay River
10. Ocqueoc River
11. Cheboygan River
12. Carp River
13. St. Marys River

Ontario

14. Lauzon Creek
15. Ritchies Rock
16. Kagawong Creek
17. Elizabeth Bay
18. Manitou River
19. Blue Jay Creek
20. Michael Bay
21. South Bay
22. Chickenechine River
23. Byng Inlet
24. Mowatt Island
25. Go Home River
26. Sturgeon River
27. Balm Beach
28. Nottawasaga River
29. Indian Creek
30. Centreville Creek
31. Meaford Shoal
32. Bothwell Creek
33. Sydenham River
34. Pottowatami River
35. Owen Sound Area
36. Oxenden Creek
37. Colpoy Bay Area
38. Lions Head
39. Willow Creek
40. Sauble River
41. Saugeen River

Figure 5.--Lake Huron, showing sites (indicated by numbers) and (in parentheses) species planted at those sites in different periods in 1873-1970 (indicated by species index code); all salmon planted in Province of Ontario sites (14-41) were kokanees except for several plants of Atlantic salmon from Lake Ontario stocks in the Severn River and the Saugeen River (41) in the 1870's, and plants of chinook salmon in the Saugeen River in 1876-79.

(In parentheses) species planted at those sites in different periods in 1873-1970 (indicated by species index code); not shown are plantings of coho and chinook salmon in Cold and Pickerel Creeks (site numbers 16 and 17) in 1933.



SPECIES INDEX

Atlantic Salmon
- Anadromous
  - A : 1872-75
- Landlocked
  - AL : 1874-1932

Chinook Salmon
- Ch1 : 1873-79
- Ch2 : 1967-70

Coho Salmon
- Co : 1966-70

Kokanee Salmon
- K : 1965-67

Masu Salmon
- M : 1929

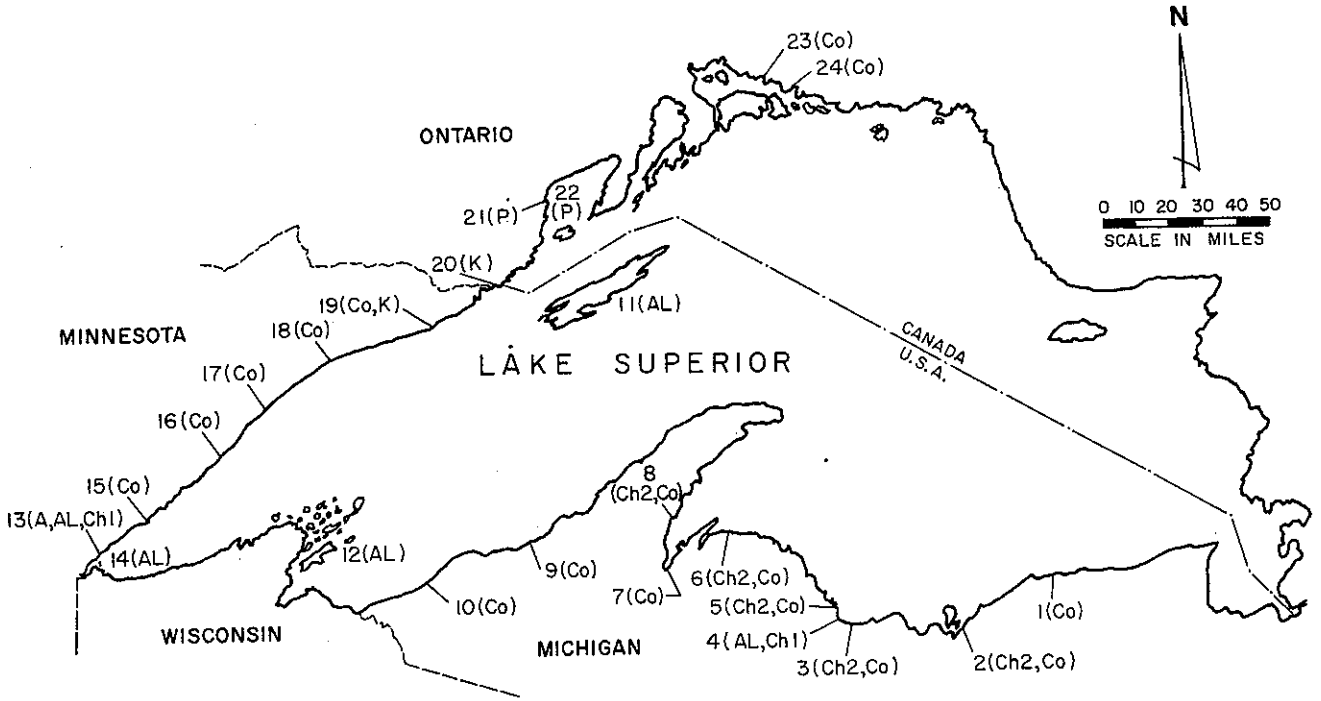
Indiana
1. Trail Creek
2. Little Calumet River

Illinois
3. Chicago Area

Wisconsin
4. Oak Creek
5. Menominee River
6. Root River
7. Sheboygan River
8. East Twin River
9. Little Manitowoc River
10. Kewaunee River
11. Ahnapee River
12. Strawberry Creek
13. Little River

Michigan
14. Menominee River
15. Big Cedar River
16. Whitefish River
17. Thompson Creek
18. Manistique River
19. Bear River
20. Boyne River
21. Porter Creek
22. Torch Lake
23. Rapid River
24. Boardman River
25. Brewery Creek
26. Platte River
27. Manistee River
28. Little Manistee River
29. Big Sable River
30. Pere Marquette River
31. White River
32. Muskegon River
33. Grand River
34. Black River
35. Kalamazoo River
36. Paw Paw River
37. St. Joseph River

Figure 6.--Lake Michigan, showing sites (indicated by numbers) and (in parentheses) species planted at those sites in different periods in 1873-1970 (indicated by species index code).



SPECIES INDEX

Atlantic Salmon
- Anadromous
  - A : 1875-81
- Landlocked
  - AL : 1874-1932

Chinook Salmon
- Ch1 : 1873-1880
- Ch2 : 1967-70

Coho Salmon
- Co : 1966-70

Kokanee Salmon
- K : 1963-66

Pink Salmon
- P : 1956

Michigan
1. Sucker River
2. Anna River
3. Chocolay River
4. Carp River
5. Dead River
6. Big Huron River
7. Falls River
8. Sturgeon River
9. Ontonagon River
10. Presque Isle River
11. Isle Royale

Wisconsin
12. Apostle Islands

Minnesota
13. St. Louis River
14. Lake Superior
15. French River
16. Beaver River
17. Two Island River
18. Kimball River
19. Brule River
20. Pigeon River

Ontario
21. Current River
22. Pie Island
23. Jackpine River
24. Gravel River

Figure 7.--Lake Superior, showing sites (indicated by numbers) and (in parentheses) species planted at those sites in different periods in 1873-1970 (indicated by species index code).

TABLE 3.--Numbers (thousands) of chinook salmon planted in the Great Lakes and their tributaries, 1873-1933.

Lake, state or province, years, and specific location	County (at stream mouth or lake area)	Figure number and site	Thousands of fish[1]	Number of years planted
Lake Ontario		Figure 3		
Ontario				
1875-82				
Bowmanville Creek	Durham	7	91	3
Wilmot Creek	Durham	9	28	2
Shelter Valley Creek	Northumberland	11	1	1
Trent River	Hastings	12	1	1
Lake Ontario	-	[2]-	[3]285	4
Total 1875-82			406	
1919-25				
Twelve-mile Creek	Welland	1	50	2
Credit River	Peel	3	487	6
Lynde Creek	Ontario	6	335	2
Soper Branch	Durham	8	30	1
Wilmot Creek	Durham	9	209	3
Graham Creek	Durham	10	30	1
Clark Creek	Hastings	14	384	5
Napanee River	Hastings	15	35	2
Total 1919-25			1,560	
Ontario total 1875-1925			1,966	
New York				
1873-1898				
Lake Ontario	-	-	4,738	3
Black River	Hamilton	21	18	1
Salmon River	Oswego	22	1,156	4
Oswego River	Oswego	24	294	5
Genesee River	Monroe	26	322	5
Sandy Creek	Monroe	27	10	1
Oak Orchard Creek	Orleans	28	30	1
Total 1873-1898			6,568	
1919				
Eastern Lake Ontario			778	
New York total			7,346	
Lake Ontario total, 1873-1919			9,312	

See footnotes at end of table.

TABLE 3.--Numbers (thousands) of chinook salmon planted in the Great Lakes and their tributaries, 1873-1933.--Continued

Lake, state or province, years, and specific location	County (at stream mouth or lake area)	Figure number and site	Thousands of fish[1]	Number of years planted
Lake Erie		Figure 4		
Ohio				
1873-80				
Cuyahoga River	Cuyahoga	14	1	1
Huron River	Huron	15	25	2
Cold Creek	Erie	17	24	3
Sandusky River	Sandusky	18	32	2
Lake Erie (Bass Islands)	Ottawa	20	40	1
Portage River	Ottawa	21	15	1
Maumee River	Lucas	22	238	5
Total 1873-80			375	
1933				
Cold & Pickerel Creeks		16, 17	79	1
Ohio total 1873-1933			454	
Michigan				
1873-80				
Maumee River	Lucas (Ohio)	22	3	1
Raisin River	Monroe	23	81	3
Huron River	Wayne	24	16	3
Detroit River	Wayne	25	33	3
Rouge River	Wayne	26	58	3
Michigan total 1873-80			191	
Lake Erie total 1873-1933			645	
Lake St. Clair		Figure 4		
Michigan				
1873-80				
Clinton River	Macomb	28	48	4
St. Clair River	St. Clair	29	14	1
Black River	St. Clair	30	12	1
Lake St. Clair total 1873-80			74	

See footnotes at end of table.

TABLE 3.--Numbers (thousands) of chinook salmon planted in the Great Lakes and their tributaries, 1873-1933.--Continued

Lake, state or province, years, and specific location	County (at stream mouth or lake area)	Figure number and site	Thousands of fish[1]	Number of years planted
Lake Huron		Figure 5		
Ontario				
1876-79				
Saugeen River	Bruce	41	45	2
Michigan				
1873-80				
Saginaw River	Saginaw	4	170	3
Rifle River	Arenac	5	32	1
Au Sable River	Iosco	7	130	3
Michigan total 1873-80			332	
Lake Huron total 1873-80			337	
Lake Michigan		Figure 6		
Michigan				
1873-80				
Menominee River	Menominee	14	62	1
Bear River	Charlevoix	19	20	2
Boyne River	Charlevoix	20	32	2
Rapid River	Kalkaska	23	12	1
Boardman River	Grand Traverse	24	8	1
Manistee River	Manistee	27	25	1
Pere Marquette River	Mason	30	14	1
White River	Muskegon	31	1	1
Muskegon River	Muskegon	32	72	4
Grand River	Ottawa	33	144	5
Kalamazoo River	Allegan	35	120	6
Paw Paw River	Berrien	36	47	3
St. Joseph River	Berrien	37	251	7
Total 1873-80			808	
Wisconsin				
1877-79				
Menominee River	Waukesha	5	8	2
Root River	Racine	6	26	2
Wisconsin total 1877-79			34	
Lake Michigan total 1873-80			842	

See footnotes at end of table.

TABLE 3.--Numbers (thousands) of chinook salmon planted in the Great Lakes and their tributaries, 1873-1933.--Continued

Lake, state or province, years, and specific location	County (at stream mouth or lake area)	Figure number and site	Thousands of fish[1]	Number of years planted
Lake Superior		Figure 7		
Michigan				
1874				
Carp River	Marquette	4	60	1
Minnesota				
1875				
St. Louis River	St. Louis	13	4	1
Lake Superior total 1874-75			64	
Great Lakes total 1873-1933			[5]11,274	

[1]Sources of planting records are as follows: for all states in 1873-80, Smiley (1884); for Ontario in 1875-82 and 1919-25, MacKay (1956); for New York in 1897-98, U.S. Fish and Fishery Commission Reports (1898-99) and 1919, U.S. Bureau of Fisheries Report (1921); and for Ohio in 1933, Trautman (1935a).
[2]Shoreline areas of eastern Lake Ontario including the St. Lawrence River (20).
[3]Includes unspecified numbers of fish planted in 1876-77 in the Saugeen River, a tributary of Lake Huron.
[4]Plants for 1878-79 only; numbers planted in 1876-77 were not separated from Lake Ontario records--see Table 6 in MacKay (1956).
[5]Includes 131,000 fish planted in unspecified State of Michigan waters.

Lake Ontario

Province of Ontario. Chinook salmon were planted in Lake Ontario and its tributaries in two periods--406,000 fish (from Sacramento River, California, stocks) in 1875-82, and 1.56 million (from British Columbia stocks) in 1919-25. Plants in 1875-82 were about three-fourths fry and one-fourth 3- to 7-inch (7.6- to 17.8-cm) fingerlings. About one-half of the fish were planted near the shore; the others were planted in four tributaries. Few survived. The weir on Wilmot Creek caught five (one weighed 15 pounds or 6.8 kg) in 1878-82 (Wilmot, 1882; Robson, 1878), and commercial fishermen caught several in 1877 (Wilmot, 1878). Despite the apparent low survival and failure of the fish to reproduce, these plants provided the first proof that this species could grow to maturity in fresh water.

The plantings in 1919-25 (90% fry, 10% fingerlings) were divided among eight tributaries. According to MacKay (1960), a few survived and reached weights up to 30 pounds (13.6 kg); most were seen in the Credit River. Although MacKay observed several adults spawning in Twelve-Mile Creek in the fall of 1927, he concluded that no young were produced there or in other tributaries.

New York. About 7 million chinook salmon were planted in 1873-1919. The plants were made in three periods: 450,000 fry in 1873-82; 6,118,000 fry (a few were fingerlings) in 1897-98; and 778,000 fingerlings in 1919. Most of the 1873-82 plants were made in tributaries and most of those in 1897-98 and 1919 in the open lake at the extreme eastern end of Lake Ontario. According to Bean (1903), plants made before 1900 were failures. He suggested that larger fish should be stocked in the future. Despite the heavy planting of fingerlings in 1919, no survivors were reported.

Lake Erie

Ohio. Chinook salmon were planted in Ohio waters of Lake Erie in 1873-80 and in 1933. The Ohio plants in 1873-80 numbered 375,000 fry, about two-thirds of which were released in the Maumee River drainage. An 1877 report on the survival of these plants was unique for chinook salmon and for that period. The Ohio State Fish Commission (1878) reported, "Of the California salmon planted in our streams, many have been taken by hook and line, about six or eight inches long." It was further stated that no more would be stocked until it was known if these fish would mature and reproduce, but annual reports in following years made no mention of survival.

