REVIEW OF FISH SPECIES INTRODUCED INTO THE GREAT LAKES, 1819–1974

Great Lakes Fishery Commission

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REVIEW OF FISH SPECIES INTRODUCED INTO THE GREAT LAKES, 1819-1974[1]

by

LEE EMERY[2]
U.S. Fish and Wildlife Service
Great Lakes Fishery Laboratory
1451 Green Road
Ann Arbor, Michigan 48105

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1451 Green Road
Ann Arbor, Michigan 48 105

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1 Contribution 630, Great Lakes Fishery Laboratory
2 Present address: U.S. Fish and Wildlife Service, Division of Program Operations-

CONTENTS

ABSTRACT

This review is based on an extensive literature search, combined with updated information obtained from biologists, and unpublished reports from private, state, and federal organizations throughout the Great Lakes basin. The chronological review lists 34 species of fishes in 13 families that were introduced into the basin from 1819 to 1974. The Salmonidae and Cyprinidae are best represented, contributing 14 and 5 of the species, respectively. The list is divided into successful and unsuccessful introductions; each species is briefly described and information about its entry into the basin and present status is given. About half of the introductions have been successful (i.e., the fish have reproduced and created viable, self-sustaining populations). Some of the successful introductions were disastrous in terms of damage inflicted on native populations (e.g., the effect of the sea lamprey, *Petromyzon marinus,* on populations of lake trout, *Salvelinus namaycush,* and lake whitefish, *Coregonus clupeaformis),* but others yielded highly favorable results (e.g., the extraordinary sport fisheries created by introductions of coho salmon, *Oncorhynchus kisutch,* and chinook salmon, *Oncorhynchus tshawytscha).*

INTRODUCTION

The Great Lakes are among the largest freshwater lakes in the world. The abundant and diverse shallow- and deep-water habitats in the basin accommodate a wide variety of fish species (Hubbs and Lagler [1970] listed 175). Because the lakes are so young geologically, many ecological niches were available and proved to be exceptionally suitable for some introduced fishes. Although many of the species were also introduced into other waters of the United States (Van Oosten 1957; Gottschalk 1967; Stroud 1975) and North America (Lachner et al. 1970), those previously reported for the Great Lakes were incomplete lists identified by state (Fukano et al. 1964; Holcomb 1964; Latta 1974), or lake (Berst and Spangler 1973; Hartman 1973; Lawrie and Rahrer 1973; Wells and McLain 1973; Crossman and Van Meter 1979), or were identified as being in the basin on the basis of a generalized geographic approach, without regard to chronology of appearance (Bailey and Smith 1981).

I document chronologically the introductions of the 34 species (designated by scientific and common names in Table 1) into the Great Lakes basin and define their current status. The list includes species that were either purposefully or accidentally introduced, or that invaded the basin from another watershed. The list also includes four other species (American eel, Arctic grayling, Atlantic salmon, and chain pickerel) that were present in parts of the basin. These four species were included because considerable efforts were made to expand their

TABLE 1. Chronological list of fishes introduced into the Great Lakes basin,

Common name[a]	Scientific name	Family	Year of first introduction[b]	Success[c]	Lake or drainage[d]
Alewife	*Alosa pseudoharengus*	Clupeidae	1819(?)	Yes	All
Sea lamprey	*Petromyzon marinus*	Petromyzontidae	1829(?)	Yes	All
American eel	*Anguilla rostrata*	Anguillidae	1829(?)	No	-
American shad	*Alosa sapidissima*	Clupeidae	1870	No	-
Arctic char	*Salvelinus alpinus*	Salmonidae	1871	No	-
Atlantic salmon	*Salmo salar*	Salmonidae	1873	No	-
Chinook salmon	*Oncorhynchus tshawytscha*	Salmonidae	1873'	Yes	All
Rainbow trout	Salmo *gairdneri*	Salmonidae	1876	Yes	All
German whitefish	*Coregonus maraena*	Salmonidae	1877	No	-
Goldfish	*Carassius auratus*	Cyprinidae	1878(?)	Yes	All
Striped bass	*Morone saxatilis*	Percichthyidae	1878	No	-
Common carp	*Cyprinus carpio*	Cyprinidae	1879(?)	Yes	All
Brown trout	*Salmo trutta*	Salmonidae	1883	Yes	All
Arctic grayling	*Thymallus arcticus*	Salmonidae	1889	No	-
Cutthroat trout	*Salmo clarki*	Salmonidae	1895	No	-
Tenth	*Tinca tinca*	Cyprinidae	1898	No	
Rainbow smelt	*Osmerus mordax*	Osmeridae	1906'	Yes	All
Chain pickerel	*Esox niger*	Esocidae	1907	No	
Mountain whitefish	*Prosopium williamsoni*	Salmonidae	1920	No	-
Mosquitofish	*Gambusia affinis*	Poeciliidae	1923	Yes	M,E
Bullhead minnow	*Pimephales vigilax*	Cyprinidae	1927(?)	No	-
Redear sunfish	*Lepomis microlophus*	Centrarchidae	1928(?)	Yes	Inland
Masu salmon	*Oncorhynchus masou*	Salmonidae	1929	No	
Orangespotted sunfish	*Lepomis humilis*	Centrarchidae	1929	Yes	E
Coho salmon	*Oncorhynchus kisutch*	Salmonidae	1933(?)[e]	Yes	All
Oriental weatherfish	*Misgurnus anguillicaudatus*	Cobitidae	1939(?)	Yes	H
White catfish	*Ictalurus catus*	Ictaluridae	1939(?)	No	-
Chum salmon	*Oncorhynchus keta*	Salmonidae	1945	No	
Margined madtom	*Noturus insignis*	Ictaluridae	1947(?)[e]	Yes	Inland
Kokanee	*Oncorhynchus nerka*	Salmonidae	1950	Yes	H
White perch	*Morone americana*	Percichthyidae	1950(?)	Yes	O,E,H
Alaska blackfish	*Dallia pectoralis*	Umbridae	1956	No	
Pink salmon	*Oncorhynchus gorbuscha*	Salmonidae	1956	Yes	All
Grass carp	*Ctenopharynogodon idella*	Cyprinidae	1974(?)	No	-