In March 1933, 79,000 yearlings (post-smolt) up to 6 inches (15.2 cm) long were planted in Pickerel and Cold Creeks, tributaries of Sandusky Bay. Only one survivor was reported. A 2.5-pound (1.1-kg) specimen was caught in July 1935 by a commercial fisherman near Kingsville, Ontario (Trautman, 1935b).

Michigan. About 191,000 fry were planted in the headwaters of five Michigan tributaries of Lake Erie in 1873-80.

Lakes Huron, Michigan, and Superior

Although few survivors or follow-up observations were reported on plants of chinook salmon in the three upper Great Lakes in 1873-80, plants there demonstrate generally the planting practices for all salmon in the Great Lakes in the early years. Chinook salmon were planted in almost every conceivable type of habitat--warmwater rivers, spring-fed creeks, natural lakes and reservoirs, bog lakes, native brook trout and grayling streams, and along the shores and near islands of the Great Lakes. For Michigan tributaries of Lake Michigan alone, 116 plants (average 7,000 fry each) were made in 26 counties. Although plants were made in every month except June, 75% were made in December and January (fry often were planted in holes cut through the ice). In 1880, Michigan planted 575 hatchery-reared adult chinook salmon but planting locations were not specified (Post, 1894).

ATLANTIC SALMON

Both forms of Atlantic salmon--landlocked and anadromous--have been planted in the Great Lakes. The landlocked form of Atlantic salmon never became established, despite plants of more than 1 million fish in a wide variety of habitats in 1874-1932 (Table 4). Although a few fish apparently survived and matured, no second generation fish were observed. Most plants were made in small lakes and their tributaries in the Great Lakes drainage in an attempt to establish local populations; some plants were made to establish the species in the Great Lakes.

About one-half of the salmon of the landlocked form were planted in Michigan. Heaviest plants were made in two areas: 178,000 fry and 2,000 fingerlings (divided among 18 years) in the St. Marys River (between Lakes Superior and Huron) and 162,000 fish (over 7 years) in Torch Lake, Michigan. The results of plants in the Great Lakes before 1933 were so poor that few landlocked Atlantic salmon have been planted since.

In 1873-1947, 743,000 anadromous Atlantic salmon were planted in the Great Lakes or their tributaries (Table 5). Most of the plants were made in 1873-75, a few in 1876-1902, and the others (in Duffin Creek, a tributary to Lake Ontario) in 1944-47. Virtually all of the planted fish were fry; survival or recovery

TABLE 4.--Numbers (thousands of landlocked Atlantic salmon planted in the Great Lakes and their tributaries, 1874-1932.

Lake, state or province, years, and specific location	County (at stream mouth or lake area)	Figure number and site	Thousands of fish[1]	Number of years planted
Lake Ontario		Figure 3		
New York				
1878-1917				
Black River	Jefferson	21	15	2
Oswego River	Oswego	24	2	1
Genesee River	Monroe	26	25	6
Lake Ontario total, 1878-1917			42	
Lake Erie		Figure 4		
Ohio				
1876-80				
Sandusky River	Sandusky	18	5	1
Lake Erie (Bass Islands)	Ottawa	20	20	1
Maumee River	Lucas	22	38	3
Total 1876-80			63	
Michigan				
1878-1932				
Huron River	Wayne	24	25	4
Rouge River	Wayne	26	4	1
Total 1876-1932			29	
Lake Erie total, 1876-1932			92	
Lake Huron		Figure 5		
Michigan				
1878-1932				
Saginaw River	Saginaw	4	5	1
Au Sable River	Iosco	7	20	3

See footnotes at end of table.

TABLE 4.--Numbers (thousands) of landlocked Atlantic salmon planted in the Great Lakes and their tributaries, 1874-1932.--Continued

Lake, state or province, years, and specific location	County (at stream mouth or lake area)	Figure number and site	Thousands of fish[1]	Number of years planted
Cheboygan River	Cheboygan	11	10	2
St. Marys River	Chippewa	13	180	18
Lake Huron total, 1878-1932			215	
Lake Michigan				
Michigan		Figure 6		
1874-1932				
Boyne River	Charlevoix	20	7	1
Torch Lake	Antrim	22	162	7
Rapid River	Kalkaska	23	72	5
Boardman River	Grand Traverse	24	20	3
Manistee River	Manistee	27	52	6
Pere Marquette River	Mason	30	35	2
Muskegon River	Muskegon	32	73	12
Grand River	Ottawa	33	11	2
Kalamazoo River	Allegan	35	33	10
St. Joseph River	Berrien	37	34	7
Lake Michigan total, 1874-1932			499	
Lake Superior		Figure 7		
Michigan				
1882-95				
Carp River	Marquette	4	36	2
Isle Royale	Keweenaw	11	70	1
Total 1882-1895			106	
Wisconsin				
1879				
Apostle Islands	Ashland	12	2	1

See footnotes at end of table.

TABLE 4.--Numbers (thousands) of landlocked Atlantic salmon planted in the Great Lakes and their tributaries, 1874-1932.--Continued

Lake, state or province, years, and specific location	County (at stream mouth or lake area)	Figure number and site	Thousands of fish[1]	Number of years planted
Minnesota				
1879-95				
St. Louis River	St. Louis	13	5	1
Near Duluth	St. Louis	14	75	3
Total 1879-1895			80	
Lake Superior total, 1879-1932			188	
Great Lakes total, 1874-1932			[2]1,036	

[1]Sources of planting records are as follows: for Michigan, Bower (MS 1937), Fukano, et al. (MS 1964), and Holcomb (MS 1964); supplemental planting records for Michigan and for all records for the other states in 1874-80 were taken from Smiley (1884), from U.S. Fish and Fishery Commission Reports from 1881 (1884) to 1903 (1905), and from U.S. Bureau of Fisheries Reports from 1904 (1905) to 1932 (1933).

[2]Includes 28,000 fish planted in unspecified waters of Michigan.

TABLE 5.--Numbers (thousands) of anadromous Atlantic salmon planted in the Great Lakes and their tributaries, 1873-1947.

Lake, state or province, years, and specific location	County (at stream mouth or lake area)	Figure number and site	Thousands of fish[1]	Number of years planted
Lake Ontario		Figure 3		
New York				
1873-1902				
Salmon River	Oswego	22	144	5
Oswego River	Oswego	24	15	1
Genesee River	Monroe	26	10	1
New York total, 1873-1902			169	

See footnote at end of table.

TABLE 5.--Numbers (thousands) of anadromous Atlantic salmon planted in the Great Lakes and their tributaries, 1873-1947--Continued.

Lake, state or province, years, and specific location	County (at stream mouth or lake area)	Figure number and site	Thousands of fish[1]	Number of years planted
Ontario				
1944-47				
Duffin Creek	Ontario	5	160	4
Lake Ontario total, 1873-1947			329	
Lake Erie		Figure 4		
Ohio				
1873-75				
Cold Creek	Erie	17	2	1
Sandusky River	Sandusky	18	10	1
Lake Erie (Bass Islands)	Ottawa	20	30	1
Maumee River	Lucas	22	10	1
Ohio total, 1873-75			52	
Michigan				
1873				
Raisin River	Monroe	23	1	1
Lake Erie total, 1873-75			53	
Lake St. Clair		Figure 4		
Michigan				
1873				
Lake St. Clair	Macomb	27	4	1
Lake Huron		Figure 5		
Michigan				
1873-75				
Au Sable River	Iosco	7	2	1
St. Marys River	Chippewa	13	25	1
Michigan total, 1873-75			27	

See footnote at end of table.

TABLE 5--Numbers (thousands) of anadromous Atlantic salmon planted in the Great Lakes and their tributaries, 1873-1947--Continued

Lake, state or province, years, and specific location	County (at stream mouth or lake area)	Figure number and site	Thousands of fish[1]	Number of years planted
Lake Michigan		Figure 6		
Michigan				
1873-75				
Boardman River	Grand Traverse	24	40	1
Manistee River	Manistee	27	41	2
Muskegon River	Muskegon	32	8	1
Grand River	Ottawa	33	1	1
Kalamazoo River	Allegan	35	1	2
St. Joseph River	Berrien	37	9	2
Michigan total, 1873-75			100	
Wisconsin				
1873-74				
Menominee River	Waukesha	5	30	2
Lake Michigan total, 1873-75			130	
Lake Superior		Figure 7		
Minnesota				
1875-81				
St. Louis River	St Louis	13	200	2
Great Lakes total, 1873-1947			743	

[1]Sources of planting records are as follows: for all states in 1873-80, Smiley (1884); for 1881-1902, U.S. Fish and Fishery Commission Reports for 1881 (1884) to 1902 (1903); for Ontario in 1944-47, McCrimmon (1950).

was extremely low. Although reports on recoveries occasionally were made in the literature, few were verified; this species often was confused with chinook salmon and the steelhead trout (Salmo gairdneri) in the early years.

In contrast to the earlier plantings, the 40,000 Atlantic salmon fry (from Miramichi River stocks in Canada) planted annually in Duffin Creek in 1944-47 demonstrated high survival to the smolt stage (McCrimmon 1950). The fry were planted at the rate of one, per linear yard (0.9 m) of stream each year. Of the 40,000 fry of anadromous salmon planted in the spring in each of the years 1945-47 (no data for the 1944 plant) survival to the following October was estimated at 4,500, 4,100, and

5,000, respectively. The average survival for the 3 years was about 11%. After 15 months (in October of the second year), average survival was about 8%.

In the spring of 1948, a trap set about 8 miles (12.9 km) above the mouth of the east branch of Duffin Creek took 600 2-year-old smolts as they migrated downstream. One 5-pound (2.3-kg) female was recaptured in Duffin Creek in the fall of 1948; however, few other adults returned in the following years.

OTHER SALMONS

Coho salmon

In 1933, 41,000 coho salmon fingerlings were planted in two small tributaries of Sandusky Bay of Lake Erie but no survivors were reported. The coho salmon were planted jointly with chinook salmon.

In 1937, the U.S. Bureau of Fisheries offered coho salmon eggs to all the states adjacent to the Great Lakes. The reaction of all the states was negative and the matter was dropped by the Bureau (C.F. Culler, personal communication; letter to John Van Oosten, December 20, 1937).

Masu salmon

About 200 fingerlings (18 months old) were planted in the North Branch of the Boyne River in Charlevoix County, Michigan, in 1929. No survivors were reported (F.A. Westerman, personal communication; letter to Carl. L. Hubbs, March 31, 1930).

EVALUATION OF PROPAGATION OF EXOTIC SALMON BEFORE 1950

Somehow, up to 1950, apparently the right species of the right size or age was never planted at the right place, at the right time, and in adequate numbers to establish either a temporary fishery or a permanent population. In the light of developments of 1950-70, it hardly seems possible that they could have failed entirely.

PLANTING OF ATLANTIC, PINK, AND KOKANEE SALMON

The years since 1950 represent the modern era for salmon in the Great Lakes. Plants of salmon usually were carefully planned; most species were planted as fingerlings or smolt; and follow-up studies of plants were the rule. Valuable new fisheries have developed for some species in some lakes. A review of the plants and results for each species follows.

ATLANTIC SALMON

The only Atlantic salmon planted in the Great Lakes in 1950-70 were in New York tributaries of Lake Ontario. In 1953-70, 410,000 2- to 6-inch (5.1-15.2 cm) spring or fall fingerlings were planted in the Black, Salmon, and Oswego Rivers. The average number of fish in 137 plants was 3,000 (D.G. Pasko, personal communication). Most of the salmon planted were anadromous forms (from the Maritime Provinces of Canada) but some were landlocked forms (from Maine). Salmon were planted in the Black and Oswego Rivers primarily to establish a put-and-take sport fishery (D.G. Pasko, personal communication). Those in the Salmon River were planted in an attempt to develop a spawning population in Lake Ontario.

For the Black River, 25,000 were planted in several of the Fulton chain of lakes (largest, 2,000 acres or 810 ha), and 69,000 were planted in their tributaries. Survival was low--few were taken by anglers.

A total of 288,000 fingerlings were planted in the Finger Lakes and their tributaries in the Oswego River system in 18 consecutive years. Survival was highest in Cayuga Lake, where a sport fishery has developed; 5- to 7-pound (2.3- to 3.2-kg) salmon have been caught by anglers. Small spawning runs have occurred in one tributary of Cayuga Lake (the

first in 1957; Webster, 1958) but no young have been reported.

Salmon were planted in the Salmon River in only 4 years (the last in 1959). Apparently none of the 28,000 fish planted were recovered.

Annual plants of Atlantic salmon in the Black and Oswego Rivers were being continued in 1970.

PINK SALMON

A planting of about 20,000 pink salmon fingerlings by the Ontario Department of Lands and Forests was the source of a self-sustaining population in Lake Superior. The plant, from British Columbia sea-run stocks, was made in June 1956 in the Current River, a tributary to Thunder Bay (R.A. Ryder, personal communication). A plant of several hundred fish also was made near Pie Island.

The first recovery of pink salmon was reported by Schumaker and Eddy (1960). In the fall of 1959, two males about 19 inches (45.7 cm) long were caught by anglers in Minnesota tributaries. These prespawners were the first recorded adults produced by natural reproduction in Lake Superior.

In the fall of 1961, four pink salmon were caught by anglers and nine pairs of spawners were observed on redds in the Poplar River in Minnesota (Schumaker and Hale, 1962). A few fish also were observed in other tributaries of Minnesota and in Ontario. The only other report on pink salmon in the early 1960's was the sighting of six prespawning fish in the Cross River, Minnesota, on September 20, 1963 (Moore and Braem, 1965).

Pink salmon were relatively scarce in most tributaries of Lake Superior until the fall of 1969. By that year, the species had spread throughout most of the lake and spawning runs occurred in many tributaries in Ontario, Minnesota, Wisconsin, and Michigan. Spawning runs of up to 1,000 fish were reported in Ontario tributaries in 1969 by R. A. Ryder (personal communication).

In the fall of 1969, pink salmon spawned for the seventh time and had completed six generations of natural reproduction (in the odd years, 1959-69). Despite the abundance of pink salmon in tributaries, this species has contributed little to the sport or commercial fishery. To increase abundance for sport and commercial fishing, Schumaker and Hale (1962) recommended that a strain of even-year spawners should be introduced in Lake Superior.

Pink salmon in Lake Superior were relatively small compared to sea-run fish. Most prespawners in Lake Superior were about 14 to 20 inches or 36 to 51 cm long and weighed 1.1 to 2.2 pounds or 0.5 to 1.0 kg (Great Lakes Fishery Commission, MS 1970a).

Pink salmon spread into Lake Huron in 1969. In the fall, a few adults were observed in the Carp River (Mackinac County), a tributary in the Upper Peninsula of Michigan (Great Lakes Fishery Commission, MS 1970a).

KOKANEE SALMON

The kokanee salmon was first introduced into the Great Lakes system in New York tributaries of Lake Ontario in 1950. In 1950-70, about 19 million were planted in the Great Lakes--primarily in Lakes Ontario and Huron. The total plantings were mostly fry (74%), but also included fingerlings (17%) and eggs (9%).

Survival of kokanee salmon in the Great Lakes and their tributaries has been poor, except for fingerlings planted in Lake Huron and in several New York lakes tributary to Lake Ontario. In Lake Huron, spawning runs have developed in several streams, and a second generation has been produced by natural reproduction in at least one stream.

The planting records are given in Table 6; results by lake and state or province follow.

Lake Ontario

Ontario. Nearly 5.4 million kokanee salmon were planted in 1964-70 in three tributaries of

TABLE 6.--Numbers (thousands) of kokanee salmon planted in the Great Lakes and their tributaries 1950-70.

Lake, state or province, years, and specific location	County or District (at stream mouth or lake area)	Figure number and site	Thousands of fish[1]	Number of years planted
Lake Ontario		Figure 3		
Ontario				
1964-70 (mostly fry)[2]				
Wilmot Creek	Durham	9	724	4
Shelter Valley Creek	Northumberland	11	1,616	7
Salmon River	Hastings	13	537	3
Lake Ontario				
Shelter Valley	Northumberland	16	666	1
Glenora	Prince Edward	17	823	3
Main Duck Island	Prince Edward	18	517	3
Charity Shoal	Prince Edward	19	499	3
St. Lawrence River	Leeds	20	5	3
Ontario total, 1964-70			5,387	
New York				
1950-70 (fingerlings)				
Oswego River		24		
Green Lake	Onondaga		77	10
Black River	Hamilton & Herkimer	21		
Third Bisby Lake			1	1
Deep Lake			3	1
Bug Lake			101	4
Limekiln and other lakes			80	1
New York total, 1950-70			262	
Lake Ontatio total, 1950-70			5,649	
Lake Erie		Figure 4		
Michigan				
1969-70 (fry and fingerlings)				
Huron River				
Cass Lake	Oakland	24	326	2

See footnotes at end of table.

TABLE 6.--Numbers (thousands) of kokanee salmon planted in the Great Lakes and their tributaries 1950-70.--Continued

Lake, state or province, years, and specific location	County or District (at stream mouth or lake area)	Figure number and site	Thousands of fish[1]	Number of years planted
Lake Huron		Figure 5		
Ontario				
1964-66 (eyed eggs)				
Lauzon Creek	Algoma	14	42	1
Kagawong Creek	Manitoulin	15	42	1
Manitou River	Manitoulin	18	360	3
South Bay	Manitoulin	21	110	2
Chickenechine River	Manitoulin	22	150	2
Go Home River	Muskoka	25	190	3
Indian Creek	Grey	29	45	3
Bothwell Creek	Grey	31	65	3
Sydenham River	Grey	32	330	2
Willow Creek	Bruce	39	140	3
Sauble River	Bruce	40	80	1
Saugeen River	Bruce	41	180	1
Ontario total, 1964-66			1,734	
1964-70 (fry)				
Ritchie's Rock	Manitoulin	15	38	1
Kagawong Creek	Manitoulin	16	80	1
Elizabeth Bay	Manitoulin	17	134	1
Manitou River	Manitoulin	18	215	2
Blue Jay Creek	Manitoulin	19	78	1
South Bay	Manitoulin	21	1,368	6
George Lake	Manitoulin	22	59	1
Byng Inlet	Parry Sound	23	581	1
Mowatt Island	Parry Sound	24	292	3
Sturgeon River	Simcoe	26	195	1
Balmy Beach	Simcoe	27	98	1
Nottawasaga River	Simcoe	28	470	2
Centreville Creek	Grey	30	24	1
Meaford Shoal	Grey	31	54	1
Bothwell Creek	Grey	32	48	1
Sydenham River	Grey	33	175	1
Pottowattomi River	Grey	34	160	1
Owen Sound	Grey	35	128	3
Oxenden Creek	Grey	36	203	2
Colpoy Bay Area	Grey	37	422	4

See footnotes at end of table.

TABLE 6--Numbers (thousands) of Kokanee salmon planted in the Great Lakes and their tributaries 1950-70.--Continued

Lake, state or province, years, and specific location	County or District (at stream mouth or lake area)	Figure number and site	Thousands of fish[1]	Number of years planted
Lion's Head	Bruce	38	582	4
Willow Creek	Bruce	39	150	1
Sauble River	Bruce	40	300	2
Saugeen River	Bruce	41	490	2
Total, 1964-70			6,344	
1965-70 (fingerlings)				
Michael Bay	Manitoulin	20	54	1
South Bay	Manitoulin	21	696	6
George Lake	Manitoulin	22	22	1
Byng Inlet	Parry Sound	23	88	2
Oxenden Creek	Grey	36	18	2
Ontario total, 1965-70			882	
Lake Huron total, 1964-70			8,956	
Lake Michigan		Figure 6		
Michigan				
1965-70 (fry and fingerlings)[3]				
Torch Lake	Antrim	22	2,239	2
Higgins Lake (Muskegon River)	Muskegon	32	1,697	4
Michigan total, 1965-70			3,936	
Lake Superior		Figure 7		
Minnesota				
1963-66 (fry)				
Brule River	Cook	19	261	4
Pigeon River	Cook	20	105	4
Lake Superior total, 1963-66			366	
Great Lakes total, 1950-70			19,233	

See footnotes on page 47.

Footnotes for table 6.

[1]Planting records were obtained from the following sources: Province of Ontario for Lake Ontario, J. R. Coleman (personal communication) and for Lake Huron, Collins (1972) and J. J. Collins (personal communication); New York, D. G. Pasko (personal communication); Michigan, unpublished planting records of the Michigan Department of Natural Resources; and Minnesota, D. E. Woods (personal communication).

[2]All fry (3,327,000) except for 20,000 fingerlings planted in Shelter Valley Creek in 1969 and 41,000 fingerlings planted near its mouth in Lake Ontario in 1970.

[3]Plantings in Torch Lake comprised 2,041,000 fry (3,000 per pound or 1,362 per kg) in 1965 and 916,000 fingerlings (500 per pound or 227 per kg), in 1966; those in Higgins Lake, a tributary of the Muskegon River, consisted of 718,000 fry in 1965, 221,000 fingerlings in 1966, 723,000 fingerlings in 1967, and 35,000 fingerlings in 1970.

Lake Ontario and in five locations in the open waters of the lake. Eggs for propagation of fish for plantings in Lake Ontario (and Lake Huron) were obtained from stream spawning and lakeshore spawning stocks in British Columbia, Washington, Colorado, and Montana. The introductions were made in Lake Ontario with the aim of establishing a permanent population. Except for a few eggs planted in the winter of 1964-65 and 81,000 2- to 3-inch (51- to 76-mm) fingerlings planted in 1969-70, all plantings were fry.

The results of the plantings were poor; only a few scattered fish have been reported caught. No captures were reported in 1968 and none were taken in experimental gill nets fished off the mouth of Shelter Valley Creek in September 1969 (Ontario Department of Lands and Forests, 1970). In 1970, the few fish reported were taken by a commercial fisherman (J. R. Coleman, personal communication).

New York. In 1950-70, 262,100 1- to 2-inch (25- to 51-mm) kokanee salmon fingerlings were planted in several lakes in the headwaters of the Black River in Hamilton and Herkimer Counties, and in Green Lake on the Oswego River in Onodaga County. The primary objective was to develop a put-and-take sport fishery. All fish were planted in Green Lake in 1950-58, but most were planted in the Black River lakes thereafter. The eggs (from Maine, Connecticut, and Montana) were hatched in November and planted as spring fingerlings (D.G. Pasko, personal communication).

Survival of fish from the different plantings varied widely. A few kokanees up to 15 inches (38 cm) long have been caught in Green Lake but survival there was generally poor. Spawning was observed on a shoreline shoal but no young were observed. A moderate sport fishery (up to 50 fish a day) developed in Bug Lake of the Fulton chain of lakes on the Black River; average length of the fish caught was about 10 inches (25.4 cm). No fish planted in other lakes are known to have survived.

Lake Erie

About 200,000 fingerlings in 1969 and 126,000 fry in 1970 were planted in Cass Lake (Oakland County), at the headwaters of the Huron River in Michigan. Few survivors have been reported.

Lake Huron

Nearly 9 million kokanee salmon were planted in Province of Ontario waters of Lake Huron and its tributaries in 1964-70 in an attempt to establish a permanent population. Eggs for planting or hatching were obtained

from British Columbia, Colorado, Montana, Washington, and Idaho. All eggs were taken from stream spawning stocks except for some that were taken from shoreline spawning stocks in Montana (Collins, 1972). Several thousand fry planted in Lake Huron in 1968 originated from eggs collected from spawners in two Lake Huron tributaries--Manitou River and Colpoy Creek.

Survivors of the various plants rarely were seen except in the fall when they spawned (some spawned after two growing seasons but most after three growing seasons; Collins, 1973). In 1966-69, spawning populations were observed in 23 tributaries and in South and Colpoy Bays (Ontario Department of Lands and Forests, 1970). Spawning adults were observed almost entirely in the Manitoulin Island area and in Georgian Bay near and in tributaries on the Bruce Peninsula.

Through 1970, the kokanee salmon had contributed little to the Lake Huron sport and fishery.

Lake Michigan

More than 3.9 million fingerlings were planted in 1965-67 and 1970 in Torch Lake and Higgins Lake in Michigan in an attempt to establish permanent populations in these inland waters, which are connected with Lake Michigan by streams. Survival apparently was extremely low in both lakes--no kokanees planted in 1965-67 are believed to have survived through 1970 (C.M. Taube, personal communication).

Lake Superior

In 1963-66, 366,000 fry were planted in Minnesota in Greenwood Lake of the Brule River drainage (261,000) and in Leo Lake of the Pigeon River drainage (105,000). Survival from these experimental plants was low; only a few fish reached maturity (length 10 to 12 inches or 25.4 to 30.5 cm) and all had disappeared by 1970 (D.E. Woods, personal communication).

COHO AND CHINOOK SALMON

Because of the importance of coho and chinook salmon in the Great Lakes, a review of some of the species characteristics, related terminology, and general planting practices is given here to help clarify later descriptions of the results of propagation.

In the Great Lakes area, coho and chinook salmon eggs incubated in hatcheries usually hatch in December and January. In streams under natural conditions, eggs usually hatch in March and April. Ages given here for salmon follow the system long used for other Great Lakes species; fish are designated as age 0 during their first year of life (or growing season), and ages I, II, ...during subsequent successive years.

Both species have been planted in the Great Lakes as smolt (the size and age at which the fish lose their parr markings, turn silvery, and start to migrate downstream to the sea or lake) to increase chances of survival (over fish planted at a smaller size), and to ensure highly developed homing instincts. Planting smolt has been a long accepted practice on the West Coast. Since, with few exceptions, all coho salmon were planted in the Great Lakes at about the same age (age I) and time of the year, the distinction between smolt and presmolt (both are used in planting records) is not made in this paper. Many plants probably included fish in both stages.

In the Great Lakes, most coho salmon smolt were planted in the spring (March to May, but usually in April) when they were about 16 months old and 4 to 6 inches (10.1 to 15.2 cm) long and weighed about 0.8 ounce or 25 g (20 fish per pound; range among plants, 12 to 30). After the first season of release, some return to the streams (or point of release) in the fall as "jacks" (precocious males; age I), but most return to spawn in the fall two growing seasons after release (age II). Few live longer than age II. These characteristics are the same as those of coho salmon planted in the Columbia River (L.R. Donaldson, personal communication).

Nearly all coho salmon eggs for plantings in the Great Lakes in 1966-69 were obtained from Columbia River stocks in 1965-67 and from fish in spawning runs in the Platte and Little Manistee Rivers, State of Michigan tributaries of Lake Michigan, in 1968-69. Eggs from Michigan and Columbia River stocks have also been the source of plantings made by other states and Ontario.

Chinook salmon (most of which were from Columbia River stocks) were planted in the spring (age 0) in the Great Lakes, when they were about 4 to 5 months old and 2 to 3 inches (51 to 76 mm) long and averaged about 0.16 ounce or 5 g (100 fish per pound). When planted in streams, the smolt usually migrate downstream to the lake within a few days. In the fall, two growing seasons after release, a few return to streams as precocious spawners (mostly males, age I). Most fish that return to the streams after three seasons of growth (age II) are mature males and most of those that return after four seasons (age III) are mature females (most females spawn at this age). Nearly all age-IV fish are females; only rarely do chinook salmon reach age V. The largest spawning runs that develop from a single plant consist of fish of ages II or III. These age characteristics of fish in the runs, which are characteristic of Columbia River stocks (L.R. Donaldson, personal communication), apparently are typical for chinook salmon planted in Lakes Michigan and Huron.

Most coho and chinook salmon were released in tributaries near their mouths, but a few plants were made in small streams in the headwaters of major tributaries and in the Great Lakes proper--near stream mouths, along the shoreline, and in the open water. Plants were made in the lakes primarily to lengthen the time of lake residency in an attempt to increase the availability of the fish to open-lake fishing and reduce the size of stream runs. (Congestion of anglers has become a serious problem in some streams that have heavy runs.) It is not yet known whether these benefits will result from lake plants.

In most states, some fish were held in streams for about 2 weeks (others as long as 8 weeks), in holding cribs, retaining ponds, or in sections of streams blocked by nets, with the hope that the homing instincts of spawning fish would be strengthened. Although these holding practices have not been fully evaluated, homing instincts of both species appear to be strong even for fish planted directly, without containment, in Michigan tributaries of Lake Michigan.

Other than the Columbia River stocks, one other strain of coho and one of chinook salmon have been planted. The Alaskan (Swan River) strain of coho salmon was planted experimentally for several years in tributaries of Lake Michigan and Superior by the State of Michigan. As adults, fish of this strain concentrate near stream mouths and migrate upstream at least 1 month earlier (in August) than do fish of the Columbia River stocks (September and October). One of the purposes of planting the Alaskan strain was to provide a more protracted fishing season for salmon, but the results have not been fully evaluated.

Chinook salmon of the Donaldson strain (Columbia River stocks selectively bred since 1949 by the University of Washington; L.R. Donaldson, personal communication) were planted experimentally in 1968-70 in Thunder Bay River, a tributary of Lake Huron, by Alpena Community College, Alpena, Michigan, in cooperation with the Michigan Department of Natural Resources, and in 1969 in Strawberry Creek, a Wisconsin tributary of Lake Michigan. Fish of this strain grow faster and the females mature a year earlier than do those of other Columbia River stocks (L.R. Donaldson, personal communication). Studies of the habits or age of spawning of this strain in Lakes Huron and Michigan have not been completed.

In the following sections I make broad comparisons of the results of the introductions of chinook and coho salmon in the Great Lakes and describe, for each lake, the numbers planted and recovered by various methods, characteristics of the fisheries, growth rates (as indicated by average weights at different ages), incidence of lamprey predation, homing instincts, and natural reproduction.

Data available on the results of the plants of coho salmon in the Great Lakes are generally adequate to describe well the rate of recovery and characteristics of the populations for each lake and make valid comparisons among the lakes. Data are now available from each of the lakes on the complete life cycle of fish from at least two plants of coho salmon.

Data available for chinook salmon are incomplete or fragmentary. Only in Lakes Michigan and Superior did fish from the first plantings (in 1967) complete most of their life cycle (age-III females in the fall of 1970). In other three lakes none were older than age II (in Lake Erie the first plantings were made in 1970). Judging by the data available through 1970, the relative rates of survival and growth in the different lakes and the percentages attacked by sea lampreys appear to be similar to those for the coho salmon.

A large majority of the coho and chinook salmon taken in the commercial fishery were caught in Canadian waters. Even there, landing of salmon was permitted only if the fish were caught by conventional gear on traditional fishing grounds. Regulations in most states permitted the landing of only a few salmon by commercial fishermen; for example, in Ohio the maximum was six fish per day for each fishing vessel.

In the following sections, sources of data for individual tables are given in the table footnotes. Although not always cited, many of the data in the text were taken from Great Lakes Fishery Commission (MSS 1969 a-e; 1970 a-e; 1971 a-e), Borgeson (MS 1970), Weaver (MS 1969), and Bullin (MS 1971).

COHO SALMON, 1966-70

Nearly 16 million coho salmon smolt were planted in the Great Lakes and their tributaries in 1966-70 (see Table 7 for planting records by lake, state, province, and year). About 65% of the fish were planted in Lake Michigan, and 87% by the State of Michigan.

Recoveries from planted stocks

The catch of coho salmon in the several lakes, as reported by the states and Province of Ontario, was largely determined by the number of smolt planted and the number of years in which plantings were made, survival, availability, fishing intensity, and the extent to which weirs were used to capture fish in spawning runs in tributaries. Despite these variables, the success or failure of the introductions and magnitude of the fisheries that were developed in the different lakes are reasonably clear.

Of the 10.5 million coho salmon planted in the Great Lakes in 1966-69, about 2 million (19%) were caught in 1966-70 (nearly all fish planted in 1966-69 completed their life cycle in 1970 or earlier). Of the fish recovered, 60% were taken by angling, 35% in weirs, and 5% by the commercial fishery (Table 8).

On the whole, the recovery percentages for planted coho salmon in the different lakes are reasonable indicators of relative levels of survival. The total percentages of planted fish recovered in each lake were: Lake Michigan, 21; Lake Huron, 17; Lake Erie, 8; Lake Superior, 6; and Lake Ontario, less than 1 (see Table 9 for numbers planted, years planted, and percentage recovery by different methods).

The relative magnitude of the coho salmon sport fishery in the different lakes is best shown by the average annual number of fish taken by anglers after the first plant in each lake (Table 9). The annual average catch was greatest in Lake Michigan (189,200 fish) and inconsequential in Lake Ontario (100 fish). The highest single year's catch was in Lake Michigan (516,000 fish in 1970).

Since the coho salmon were planted in the Great Lakes to support a sport fishery, the ratio of pounds planted to pounds caught by anglers is probably the best measure of the relative success of the plants in the different lakes. The estimated number of pounds recovered by the sport fishery for each pound planted (on the assumption that the fish planted averaged 20 per pound) was 23 for Lake Michigan, 18 for Lake Huron, 4 for Lake

TABLE 7.--Numbers (thousands) of coho salmon planted in the Great Lakes and their tributaries, 1966-70.

Lake, state or province, years, and specific location	County (at stream mouth or lake area)	Figure number and site	Thousands of fish[1]
Lake Ontario		Figure 3	
Ontario			
1969			
Bronte River	Halton	2	20
Credit River	Peel	3	90
Humber River	York	4	20
Total 1969			130
1970			
Bronte River	Halton	2	20
Credit River	Peel	3	100
Humber River	York	4	25
Total 1969-70			145
Ontario total, 1969-70			275
New York			
1968			
Salmon River	Oswego	22	41
1969			
Little Salmon River	Oswego	23	89
Oak Orchard Creek	Orleans	28	20
Total 1969			109
1970			
Salmon River	Oswego	22	250
Sterling Creek	Cayuga	25	50
Total 1970			300
New York total, 1968-70			451
Lake Ontario total, 1969-70			726

See footnotes at end of table.

TABLE 7.--Numbers (thousands) of coho salmon planted in the Great Lakes and their tributaries, 1966-70.--Continued

Lake, state or province, years, and specific location	County (at stream mouth or lake area)	Figure number and site	Thousands of fish[1]
Lake Erie		Figure 4	
New York			
1968			
Cattaraugus Creek	Cattaraugus	2	5
1969			
Cattaraugus Creek	Cattaraugus	2	10
1970			
Eighteen-Mile Creek	Erie	1	24
Cattaraugus Creek	Cattaraugus	2	30
Lake Erie	Chautaqua	3	20
Total 1970			74
New York total, 1968-70			89
Pennsylvania			
1968			
Trout Run	Erie	7	34
Unnamed tributary	Erie	8	10
Godfrey Run	Erie	9	20
Grimshaw Run	Erie	10	15
Elk Creek	Erie	11	7
Total 1968			86
1969			
Orchard Beach Run	Erie	4	2
Six-Mile Creek	Erie	5	1
Walnut Creek	Erie	6	21
Trout Run	Erie	7	30
Godfrey Run	Erie	9	60
Grimshaw Run	Erie	10	19
Total 1969			133

See footnotes at end of table.

TABLE 7.--Numbers (thousands) of coho salmon planted in the Great Lakes and their tributaries, 1966-70.--Continued

Lake, state or province, years, and specific location	County (at stream mouth or lake area)	Figure number and site	Thousands of fish[1]
1970			
Orchard Beach Run	Erie	4	4
Six-Mile Run	Erie	5	8
Walnut Creek	Erie	6	25
Trout Run	Erie	7	43
Godfrey Run	Erie	9	75
Grimshaw Run	Erie	10	10
Elk Creek	Erie	11	32
Total 1970			197
Pennsylvania total, 1968-70			416
Ohio			
1968			
Chagrin River	Geauga	13	30
1969			
Conneaut Creek	Ashtabula	12	28
Chagrin River	Geauga	13	31
Huron River	Erie	15	28
Lake Erie (Bass Islands)	Ottawa	20	5
Total 1969			92
1970			
Conneaut Creek	Ashtabula	12	74
Chagrin River	Geauga	13	40
Huron River	Erie	15	95
Lake Erie (Kelley Island)	Erie	19	10
Lake Erie (Bass Islands)	Ottawa	20	35
Total 1970			254
Ohio total, 1968-70			376
Lake Erie total, 1968-70			881

See footnotes at end of table.

TABLE 7.--Numbers (thousands) of coho salmon planted in the Great Lakes and their tributaries, 1966-70.--Continued

Lake, state or province, years, and specific location	County (at stream mouth or lake area)	Figure number and site	Thousands of fish[1]
Lake Huron		Figure 5	
Michigan			
1968			
Tawas River (Cold Creek)	Iosco	6	177
Au Sable River	Iosco	7	75
Thunder Bay River	Alpena	9	100
Carp River	Mackinac	12	50
Total 1968			402
1969			
Tawas River (Cold Creek)	Iosco	6	200
Au Sable River	Iosco	7	217
Thunder Bay River	Alpena	9	150
Carp River	Mackinac	12	100
Total 1969			667
1970			
Lakeport Creek	St. Clair	1	25
Elk Creek	Sanilac	2	25
Diamond Creek	Huron	3	25
Tawas River	Iosco	6	60
Au Sable River	Iosco	7	236
Thunder Bay River	Alpena	9	100
Carp River	Mackinac	12	100
Total 1970			571
Lake Huron total, 1968-70			1,640
Lake Michigan		Figure 6	
Michigan			
1966			
Platte River	Benzie	26	265
Manistee River (Bear Creek)	Manistee	27	395
Total 1966			660

See footnotes at end of table.

TABLE 7.--Numbers (thousands) of coho salmon planted in the Great Lakes and their tributaries, 1966-70.--Continued

Lake, state or province, years, and specific location	County (at stream mouth or lake area)	Figure number and site	Thousands of fish[1]
1967			
Thompson Creek	Schoolcraft	17	46
Platte River	Benzie	26	503
Manistee River (Bear Creek)	Manistee	27	750
Little Manistee River	Manistee	28	433
Total 1967			1,732
1968			
Whitefish River	Delta	16	100
Thompson Creek	Schoolcraft	17	25
Bear River	Emmet	19	52
Porter Creek	Charlevoix	21	50
Brewery Creek	Leelanau	25	101
Platte River	Benzie	26	309
Manistee River	Manistee	27	75
Little Manistee	Lake	28	148
Pere Marquette River	Oceana	30	99
Muskegon River	Newaygo	32	220
Total 1968			1,179
1969			
Big Cedar River	Menominee	15	62
Whitefish River	Delta	15	162
Thompson Creek	Schoolcraft	17	27
Manistique River	Schoolcraft	18	50
Bear River	Emmet	19	300
Porter Creek	Charlevoix	21	50
Brewery Creek	Leelanau	25	100
Platte River	Benzie	26	1,092
Manistee River	Manistee	27	100
Little Manistee River	Manistee	28	700
Pere Marquette River	Oceana	30	100
Grand River	Kent-Iona	33	100
Kalamazoo River	Allegan	35	100
St. Joseph River	Berrien	37	100
Total 1969			3,043

See footnotes at end of table.

TABLE 7.--Numbers (thousands) of coho salmon planted in the Great Lakes and their tributaries, 1966-70.--Continued

Lake, state or province, years, and specific location	County (at stream mouth or lake area)	Figure number and site	Thousands of fish[1]
1970			
Menominee River	Menominee	14	50
Big Cedar River	Menominee	15	50
Whitefish River	Delta	16	100
Thompson Creek	Schoolcraft	17	73
Manistique River	Schoolcraft	18	50
Bear River	Emmet	19	277
Porter Creek	Charlevoix	21	75
Brewery Creek	Leelanau	25	200
Platte River	Benzie	26	778
Manistee River	Manistee	27	100
Little Manistee River	Manistee	28	550
Big Sable River	Mason	29	200
Grand River	Ionia	32	190
Black River	Van Buren	34	50
Kalamazoo River	Allegan	35	100
St. Joseph River	Berrien	37	100
Total 1970			2,943
Michigan total, 1966-70			9,557
Indiana			
1970			
Trail Creek	La Porte	1	38
Little Calumet Creek	Porter	2	10
Indiana total, 1970			48
Illinois			
1969			
Great Lakes Harbor	Lake	3	10
Wisconsin			
1968			
Ahnapee River	Kewaunee	11	25

See footnotes at end of table.

TABLE 7.--Numbers (thousands) of coho salmon planted in the Great Lakes and their tributaries, 1966-70.--Continued

Lake, state or provinces, years, and specific location	County (at stream mouth or lake area)	Figure number and site	Thousands of fish[1]
1969			
Sheboygan River	Sheboygan	7	47
Little Manitowoc River	Manitowoc	9	46
Kewaunee River	Kewaunee	10	40
Ahnapee River	Kewaunee	11	45
Little River	Marinette	13	40
Total 1969			218
1970			
Oak Creek	Milwaukee	4	50
Sheboygan River	Sheboygan	7	58
East Twin River	Manitowoc	8	25
Little Manitowoc River	Manitowoc	9	50
Kewaunee River	Kewaunee	10	50
Ahnapee River	Kewaunee	11	55
Little River	Marinette	13	50
Total 1970			338
Wisconsin total, 1968-70			581
Lake Michigan total, 1966-70			10,196
Lake Superior		Figure 7	
Michigan			
1966			
Big Huron River	Baraga	6	192
1967			
Big Huron River	Baraga	6	467

See footnotes at end of table.

TABLE 7.--Numbers (thousands) of coho salmon planted in the Great Lakes and their tributaries, 1966-70.--Continued

Lake, state or provinces, years, and specific location	County (at stream mouth or lake area)	Figure number and site	Thousands of fish[1]
1968			
Sucker River	Alger	1	40
Anna River	Alger	2	175
Chocolay River	Marquette	3	25
Falls River	Baraga	7	60
Ontonagon River	Ontonagon	9	50
Presque Isle River	Gogebic	10	32
Total 1968			382
1969			
Sucker River	Alger	1	50
Anna River	Alger	2	226
Falls River (Daults Creek)	Baraga	7	50
Sturgeon River	Baraga	8	75
Ontonagon River	Ontonagon	9	75
Presque Isle River	Gogebic	10	50
Total 1969			526
1970			
Sucker River	Alger	1	50
Anna River	Alger	2	150
Dead River	Marquette	5	75
Falls River (Daults Creek)	Baraga	7	82
Sturgeon River	Baraga	8	50
Presque Isle River	Gogebic	10	50
Total 1970			457
Michigan total, 1966-70			2,024
Minnesota			
1968			
Two Island River	Lake	17	4
Kimball River	Cook	18	2
Brule River	Cook	19	67
Total 1968			73

See footnotes at end of table.

TABLE 7.--Numbers (thousands) of coho salmon planted in the Great Lakes and their tributaries, 1966-70.--Continued

Lake, state or province, years, and specific location	County (at stream mouth or lake area)	Figure number and site	Thousands of fish[1]
1969			
French River	St. Louis	15	110
Kimball River	Cook	18	3
Brule River	Cook	19	1
Brule River	Cook	19	77
Total 1969			191
1970			
French River	St. Louis	15	63
Beaver River	Lake	16	23
Total 1970			86
Minnesota total, 1968-70			350
Ontario			
1969			
Jackpine River	Nipigon District	23	10
Gravel River	Nipigon District	24	10
Ontario total, 1969			20
Lake Superior total, 1966-70			2,394
Great Lakes total, 1966-70[2]			15,837

[1]Records of plantings were provided by fishery agencies of the states and province; the only annual series of planting records were published by the State of Michigan (Michigan Department of Conservation, MSS 1967, 1968, and Michigan Department of Natural Resources, MSS 1969, 1970).

[2]All coho salmon were smolt except for 74,000 fall fingerlings (age 0) planted in Minnesota tributaries of Lake Superior in 1968.

TABLE 8.--Numbers of coho salmon (all ages and sources combined) caught by various methods in the Great Lakes, 1966-70; percentages of lake totals given in parentheses (numbers less than 100 not shown)[1].

Lake, state or province	Year(s)	Method of capture				Total
		Angling	Commercial fishing	Weir	Other[2]	
Lake Ontario						
Lake total	1968-70	400 (25)	600 (38)	400 (25)	200 (12)	1,600
Lake Erie						
New York	1968-70	500	100	-	200	800
Pennsylvania	1968-70	4,600	-	5,300	400	10,300
Ohio	1968-70	9,400	-	-	500	9,900
Ontario	1968-70	900	7,000	-	-	7,900
Lake total	1968-70	15,400 (53)	7,100 (25)	5,300 (18)	1,100 (4)	28,900
Lake Huron						
Michigan	1967-70	118,700	-	6,000	-	124,700
Ontario	1967-70	-	57,200	-	-	57,200
Lake total	1967-70	118,700 (65)	57,200 (31)	6,000 (4)	-	181,900
Lake Michigan						
Michigan	1966-70	872,800	-	691,300	400	1,564,500
Indiana	1967-70	32,600	39,800	-	-	72,400
Illinois	1968-70	12,000	-	-	-	12,000
Wisconsin	1967-70	37,500	1,600	11,400	300	50,800
Lake total	1966-70	954,900 (56)	41,400 (2)	702,700 (42)	700 (<1)	1,699,700
Lake Superior						
Michigan	1967-70	102,500	-	2,600	500	105,600
Wisconsin	1968-70	8,300	100	-	-	8,400
Minnesota	1968-70	1,300	800	900	700	3,700
Ontario	1968-70	-	200	-	-	200
Lake total	1968-70	112,100 (95)	1,100 (1)	3,500 (3)	1,200 (1)	117,900 (100)
Great Lakes total	1966-70	1,201,500 (60)	107,400 (5)	717,900 (35)	3,200 (<1)	2,030,000

[1]Catch data provided by fishery agencies of the states and province.
[2]Primarily experimental gear.

TABLE 9.--Numbers of coho salmon planted in the Great Lakes (percentages of Great Lakes total in parentheses) in 1966-69, percentage recovered by various methods, and numbers caught by angling.

Lake	Years planted	Numbers planted		Years of recovery	Percentage recovered				Numbers caught by angling	
		Total	Annual average		Angling	Weirs	Commercial fishing	Total	Annual average	Annual high
Ontario	1968-69	240,000(3)	120,000	1968-70	<1	<1	<1	<1	100	300
Erie	1968-69	356,000(3)	178,000	1968-70	4	2	2	8	5,100	10,000
Huron	1967-69	1,069,000(10)	356,000	1967-70	11	1	5	17	29,000	74,000
Michigan	1966-69	7,567,000(65)	1,892,000	1966-70	12	9	<1	21	189,200	516,000
Superior	1966-69	1,961,000(19)	490,000	1967-70	6	<1	<1	6	28,200	64,000

Superior, 3 for Lake Erie, and less than 1 for Lake Ontario.

For the most part, the Great Lakes coho salmon fishery as been a Michigan fishery. Michigan waters of Lakes Superior, Michigan, and Huron accounted for 87% of the total catch, 91% of the angling catch, and 96% of the weir catch. Lake Michigan alone contributed about 75% of all coho salmon taken.

The following description of recoveries and characteristics of the fisheries for each lake incorporate, in part, the data in Tables 8 and 9.

Lake Ontario. Of the 240,000 coho salmon smolt planted in 1968-69, only 1,600 (0.7%) were recovered in 1968-70. Angling was almost a complete failure and only a few hundred fish were taken in weirs and in commercial and experimental gear. Probably survival was best in the Credit River, Ontario. About 1,200 mature coho salmon were estimated to have migrated into that river in the fall of 1970 (90,000 were planted in the stream in 1969).

The homing instincts of spawning salmon in Lake Ontario apparently were not strong. Fish marked when planted were commonly recovered as spawning adults in tributaries other than those in which they were planted.

The extremely low survival of coho salmon in Lake Ontario undoubtedly was caused primarily by severe sea lamprey predation (described later).

Lake Erie. In 1968-69, 346,000 fin-clipped and 10,000 unmarked coho salmon were planted in Lake Erie. About 28,900 (8% of the number planted) were caught in 1968-70--53% by angling, 25% by commercial fishermen, and 22% in weirs and experimental gear (compiled from data in Anonymous, MSS 1969, 1970; Baker, MS 1971; Great Lakes Fishery Commission, MS 1970d, MS 1971d). The unmarked fish recovered apparently included some unmarked fish from Lake Huron. For example, 47% of the Lake Erie commercial catch in 1969 (2,500 fish) and 20% of the Ohio sport catch in 1970 were unmarked as compared with less than 3% unmarked fish planted. (None of the coho salmon planted in Lake Huron in 1967-68 were marked, but 18% of those planted in 1969 were marked; some of the marked 1969 fish were caught in Lake Erie in 1970.)

Since some of the coho salmon caught in Lake Erie were from Lake Huron plantings, the recorded recovery of fish planted in Lake Erie was less than 8%; however, the difference was probably more than compensated for by the recapture of salmon in the Ohio commercial fishery that were not included in recoveries (in 1969-70, about 13,000 coho salmon were reported to have been caught and released).

Sport fishing for salmon in Lake Erie was fair at best. About 90% of the anglers' catch was from streams. Virtually all of the Ohio sport catch (80% of the lake total in 1970) was in streams--the largest share in the Chagrin River. Of the 2,200 salmon caught by anglers in the Chagrin River in 1970, an estimated 87% were taken by snagging (Baker, MS 1971).

Of the small numbers (10% of the total) of salmon taken by anglers in the open lake, most

were taken in Pennsylvania, where sport fishing was banned in streams. A small sport fishery also developed in Ohio near warmwater outlets at Cleveland and Lorain in January and February, 1969 and 1970.

Straying of coho salmon spawners in Lake Erie was not unusual. For example, of the fish caught by anglers in the Chagrin River, Ohio, in 1970, 63% had been planted in Ohio waters, 17% in Pennsylvania, and 1% in New York; 19% were of unknown origin (possibly from Lake Huron).

For the lake as a whole, about 80% of the fish caught were age II and 20% were age I. In the spawning runs in tributaries, about 98% were age-II fish.

Lake Huron. Of the one million coho salmon smolt planted in Lake Huron in 1967-69, about 182,000 (17%) were recovered in 1967-70. Anglers accounted for 65% of the recoveries and weirs 4%, all in Michigan waters; 31% were caught by commercial fishermen in Canadian waters (compiled from data in Great Lakes Fishery Commission, MS 1969c, MS 1970c, MS 1971c). Despite the relatively high recovery by anglers (nearly 12% of the fish planted), sport fishing was only fair--most fish were caught by snagging in the tributaries in the fall; only a few were caught in the open lake, primarily near the mouths of tributaries.

About 70% of the coho salmon (nearly all age II) caught by Canadian commercial fishermen were taken in the open waters of southeastern Lake Huron in April.

Weir catches of adult coho salmon in Michigan tributaries in the fall of 1969-70 generally were low (Bullin, MS 1971). Many fish apparently circumvented the weirs and escaped upstream; nonetheless, the numbers of fish observed in the runs, as compared with the numbers planted, were relatively small.

Data on recoveries from individual plants were reported only for the 1968 plants in the Tawas and AuSable Rivers. In 1969, total known recoveries from the 1968 plants totaled 6% for the Tawas River and 5% for the AuSable River (Weaver, MS 1969).

Lake Michigan. Of the 7.6 million coho salmon smolt planted in Lake Michigan in 1966-69, 21% were recovered in 1966-70. Of those recovered 56% were taken by angling, 42% in weirs, and 2% by commercial fishing.

Of the 6.6 million coho salmon smolt planted in Michigan tributaries in 1966-69, nearly 1.6 million (24%) were recovered in Michigan waters alone in 1966-70 (Table 10). Anglers accounted for 56% of the recoveries and weirs for 44%. The high percentage of coho salmon caught in weirs in 1966-68 (71 to 80% of the total recovery) indicates that most salmon escaped the sport fishery and were caught in weirs as they migrated upstream to spawn. The situation changed in 1969-70, however, owing to greatly increased sport fishing intensity as well as improved sport fishing techniques used by anglers. Percentages of the total recoveries made by anglers were 80 in 1969 and 68 in 1970; the percentage recoveries in weirs of fish planted in tributaries on which weirs were installed declined from 22% in 1967-68 to 15% in 1969-70.

Weirs usually were operated from September to mid-December in Michigan tributaries.[7] Most recoveries in weirs were made in three structures--the Platte and Manistee River weirs in 1966-67, and Platte and Little Manistee River weirs in 1968-70. Recoveries in weirs (Table 10) were low in 1966 because numbers planted in that year were relatively small and all the recoveries were jacks (in 1966-70, jacks contributed about 6% of the weir catch). The relatively low catch (68,500 fish) in weirs in 1969 was caused by the reduction in numbers of salmon planted in the Platte and Little Manistee Rivers in 1968. Survival of fish planted in these two rivers undoubtedly was much higher than the average for all Michigan tributaries. Average annual

[7]The Michigan Department of Natural Resources operated weirs in 1966-70 to assess survival and describe population and biological characteristics of coho (and chinook) salmon, to obtain eggs for propagation, and to prevent littering of the stream with salmon carcasses. Many of the fish caught were sold and some were given to licensed sport fishermen. The fish sold were used as human or animal food, and the roe was used for caviar and packaged fish bait.

TABLE 10.--Numbers of coho salmon recovered, and percentage recovery for Michigan waters of Lake Michigan, 1966-70; percentage contributed by angling and weirs to the total each year in parentheses.

Year	Number planted	Method of recovery		Total	Percentage recovery of previous year's plant
		Angling	Weirs		
1966	660,000	1,500(29)	3,760(71)	5,260	--
1967	1,732,000	40,300(20)	165,724(80)	206,000	31
1968	1,179,000	94,000(29)	226,200(71)	320,000	19
1969	3,043,000	269,000(80)	68,500(20)	337,500	29
1970	--	475,000(68)	227,100(32)	702,100	23
1966-70	6,614,000	879,800(56)	691,284(44)	1,571,000	24

recovery of fish planted in streams with weirs was 19% as compared to 24% total recovery of all Michigan plants.

Weir catches indicated strong homing instincts for coho salmon planted in tributaries of Lake Michigan. For example, percentages of marked fish planted and recovered, respectively, were 18.9 (1966) and 16.7 (1967) in the Platte River; 40 (1968) and 43 (1969) in Brewery Creek; and 25 (1968) and 23.4 (1969) in the Whitefish River. As near as can be determined, 5 to 10% of the spawning adults strayed from their parent stream. These fish were found in a number of planted and unplanted tributaries in Michigan and a few tributaries in Wisconsin.

The sport fishery catch in Michigan increased sharply from year to year because of the increase in the number of smolt planted (from 660,000 in 1966 to 3,043,000 in 1969; Table 10) as well as the previously mentioned increased fishing intensities and improved fishing skills. Coho salmon fishing has been spectacular. Open lake fishing was good in the spring in lower Lake Michigan and in August into October along the eastern shoreline, as far out as 7 miles (11 km), from Saugatuck to Grand Traverse Bay. In September and October, fishing also was good in estuarine lakes (principally near the mouths in the Platte and Little Manistee and Manistee Rivers), and in most tributaries where coho salmon were planted. Most salmon caught in Michigan tributaries, as in most tributaries of the Great Lakes, were snagged.

Most of the coho salmon caught by anglers in Michigan waters of Lake Michigan were taken in the fall. For example, of the 269,000 fish taken by angling in 1969, 10% were caught in the spring (to June 30) mainly off piers or in the open lake; 34% in summer (to September 30) primarily in the open lake; and 56% in the fall and early winter (to December 31) mostly in estuaries and tributaries (Jamsen, Ryckman, and Jamsen, MS 1970).

The Alaskan strain of coho salmon exhibited characteristics different from those of the Columbia River stocks. Of 46,400 marked smolt released in Thompson's Creek in May 1967, most migrated into Lake Michigan within 5 days. Within a few months (August through October), a large run of jacks returned to Thompson's Creek and about 5,000 were caught by anglers in the lake near the mouth of the creek and in the creek. In the fall of 1968, 6,000 age-II fish were caught by anglers and 2,000 were caught in the Thompson Creek weir (Great Lakes Fishery Commission, MS 1969b). In all, 28% of the fish of the Alaskan

strain planted in 1967 were recovered at the mouth of, or in, Thompson Creek in 1967-68. Several characteristics of the catch thus differed considerably from those of the Columbia River stocks in Lake Michigan: the high recovery of fish from one plant in a highly localized area, the high recovery rate for jacks (38% of all fish recovered), and the small size of the fish (average weight at age I, 0.5 pound or 0.2 kg, and at age II, 6.9 pounds or 3.1 kg).

Although no coho salmon were planted in Indiana waters of Lake Michigan before 1970, 72,400 fish were caught there in 1967-70 (Table 8). Nearly all of these fish, taken primarily by anglers and commercial fishermen in the open lake in March and April, probably were from Michigan plants. Commercial fishing for salmon was banned in Indiana in 1969 and 1970.

About 12,000 coho salmon were caught by anglers in Illinois waters in 1968-70, primarily in the spring. Although a few of the salmon were known to be survivors of the 1969 plant in Chicago Harbor, most were from Michigan plants. Because of a lack of suitable tributary streams in Illinois, salmon smolt were held in floating cages in harbor areas before release in an attempt to develop strong shoreline homing instincts.

Of the 243,000 marked coho salmon planted in Wisconsin tributaries in 1968-69, about 43,000 (17%) were recovered in 1968-70. An additional 8,000 fish that were caught were presumably from Michigan plants. Of the total, about 95% were age-II fish and 5% were jacks. Weir catches indicated that about 16% of the spawning fish had strayed from their parent streams.

The sport catch in Wisconsin increased from 1,000 fish in 1967 to 20,000 in 1970. By 1970 most of the sport catch was in the Sheboygan River (the most southerly Wisconsin tributary planted with coho salmon) and areas to the north. Most of the fish caught in 1969 were taken in October (74% of the catch off piers and breakwaters, 62% of the open-lake catch, and 79% of the stream catch). Coho salmon planted in Michigan supported two small open-water fisheries in Wisconsin waters. Nearly all salmon caught in the spring south of Sheboygan River apparently were from Michigan plants, as were nearly all those caught in all seasons 2 or more miles from shore north of the Sheboygan River (R.J. Poff, personal communication).

Lake Superior. Of the 1,961,000 coho salmon planted in Lake Superior in 1966-69, 117,900 (6%) were recovered in 1967-70. Of those recovered, 95% were taken by angling. Although some weirs were operated in the fall in Michigan and Minnesota, catches in most streams usually were too small to justify extensive operation of weirs to monitor spawning runs.

Most of the coho salmon were planted in Michigan waters in 1966-69 (1,567,000 smolt; 80% of the lake total) and were recovered there in 1966-70 (105,600 recoveries; 81% of the lake total).

The wide distribution of planted fish in Lake Superior and the extent of straying was indicated by recaptures of fish planted in the Big Huron River, Michigan. In 1966, 192,000 smolt were stocked (the only plant in Lake Superior that year). Although only about 1,700 returned to the river as adults in the fall of 1967, others strayed to 33 Michigan tributaries (Peck, 1970). In May 1967, 467,000 smolt were planted in the same river. Less than 1% returned to spawn in 1968. Of the 10,500 fish from this planting caught by angling in 1968, about 64% were estimated to have been caught in Wisconsin and Minnesota waters primarily in the spring, and only 36% in Michigan waters (Great Lakes Fishery Commission, 1969a). In the fall of 1968 only 2,500 adults were observed in the Big Huron River spawning run.

Of the 526,000 smolt planted in six Michigan tributaries in 1967, 43,000 (11%) were recovered by angling in Michigan in 1968--53% in the spring and 47% in the fall (almost no fish were caught in the summer).

The sport catch of coho salmon in Michigan was 2,500 in 1968, 60,000 in 1969, and 40,000 in 1970. The decline in 1970 occurred despite an increase in the numbers planted (382,000 in 1968; 507,000 in 1969). Since most of the

coho salmon were caught by anglers fishing primarily for lake trout, recoveries of coho salmon were partly determined by fishing intensity for lake trout (Great Lakes Fishery Commission, MS 1971a).

Although no coho salmon were planted in Wisconsin waters in 1966-70, a fair open-water coho salmon sport fishery developed there in 1968-70 (2,500 to 3,000 fish per year of which about 88% were caught in May and June). All or most were recoveries from Michigan plantings. About 67% of the fish recorded were caught near Ashland where fishing intensity for salmon and trout in Wisconsin waters was greatest.

Only 3,700 coho salmon were recovered in Minnesota in 1966-70. Despite plants of 73,000 smolt in three tributaries in 1968, 191,000 in four tributaries in 1969, and 86,000 in two tributaries in 1970, only 1,300 coho salmon were taken by anglers. Of the fish released in 1969, 110,000 were planted in the French River but few were recovered. Only 507 were caught by weir in the river in the fall of 1970, 395 in experimental gear in the lake near the river mouth, and 1,056 by anglers. Stray coho salmon were observed in 15 streams that were not planted, but the highest count for any one stream was only 30 fish.

The Province of Ontario planted 20,000 coho salmon smolt in two tributaries east of Nipigon Bay in 1969. Although sport and commercial catches were examined and experimental gear was used to evaluate survival in 1966-70, only a few hundred fish were recovered.

Average weights and growth

The average weight of coho salmon in the fall of their third year of life varied widely among the lakes (Table 11). Although average weights of age-I fish ranged only from 1 to 2 pounds (0.5 to 0.9 kg), their value for describing differences in weight (as a reflection of growth rate) is limited because usually only the largest fish were taken as jacks in the fall. This bias was not apparent for age-II fish--both sexes were well represented and most fish had completed their life's growth.

TABLE 11.--Average weight and incidence of sea lamprey scars and wounds for coho salmon in the Great Lakes in the fall, 1966-70; number of fish in parentheses[1]

Lake and years of observation	Growing seasons completed	Average weight[2]		Percentage of fish bearing lamprey wounds and scars
		Pounds	Kilograms	
Ontario				
1968-70	2	1.5(312)	0.7	30(175)
	3	4.9(216)	2.2	96(216)
Erie				
1969-70	2	1.3 --	0.6	- --
	3	4.3 --	2.0	4 --
Huron				
1968-70	2	2.0(93)	0.9	10(1,223)
	3	8.8 --	4.0	62 --
Michigan				
1966-70	2	[2]1.6 --	0.7	1(114)
	3	[2]8.8 --	4.0	3(2,229)
Superior				
1967-70	2	1.0 --	0.5	- --
	3	3.0 --	1.4	1(858)

[1]Data from Great Lakes Fishery Commission (MSS 1969 a, b, c, d, e; MSS 1970 a, b, c, d, e; MSS 1971 a, b, c, d, e) and Borgeson (MS 1970). Number of fish are not reported for some values because averages included some unquantified samples; most numbers exceeded 200.

[2]For the Alaskan strain, average weights were 0.5 pound (227 grams) for fish that had completed 2 growing seasons and 6.9 pounds (3.1 kilograms) for fish that had completed 3 growing seasons.

Age-II fish were largest in Lakes Michigan and Huron (8.8 pounds or 4.0 kg), smaller in Lakes Ontario and Erie, and smallest in Lake Superior (3.0 pounds or 1.4 kg). The largest coho salmon caught in Lake Michigan was 33.2 pounds (15 kg) and in Lake Huron 20 pounds (9.1 kg); few larger than 10 pounds (4.5 kg) were reported for Lake Superior, Erie, and Ontario.

Growth rates of coho salmon (as indicated by average weights in pounds) appear to have declined in Lakes Huron and Michigan (Table 12; comparable data are not available for the other Great Lakes). In Lake Huron, fish planted in 1969 were smaller at the same age than fish planted in 1968. For example, fish that had completed 3 growing seasons (age II) weighed 9.1 pounds (4.1 kg) in 1969 and 8.5 pounds (3.9 kg) in 1970. In Lake Michigan, the average weights of coho salmon in 1967-70 decreased as the number of fish planted increased. For example, after three growing

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Growth rates of coho salmon (as indicated by average weights in pounds) appear to have declined in Lakes Huron and Michigan (Table 12; comparable data are not available for the other Great Lakes). In Lake Huron, fish planted in 1969 were smaller at the same age than fish planted in 1968. For example, fish that had completed 3 growing seasons (age II) weighed 9.1 pounds (4.1 kg) in 1969 and 8.5 pounds (3.9 kg) in 1970. In Lake Michigan, the average weights of coho salmon in 1967-70 decreased as the number of fish planted increased. For example, after three growing

TABLE 13.--Numbers (in thousands) of chinook salmon planted in the Great Lakes and their tributaries, 1967-70.

Lake, state, years, and specific location	County (at stream mouth or lake area)	Figure number and site	Thousands of fish[1]
Lake Ontario		Figure 3	
New York			
1969			
Little Salmon River	Oswego	23	70
1970			
Salmon River	Oswego	22	141
Lake Ontario total, 1969-70			211
Lake Erie		Figure 4	
Ohio			
1970			
Chagrin River	Geauga	13	65
Huron River	Erie	15	65
Kelley Island	Erie	19	20
Lake Erie total, 1970			150
Lake Huron		Figure 5	
Michigan			
1968			
Thunder Bay River	Alpena	9	[2]74
Ocqueoc River	Presque Isle	10	200
1969			
Mill Creek	Alcona	8	5
Thunder Bay River	Alpena	9	[2]45
Ocqueoc River	Presque Isle	10	200
1970			
Au Sable River	Iosco	7	503
Thunder Bay River	Alpena	9	[2]100
Lake Huron total, 1968-70			1,127

See footnotes at end of table.

TABLE 13.--Numbers (in thousands) of chinook salmon planted in the Great Lakes and their tributaries, 1967-70.--Continued

Lake, state, years, and specific location	County (at stream mouth or lake area)	Figure number and site	Thousands of fish[1]
Lake Michigan		Figure 6	
Michigan			
1967			
Little Manistee River	Manistee	28	591
Muskegon River	Newaygo	32	211
1968			
Little Manistee River	Manistee	28	322
Muskegon River	Newaygo	32	365
1969			
Little Manistee River	Manistee	28	300
Muskegon River	Newaygo	32	352
1970			
Menominee River	Menominee	14	100
Bear River	Emmet	19	200
Little Manistee River	Manistee	28	309
Big Sable River	Mason	29	100
Muskegon River	Newaygo	32	500
Grand River	Ottawa-Kent	33	466
Michigan total, 1967-70			3,816
Indiana			
1970			
Trail Creek	La Porte	1	50
Little Calumet Creek	Porter	2	50
Illinois			
1970			
Diversey Harbor	Cook	3	10
Wisconsin			
1969			
Strawberry Creek	Door	12	66

See footnotes at end of table.

TABLE 13.--Numbers (in thousands) of chinook salmon planted in the Great Lakes and their tributaries, 1967-70.--Continued

Lake, state, years, and specific location	County (at stream mouth or lake area)	Figure number and site	Thousands of fish[1]
1970			
Strawberry Creek	Door	12	118
Wisconsin total, 1969-70			184
Lake Michigan total, 1967-70			4,110
Lake Superior		Figure 7	
Michigan			
1967			
Big Huron River	Baraga	6	34
1968			
Chocolay River	Marquette	3	50
1969			
Anna River	Alger	2	50
1970			
Dead River	Marquette	5	75
Sturgeon River	Baraga	8	100
Total 1970			175
Lake Superior total, 1967-70			318
Great Lakes total, 1967-70			5,916

[1]Records of plantings were provided by state fishery agencies.
[2]All of the chinook salmon planted in 1968-69, and 40,000 of those planted in 1970 were of the Donaldson strain.

TABLE 14.--Number of chinook salmon (ages and sources combined) caught by various means in Great Lakes, 1968-70; percentages of Great Lakes totals given in parentheses (quantities less than 100 not shown)[1].

Lake, state or province	Year(s)	Method of capture			Total
		Angling	Commercial fishing	Weir	
Lake Ontario					
New York	1970	100	-	-	100
Ontario	1970	-	100	-	100
Total	1970	-	-	-	200
Lake Huron					
Ontario	1969	-	1,000	-	1,000
	1970	-	3,000	-	3,000
Michigan	1969	1,000	-	-	1,000
	1970	18,000	-	-	18,000
Total	1969-70	19,000	4,000	-	23,000
Lake Michigan					
Michigan	1968	7,500	-	11,600	19,100
	1969	109,000	-	26,300	135,300
	1970	150,000	-	40,000	190,000
Wisconsin	1969	200	-	-	200
	1970	600	-	800	1,400
Total	1968-70	267,300	-	78,700	346,000
Lake Superior					
Michigan	1969	7,000	-	-	7,000
	1970	5,000	-	-	5,000
Total	1969-70	12,000	-	-	12,000
Great Lakes total	1968-70	298,400 (79)	4,100 (1)	78,700 (20)	[2]381,200

[1]Data from Great Lakes Fishery Commission (MSS 1970 a,b,c,d,e; MSS 1971 a,b,c,d,e) and Jamsen, et al. (MS 1970).

[2]Only a few scattered recoveries of chinook salmon were reported for Lake Erie, for Illinois and Indiana waters of Lake Michigan, and for Wisconsin, Minnesota, and Ontario waters of Lake Superior.

TABLE 15.--Average weight and incidence of sea lamprey scars and wounds for chinook salmon in the Great Lakes in the fall, 1968-70; number of fish in parentheses[1].

Lake, and year planted	Year of observation	Growing seasons completed	Average weight[2]		Percentage bearing lamprey scars or wounds
			Pounds	Kilograms	
Ontario					
1969	1970	2	3.5(31)	1.6	71(31)
1970	1970	1	1.0(26)	0.5	0(26)
Huron					
1968	1968	1	0.9(6)	0.4	- -
	1969	2	6.6(401)	3.0	63(401)
	1970	3	16.4(118)	7.4	52(118)
1969	1970	2	7.9(61)	3.6	21(61)
Michigan					
1967	1968	2	6.1 -	2.8	- -
	1969	3	16.4 -	7.4	- -
	1970	4	23.0 -	10.4	- -
1969	1970	2	6.6(750)	3.0	0(750)
Superior					
1967	1969	2	3.1 -	1.4	0 -
	1970	3	8.2 -	3.7	16 -

[1]Data from Great Lakes Fishery Commission (MSS 1969 a, b, c, e; MSS 1970 a, b, c, e; MSS 1971 a, b, c, e) and Borgeson (MS 1970).

[2]Number of fish for some values are not reported because averages included some unquantified samples; most numbers exceeded 200.

Lake Ontario. The survival and recovery of chinook salmon planted in Lake Ontario were very low; reports on the species were fragmentary at best. In New York, about 70,000 smolt were planted in the Little Salmon River in 1969 and 141,000 in the Salmon River in 1970. A few of the 1969 fish were caught--71 by anglers in the Little Salmon River in the fall of 1970 and 13 in experimental nets. Ontario commercial fishermen in 1970 caught 10 fish from the 1969 plant and 70 from the 1970 plant.

Lake Erie. Of the 150,000 smolt planted in Lake Erie in 1970, only one recovery was reported.

Lake Huron. About 1 million chinook salmon smolt were planted in four Michigan tributaries in 1968-70. In 1969-70, about 23,000 (8% of the 274,000 planted in 1967-68) were caught--19,000 by angling in Michigan waters and 4,000 by commercial fishermen in Ontario waters.

Lake Michigan. About 4 million smolt were planted in Lake Michigan in 1967-70, of which 95% were planted by the State of Michigan. All fish planted in Michigan in 1967-69 and 77% in 1967-70 were planted in the Little Manistee and Muskegon Rivers. Of the 591,000 smolt planted in the Little Manistee River in the spring of 1967, 8% were caught in the weir in this stream in the fall in 1968-70--2% in 1968, 3% in 1969, and 3% in 1970 (Great Lakes Fishery Commission, MS 1971b). The total lake-wide recovery from the 1967 plants in 1968-70 was estimated to be 20% (118,000 fish)--12% by angling in addition to the 8% from weirs.

Sport fishing for chinook salmon in Michigan waters was most productive in the fall. Of the 109,000 fish taken by anglers in 1969, less than 1% were caught in the spring (to June 30), 32% in the summer (July-September), and 67% in the fall and early winter (October-December).

In 1969-70 about 1,600 chinook salmon were caught by anglers or in weirs in Wisconsin waters. These fish (of the Donaldson strain) had been planted in Strawberry Creek in 1969. In the fall of 1970, a weir and by-pass pond, constructed for catching returning adults in Strawberry Creek, caught about 800 fish. Chinook salmon were rarely taken in Indiana and Illinois waters of Lake Michigan.

Lake Superior. Chinook salmon were planted only in Michigan waters of Lake Superior. In 1967-70, 318,000 were planted in five tributaries. Of the 34,000 smolt planted in the Big Huron River in the spring of 1967, only 8 were recovered by various means in the river in the fall of 1969 and only a few spawning females (age III) were recovered there in the fall of 1970 (Great Lakes Fishery Commission, MS 1971a). Survival of the 1967 plant (the first for Lake Superior and the only one in 1967) was extremely poor.

Anglers caught 7,000 chinook salmon in Michigan waters in 1969 and 5,000 in 1970 (Great Lakes Fishery Commission, MS 1971a). If the entire catch was from the 1967-69 plants, angling recovery was bout 8%.

Chinook salmon rarely were taken in Wisconsin, Minnesota, and Ontario waters of Lake Superior.

Despite the relatively high rate of return of chinook salmon to the anglers in the upper three lakes, sport fishing for this species was considered to be only fair in Lakes Huron and Superior, and less than spectacular in Lake Michigan. Major problems have been the failure of the fish to take anglers' lures readily (a large majority were taken by snagging), and their highly limited availability (most were taken in estuaries and tributaries in October and November).

Average weights and growth

Chinook salmon grew fastest in Lake Huron (average weight 7.2 pounds or 3.3 kg in the fall--age I) and slowest in Lake Superior (3.1 pounds or 4.1 kg; Table 15). Fish planted in 1967 in Lake Michigan weighed 6.1 pounds (2.8 kg) in the fall of 1968 (age I), 16.4 pounds (7.4 kg) in 1969 (age II), and 23.0 pounds (10.4 kg) in 1970 (age III). Trophy fish weighing up to 40 pounds (18.2 kg) have been taken from Lake Michigan.

Incidence of sea lamprey predation

The incidence of sea lamprey predation for age-I fish in the fall was highest (71%) for Lake Ontario and lowest (nil) for Lake Michigan (Table 15). Lamprey predation declined in 1969-70 in Lake Huron (63% for age-I fish in the fall of 1969 and 21% for fish of the same age in 1970). It increased with the size of fish in Lake Superior (0% for age-I fish averaging 3.1 pounds or 1.4 kg but 16% for age-II fish averaging 8.2 pounds or 3.5 kg). In September 1969, lamprey predation in Lake Huron was so serious that one-third to one-half of nearly 1,000 chinook salmon observed near the mouth of the Ocqueoc River carried attached lampreys (King and Applegate, 1969). Of the 401 fish sampled, 63% bore lamprey wounds or scars.

Natural reproduction

The first major spawning run of female chinook salmon in all the Great Lakes occurred in the Little Manistee and Muskegon Rivers in 1970. Redds were common on the shoals in some areas and large numbers of eggs were deposited (in the spring of 1971, a few stream-hatched smolt were caught in these tributaries).[9] Gross observations on the straying of spawners into other tributaries of Lake Michigan suggest that the homing instincts of chinook salmon were strong--a great majority returned to the tributary in which they were planted.

STATUS OF THE COHO AND CHINOOK SALMON FISHERIES

Because salmon are planted primarily to support a put-and-take fishery, most of the states have maintained or plan to maintain artifical propagation from eggs collected from spawning stocks within their own waters. Introductions of some Columbia River salmon, or other strains, will be continued not only because of the ready availability of eggs, but to minimize the possibility of degradation of Great Lakes stocks (self-sustaining landlocked populations are extremely rare, although one for coho salmon has been reported in Russia and one for chinook salmon in New Zealand--see footnotes 8 and 9).

Since the numbers of coho and chinook salmon smolt produced by natural reproduction have been (and are expected to continue to be) small compared with the numbers planted, the density of the populations in the lakes, principally as related to the availability of forage fish, generally can be controlled. So far, optimum density, or optimum numbers that should be planted in any of the lakes has not been determined. On the other hand, factors that have limited the development of salmon fisheries in the different lakes are now reasonably clear.

The success of the planting of coho and chinook salmon in Lake Michigan may be attributed to a number of factors: the large number of suitable tributaries, a suitable lake habitat (primarily as it is related to water temperatures and dissolved oxygen concentrations), a strong forage base (primarily alewives, Alosa pseudoharengus), high availability to the angler in most months (principally as related to the habits, distribution, and migration of salmon in the lake, estuaries, and tributaries), strong homing instincts, widespread and relatively intensive sport fishing, and sufficient control of sea lampreys.

Despite these favorable conditions, the capacity of Lake Michigan to support salmon

[9] Stokell (1955), who described the results of planting chinook salmon in several freshwater landlocked lakes in New Zealand, reported that the fish grew up to 6 to 8 pounds (2.7 to 3.6 kg) and spawned successfully. Their progeny, however, grew to only 2 pounds (0.9 kg) and all were infertile. He concluded that even under the most favorable circumstances, chinook salmon were capable of developing only two generations in fresh water; however, in 1972 C. J. Hardy (personal communication) reported a self-supporting freshwater population of chinook salmon in Lake Coleridge, New Zealand. The population has supported a good sport fishery since 1922 but the fish grow slowly--at maturity most weigh 2 to 3 pounds (0.9 to 1.4 kg), and only a few reach 6 pounds (2.7 kg). Fish planted in landlocked lakes were hatched from eggs obtained from self-sustaining sea-run stocks that had been established in several rivers of New Zealand in the early 1900's. The eggs originally were obtained from chinook salmon from the Sacramento River, California (Hardy, 1972).

is also limited. In fact, the large number of coho and chinook salmon and lake trout (Salvelinus namaycush), brown trout (Salmo trutta), and steelhead trout planted in Lake Michigan already may be taxing the forage base. A predatory-prey balance that will limit the number of salmon that Lake Michigan can support may soon be reached as the number of salmonids planted is increased. The 20% decline in average weight of prespawning coho salmon from 1967 to 1970 may be the first symptom of the effects of increased plantings.

Despite rather severe sea lamprey predation on salmon in Lake Huron and the apparent weak forage base (as compared to that in Lake Michigan), relative survival, as well as growth, of coho and chinook salmon was closely similar to that in Lake Michigan; however, if plantings in Lake Huron had equaled those in Lake Michigan, survival and growth probably would have been considerably less. Since effective control of lampreys in Lake Huron is expected within the next few years, conditions for salmon there are likely to improve. Even so, plantings of coho and chinook salmon are not expected to be greatly increased in the near future because of the poor quality of sport fishing for salmon, and the probability that heavier plantings of salmon may suppress the splake (Salvelinus namaycush x S. fontinalis), which will be the fish planted in greatest numbers.

The poor quality of the salmon sport fishery in Lake Huron tributaries was described by Mears (MS 1972). He wrote that virtually all of the 10,000 coho and chinook salmon caught in Thunder Bay River each year in 1969 and 1970 were snagged below a dam near the river mouth in a period of about a month in the fall. During the 1970 fall fishery, most anglers lost their earlier enthusiasm for snagging large fish and returned to angling for trout. (This same problem applies to other areas in the Great Lakes region and, as a consequence, reduces the value and need of increased plantings of either species in some tributaries.)

An example of the failure of chinook salmon to take anglers' lures in the open lake was demonstrated at the Ocqueoc River, where a weir at the river mouth in the fall of 1969 and 1970 barred the entry of mature chinook salmon that had been planted there as smolt. Despite the heavy concentrations of chinook salmon off the river mouth in September and October, few were taken by anglers.

The planting of coho and chinook salmon in Lake Superior has been only marginally successful. The relatively low survival and slow growth (coho salmon caught by anglers in 1967-70 averaged only about 1.5 pounds or 0.7 kg) suggest that forage for salmon may be scarce. A further reason for the poor sport fishery was the weak homing instincts of planted fish. The salmon were so widely distributed at all stages of life after planting that their availability to the angler generally was low (this same problem was evident in Lakes Ontario and Erie, and to a lesser extent in Lake Huron). It seems unlikely that a further increase in numbers of coho and chinook salmon planted in United States waters of Lake Superior will greatly increase the sport fishing catch.

For the most part, Lake Erie does not provide suitable habitat for salmon. Eutrophication and oxygen depletion in the summer in the deep cold waters of the lake undoubtedly restrict the distribution of the salmon and may reduce the availability of forage. Although rainbow smelt (Osmerus mordax) are abundant in Lake Erie, the relatively slow growth of the salmon suggests that smelt are not abundantly available during the major growing season of the salmon. Because of these conditions, plantings of coho and chinook salmon in Lake Erie cannot be expected to be highly successful.

Until sea lampreys are controlled in Lake Ontario (at least to the extent that lampreys are not the dominant limiting factor), there will be no salmon fishery nor will the potential of salmon in Lake Ontario be known.

For the Great Lakes as a whole, sport fishing success has been best in Lake Michigan where coho and chinook salmon survival is highest, growth is fastest, and homing instincts are strongest.

Analysis of the results of the recent plants of salmon in the Great Lakes give evidence that salmon management is still primarily experimental and that concepts of salmon management may be greatly altered in the next decade.

ACKNOWLEDGMENTS

This history of the salmon of the Great Lakes was based almost entirely on past publications, and on personal communications from members of fishery agencies of the Great Lakes States and the Province of Ontario. I especially thank the following colleagues for contributing information: Robert Saalfeld, Great Lakes Fishery Commission; Paul Vidal and Bruce Muench, Illinois Department of Conservation; Robert W. Hollingsworth, Indiana Department of Natural Resources; Jack Bails, Mercer Patriarche, John Scott, Thomas M. Stauffer, Clarence Taube, and Wayne Tody, Michigan Department of Natural Resources; Richard Hassinger and Donald E. Woods, Minnesota Department of Conservation; William A. Pearce and Donald G. Pasko, New York Department of Environmental Conservation; Russell L. Scholl, Ohio Department of Natural Resources; Clarence F. Clark and Milton B. Trautman, Ohio State University; W. J. Christie, John R. Coleman, John J. Collins, W.R. Henson, and R.A. Ryder, Ontario Ministry of Natural Resources; Arthur E. Bradford and Shyrl Hood, Pennsylvania Fish Commission; W.B. Scott, Royal Ontario Museum, Toronto; L.P. Donaldson, University of Washington; and Ronald J. Poff, Wisconsin Department of Natural Resources.

REFERENCES

Adamson, W.A.
1857. The decrease, restoration, and preservation of salmon in Canada. Can. J. Ind. Sci. Art, 2: 1-7.

Anonymous.
MS 1969. Minutes of the Coho Committee meeting. N.Y. Conserv. Dep., Albany, N.Y., 6 p. and append.

Anonymous.
MS 1970. Minutes of the Coho Committe meeting. N.Y. Conserv. Dep., Albany, N.Y., 3 p. and append.

Atkins, Charles G.
1874. On the salmon of eastern North America and its artificial culture. Rep. U.S. Fish Fish. Comm. (1872-73), p. 226-335.

Atkins, Charles G.
1884. Notes on the land-locked salmon. Trans. Amer. Fish-Cult. Ass. [Trans. Amer. Fish. Soc.], 13: 40-56.

Baker, Carl T., Jr.
MS 1971. Lake Erie fish research. Dingell-Johnson Annu. Job Progr. Rep. F-35-R-9, No. 5 (1970), Ohio Dep. Natur. Resour., 25 p.

Bean, T.H.
1903. Landlocked salmon, p. 327-328. In The food and game fishes of New York. N.Y. Forest, Fish Game Comm.

Blair, A.A.
1938. Scales of Lake Ontario salmon indicate a landlocked form. Copeia 1938 (4): 206.

Bonnycastle, Richard H.
1842. The Canadas in 1841. London, 2 vols., I: p. 88; II: p. 52.

Borgeson, David P.
MS 1970. Coho salmon status report, 1967-68. Mich. Dep. Natur. Resour., Fish Manage. Rep. 3, 31 p.

Bower, Spencer.
MS 1937. Summary of land-locked salmon plants in Michigan. Mich. Dep. Conserv., 5 p.

Bowles, B.F.
1872. Landlocked salmon. Proc. Amer. Fish-Cult. Ass. [Trans. Amer. Fish. Soc.] 1: 39-46.

Bullin, Bill
MS 1971. Anadromous fish report, Region II, fall 1970. Mich. Dep. Natur. Resour., 6 p. and append.

Collins, John D.
1885. Propagation of the salmon in the Salmon River, Oswego County, New York. Bull. U.S. Fish Comm. 5: 287-288.

Collins, John J.
1972. Introduction of kokanee salmon (Oncorhynchus nerka) into Lake Huron. J. Fish. Res. Bd. Can. 28 (12): 1857-1871.

Cutting, Richard C.
1966. Atlantic salmon, Salmo salar Linnaeus, p. 27-29. In W. Harry Everhart, Fishes of Maine, 3d ed., Publ. Maine Dep. Inland Fish Game, Augusta.

DeKay, James E.
1842. Fishes, p. 241-242. In Natural history of New York, Part IV, Geol. Surv., Albany.

Dvinin, P.A.
1949. Lake Coho, Oncorhynchus kisutch (Walbaum) Morpha relictus Nova. Doklady Akademii Nauk SSR, 69(5): 695-697. (Transl. from Russian by Fish. Res. Bd. Canada, Transl. Ser. 285.)

Edmunds, M.C.
1874a. Obstructions in the tributaries of Lake Champlain. Rep. U.S. Fish Fish. Comm. (1872-73), p. 622-629.

Edmunds, M.C.
1874b. In Reports of the Special Conferences with American Fish Culturists' Association and State Commissioners of Fisheries. Rep. U.S. Fish Fish. Comm. (1872-73), p. 766.

Follett, Richard
1932. Salmo salar of the St. Lawrence River. Trans. Amer. Fish. Soc. 62: 366-368.

Fox, W. Sherwood
1930. The literature of Salmo salar in Lake Ontario and tributary streams. Trans. Roy. Soc. Can., Sect. 2, Ser. 3, 24: 45-55.

Fukano, K.G., H. Gowing, and M.J. Hansen.
MS 1964. Introduction of exotic fish into Michigan. Mich. Dep. Conserv., Inst. Fish. Res., Rep. 1689, 49 p.

Goode, G. Brown
1881. Epochs in the history of fish culture. Trans. Amer. Fish-Cult. Ass. [Trans. Amer. Fish. Soc.] 10: 34-59.

Goode, George Brown
1884. The salmon--Salmo salar, p. 468-474. In The fisheries and fishery industries of the United States. Section 1, Natural history of useful aquatic animals, U.S. Comm. Fish Fish.

Great Lakes Fishery Commission
MSS 1969 a-e, Minutes, annual lake committee meetings (1968) for Lake Superior (a, 93 p.), Lake Michigan (b, 49 p.), Lake Huron (c, 34 p.), Lake Erie (d, 12 p.), and Lake Ontario (e, 12 p.).

Great Lakes Fishery Commission
MSS 1970 a-e, Minutes, annual lake committee meetings (1969) for Lake Superior (a, 65 p.), Lake Michigan (b, 51 p.), Lake Huron (c, 18 p.), Lake Erie (d, 39 p.), and Lake Ontario (e, 21 p.).

Great Lakes Fishery Commission
MSS 1971 a-e, Minutes, annual lake committee meetings (1970) for Lake Superior (a, 66 p.), Lake Michigan (b, 70 p.), Lake Huron (c, 34 p.), Lake Erie (d, 69 p.), and Lake Ontario (e, 32 p.).

Green, Seth
1874. In Reports of the Special Conferences with American Fish-Culturists' Association and State Commissioners of Fisheries. Rep. U.S. Fish Fish. Comm. (1872-73), p. 766.

Green, Seth
1882. Salmon caught in the Genesee River, New York. Bull. U.S. Fish Comm. 1(1881): 23-24.

Hamlin, A.C.
1874. On the salmon of Maine. Rep. U.S. Fish Fish. Comm. (1872-73), p. 338-356.

Hardy, C.J.
1972. Quinnat salmon investigations - review of investigations of technical field service of the Council of South Island Acclimatisation Societies - February 1969. New Zealand Mar. Dep. Fish., Tech. Rep. 84, 38 p.

Holcomb, Dennis E.
MS 1964. A history of intentional introductions of exotic fishes in Michigan. M. Sci. thesis, Univ. Michigan, Ann Arbor, Mich., 33 p.

Huntsman, A.G.
1931. The Maritime salmon of Canada. Bull. Biol. Bd. Can. 21: 1-99.

Huntsman, A.G.
1944. Why did the Lake Ontario salmon disappear? Trans. Roy. Soc. Can., Sect. 5, Ser. 3, 38: 83-102.

Jamsen, Gale C., J.R. Ryckman, and F.W. Jamsen
MS 1970. Michigan's 1969 salmon and trout sport fishery. Mich. Dep. Natur. Resour., Res. Develop. Rep. 203, 10 p. and append.

Jesuit Relations and Allied Documents
1899a. Trends and explorations of the Jesuit Missionaries of New France (1610-1791). Lower Canada and Iroquois, 1632-57, Vol. 42, p. 71, 73, 79 (1-301). English translation edited by R.G. Thwaites. The Imperial Press, Cleveland, Ohio.

Jesuit Relations and Allied Documents
1899b. Trends and explorations of the Jesuit Missionaries of New France (1610-1791). Lower Canada and Iroquois, 1669-70, Vol. 43, p. 149, 261 (1-326). English translation edited by R.G. Thwaites. The Imperial Press, Cleveland, Ohio.

Jesuit Relations and Allied Documents
1899c. Trends and explorations of the Jesuit Missionaries of New France (1610-1791). Lower

Canada, Iroquois, Ottawa, and Hudson Bay, 1671-72, Vol. 56, p. 49-51 (1-302). English translation edited by R.G. Thwaites. The Imperial Press, Cleveland, Ohio.

Kendall, William Converse
1924. The status of fish culture in our inland public waters and the role of investigations in the maintenance of fish resources. Roosevelt Wild Life Bull. 2(3): 205-351.

King, Louis E., Jr., and Vernon C. Applegate
MS 1969. Report of appearance of salmon in Hammond Bay of Lake Huron and of salmon runs in the Ocqueoc River, Presque Isle County, Michigan - 1969. U.S. Bur. Commer. Fish., Great Lakes Fish. Lab., Admin. Rep., 11 p.

King, W. Ross
1866. The sportsman and naturalist in Canada. P. 245-263, London.

MacKay, H.H.
1956. The spring salmon. Sylva 12(6): 25-33.

MacKay, H.H.
1960. Atlantic salmon. Sylva 16(6): 25-38.

MacKay, H.H.
1963. Fishes of Ontario. Publ. Ont. Dep. Lands Forests, 300 p.

McCrimmon, H.R.
1950. The reintroduction of Atlantic salmon into tributary streams of Lake Ontario. Trans. Amer. Fish. Soc. 78(1948): 128-132.

Mears, Thomas E.
MS 1972. The Alpena Community College chinook salmon Fish. Soc. program. Alpena Community College, Alpena, Mich., 4 p.

Michigan Department of Conservation
MS 1967. Michigan 1966 fish planting record. Unpaged.

Michigan Department of Conservation
MS 1968. Michigan 1967 fish planting record. Unpaged.

Michigan Department of Natural Resources
MS 1969. Michigan 1968 fish planting record. Unpaged.

Michigan Department of Natural Resources
MS 1970. Michigan 1969 fish planting record. Unpaged.

Miller, Barry R., and John A. Scott
MS 1968. Assessment of salmon and steelhead migrations, Huron River, Baraga County, Michigan, fall 1967. Mich. Dep. Natur. Resour., Fish Div., Dist. I Rep., 24 p.

Moore, Harry H., and Robert A. Braem
1965. Distribution of fishes in U.S. streams tributary to Lake Superior. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 516, 61 p.

Ohio State Fish Commission
1878. Report of the Superintendent, p. 71. In 2d Annu. Rep. (1877), Ohio State Fish Comm., 116 p.

Ontario Department of Lands and Forests
1970. Research Review 69. (2d) Annu. Progr. Rev. Res. Br., Dep. Lands Forests (1969), 152 p.

Peck, James W.
1970. Straying and reproduction of coho salmon, Oncorhynchus kisutch, planted in a Lake Superior tributary. Trans. Amer. Fish. Soc. 99(3): 591-595.

Post, Hoyt
1894. Fish culture in Michigan. Bull. U.S. Fish. Comm. (1893) 13: 201-211.

Ricker, W.E.
1938. "Residual" and kokanee salmon in Cultus Lake. J. Fish. Res. Bd. Can. 4(3): 192-218.

Robson, John J.
1878. California salmon in Lake Ontario. Forest and Stream 10: 482.

Schumaker, R.E., and S. Eddy
1960. The appearance of pink salmon, Oncorhynchus gorbusha (Walbaum), in Lake Superior. Trans. Amer. Fish. Soc. 89(4): 371-372.

Schumaker, Robert E., and John G. Hale
1962. Third generation pink salmon, Oncorhynchus gorbusha (Walbaum), in Lake Superior. Trans. Amer. Fish. Soc. 91(4): 421-422.

Scott, W.B.
1967. Freshwater fishes of eastern Canada. 2d ed. Univ. Toronto Press, 137 p.

Smiley, Chas. W.
1884. A statistical review of the production and distribution to public waters of young fish, by the United States Fish Commission, from its organization in 1871 to the close of 1880, p. 825-1035. In Rep. U.S. Comm. Fish Fish. (1881).

Smith, A.J.
1875. In Rep. Comm. Fish Fish. Can. (7th Annu. Rep. Dep. Mar. Fish., 1874), p. 16-17.

Smith, Hugh M.
1892. Report on an investigation of the fisheries of Lake Ontario. Bull. U.S. Fish. Comm. (1890) 10: 195-202.

Smith, Hugh M., and Merwin Marie Snell
1891. Review of the fisheries of the Great Lakes in 1885: The fisheries of Lake Ontario. Rep. U.S. Fish Fish. Comm. (1887), p. 296-328.

Smith, Stanford H.
1972. Factors of ecologic succession in oligotrophic fish communities of the Laurentian Great Lakes. J. Fish. Res. Bd. Can. 29(6): 717-730.

Stauffer, Thomas M.
MS 1971. Production of juvenile rainbow trout and coho salmon in five Lake Superior tributaries, p. 149-156. In Dingell-Johnson Annu. Progr. Reps., July 1, 1970-June 30, 1971, Res. Develop. Div., Mich. Dep. Natur. Resour.

Stokell, G.
1955. Freshwater fishes of New Zealand. Simpson and Williams, Christchurch, 145 p., 42 pl.

Trautman, M.B.
MS 1935a. The attempted introduction of Pacific salmon in Lake Erie waters. Mich. Dep. Conserv. Inst. Fish. Res. Rep. 298, 4 p.

Trautman, M.B.
MS 1935b. The recent capture of a king salmon (Oncorhynchus tshawytscha) in Lake Erie. Mich. Dep. Conserv., Inst. Fish. Res., Rep. 297, 2 p.

U.S. Bureau of Fisheries
1905-1933. Annual Reports for 1904 (1905) to 1932 (1933).

U.S. Fish and Fisheries Commission
1873-1905. Annual reports for 1871-72 (1873) to 1903 (1905).

Warner, Kendall
1966. Landlocked salmon, Salmo salar Linnaeus, p. 31-32. In W. Harry Everhart, Fishes of Maine, 3d ed. Publ. Maine Dep. Inland Fish. Game, Augusta.

Watson, W.C.
1876. The salmon of Lake Champlain and its tributaries. Rep. U.S. Fish Fish. Comm. (1874-75), p. 531-540.

Weaver, David L.
MS 1969. Anadromous fish report, Region II. Mich. Dep. Natur. Resour., 44 p.

Webster, Dwight
1958. Return to Cayuga. N.Y. State Conserv., February-March, p. 29.

Wilmot, Samuel
1869. Report to the Minister of Marine and Fisheries. [1st] Annu. Rep. [Can.] Dep. Mar. Fish. 1868, Append. 6, p. 84-94.

Wilmot, Samuel
1870. Report of S. Wilmot, Esq., on the fish-breeding establishment at Newcastle, Ontario, during the season of 1869. [2d] Annu. Rep. [Can.] Dep. Mar. Fish. 1869, Append. 9, p. 59-65.

Wilmot, Samuel
1871. Report of S. Wilmot, Esq., on the fish-breeding establishment at Newcastle, Ontario, during the season of 1870. [3d] Annu. Rep. [Can.] Dep. Mar. Fish. 1870, Append. 1, p. 271-277.

Wilmot, Samuel
1872. Report of S. Wilmot, Esq., on the fish-breeding establishment at Newcastle, Ontario, during the season of 1871. [4th] Annu. Rep. [Can.] Dep. Mar. Fish. 1871, Append. 1, p. 76-85.

Wilmot, Samuel
1873. Report of S. Wilmot, Esq., on the fish-breeding establishment at Newcastle, Ontario, during the season of 1872. [5th] Annu. Rep. [Can.] Dep. Mar. Fish. 1872, Append. H, p. 96-104.

Wilmot, Samuel
1874. Report of Samuel Wilmot, Esq., on fish culture and transactions of the fish-breeding establishment at Newcastle, Ontario, during the season of 1873. 6th Annu. Rep. [Can.] Dep. Mar. Fish. 1873, Append. H, p. 106-121.

Wilmot, Samuel
1875. Report of Samuel Wilmot, Esq., on the several government fish-breeding establishments in Ontario, Quebec, and New Brunswick, for the season of 1874. Rep. Comm. Fish Fish. Can. [7th Annu. Rep. Dep. Mar. Fish.], p. 178-1?

Wilmot, Samuel
1876. Report of Samuel Wilmot, Esq., in relation to fish culture in Canada for the year 1875. 8th Annu. Rep. Comm. Fish Fish. Can. [Dep. Mar. Fish.], Append. 22, p. 227-242.

Wilmot, Samuel
1877. Report of Samuel Wilmot, Esq., on the several fish-breeding establishments on fish culture in Canada, during the season 1876. Rep. [Can.] Comm. Fish. [Dep. Mar. Fish.], 9th Annu. Rep. Minister Mar. Fish., Suppl. 4, p. 365-371.

Wilmot, Samuel
1878. Report of Samuel Wilmot, Esq., on the several fish-breeding establishments and fish-culture in Canada, during the season of 1877. Rep. [Can.] Comm. Fish. [Dep. Mar. Fish.], 10th Annu. Rep. Minister Mar. Fish., Suppl. 5, p. 3-26.

Wilmot, Samuel
1879. Report of Samuel Wilmot, Esq., on the several fish-breeding establishments and fish culture in

Canada, during the season of 1878. Rep. [Can.] Comm. Fish. [Dep. Mar. Fish.], 11th Annu. Rep. Minister Mar. Fish., Suppl. 4, p. 341-367.

Wilmot, Samuel
1880. Report of Samuel Wilmot, Esq., on the several fish-breeding establishments and fish culture in Canada, during the season of 1879. 12th Annu. Rep. [Can.] Comm. Fish. [Dep. Mar. Fish.], p. 5-21.

Wilmot, Samuel
1881. Ontario salmon. Spec. Rep., Fish. Statements 1880, 11th [sic] Annu. Rep. [Can.] Minister Mar. Fish., Suppl. 2, p. 35-40.

Wilmot, Samuel
1882. Report of Samuel Wilmot, Esq., on fish-breeding operations in the Dominion of Canada during the year 1881, with remarks on the decline of the salmon fisheries, p. 3-47. In Report on fish breeding in the Dominion of Canada, 1881, 14th Annu. Rep., Dep. Mar. Fish. Suppl. 2.

Witcher, W.F., and W.H. Venning
1870. In [2d] Annu. Rep. [Can.] Dep. Mar. Fish. (1869), p. 66-69.

Wright, R. Ramsey
1892. Preliminary report on the fish and fisheries of Ontario. Ont. Game and Fish Comm. Rep., p. 419-476.

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Technical Papers--continued.

31-40. Ten Papers on Oxytetracycline and Fish. 1969. 67 p.
41. Ecology of Juvenile Tarpon and the Effects of Dieldrin on Two Associated Species, by Richard Archer Wade. 1969. 85 p.
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