a--Common and scientific names follow Robins (1980) except for the Japanese Masu salmon and the European German whitefish
b--Question marks indicate that the year of introduction is uncertain
c-Now produce self-sustaining populations
d-Michigan (M), Huron (H), Erie (E), and Ontario (0)
e-Later introductions are creditied with establishing the species

limited ranges to additional lakes in the basin. Although considerable effort was made to expand the range of three other native species (lake whitefish, *Coregonus clupeaformis,* walleye, *Stizostedion vitreum vitreum,* and brook trout, *Salvelinus fontinalis),* they are not included in the list because they were naturally present in many areas throughout the basin. Introductions of three hybrids-splake (♀ lake trout *x* ♂ brook trout), tiger muskellunge (♀ muskel-

lunge, *Esox masquinongy* x ♂ northern pike, *Esox lucius),* tiger trout (♀ brown trout x ♂ brook trout)-as well as palomino and golden trout (which are genetic varieties of the rainbow trout) were arbitrarily excluded from the list. Also excluded were miscellaneous introductions (e.g., various species of flounder, piranha and tilapia, and ornamental aquarium fishes) that would be unable to survive because of low winter temperatures or other physiological stressors (Anonymous 1976; Stroud 1976; Bailey and Smith 1981; Ver Duin 1984a).

The impetus for the purposeful introductions of fish into the Great Lakes was created by the decline of commercial food fishes along the Atlantic Coast (e.g., American shad and Atlantic salmon) and the decline of commercial species such as lake whitefish and lake trout in the Great Lakes. In response to these problems, the U.S. Fish Commission was created in 1871, marking the beginning of organized federal investigations into fisheries and fish propagation (Baird 1874; McDonald 189 1).

The introduction of the American shad into the Great Lakes in 1870 marked the beginning of an era of fish culture and development by the U.S. Fish Commission and various fishery agencies of states adjoining the Great Lakes. Their efforts were directed toward the redistribution of endemic fishes and introductions of species from Europe and various regions of North America (Leonard 1979ab).

Many introductions during the 1870s (e.g., American eel, American shad) had little chance of success because environmental, physiological, and ecological factors that limit survival were not adequately considered, and some fish were released into environments that were totally unsuitable for establishing self-sustaining populations. In addition, sentiments began to shift against the introduction of species from other countries. For example, by the late 1890s the introduction of common carp was considered a serious problem, and the importation of fish from foreign countries was severely curtailed between 1900 and 1950 (Radonski et al. 1981). In an attempt to prevent a recurrence of the "common carp mistake," introductions in 1900-50 consisted primarily of transplanted North American species.

Ten fish species were introduced or reintroduced between 1950 and 1974. Five of these (Alaska blackfish, Atlantic salmon, chinook salmon, coho salmon, and kokanee salmon) were introduced to develop sport fisheries, three (pink salmon, grass carp, and the margined madtom) were introduced accidentally, and two (white perch and the orangespotted sunfish) were invaders that extended their ranges naturally from waters outside the basin through man-made canals or other access routes.

Although some of these introductions severely disturbed biological equilibria in the Great Lakes basin, others created spectacular new sport fisheries. Still others, like the pink salmon, are relatively recent additions to the basin and whose ultimate effects are not yet known.

The annotated list that follows is divided into two general categories-successful and unsuccessful introductions. Successful introductions are those that produced offspring that, in turn, sustained a population. The species have been listed chronologically (from earliest to most recent introductions) for each category. The total list contains 34 species divided among 13 families of fishes

introduced between 1819 and 1974 (Table 1); no additional introductions were reported in 1975-84. The Salmonidae and Cyprinidae were best represented, contributing 14 and 5 species, respectively.

SUCCESSFUL INTRODUCTIONS

The 17 species described here were either accidental or purposeful introductions; all have developed small to extremely large self-sustaining populations. Some of these introductions (e.g., that of the sea lamprey) disrupted the ecological community so severely that they depleted certain native fishes (e.g., lake trout and lake whitefish); this depletion, in turn, caused severe economic problems for commercial fisheries dependent on the species and began an era of costly lamprey control and stocking of hatchery-reared yearling lake trout.

Some other introductions (e.g., various salmonids), especially in Lake Michigan, created spectacular new and valuable sport fisheries and helped to control extremely abundant populations of alewives.

ALEWIFE

Alosa pseudoharengus (Wilson). Alewives are known to have colonized Lake Ontario by 1873, when they were first sighted in the lake (Wright 1892, Aron and Smith 1971, Scott and Crossman 1973), but much uncertainty exists as to whether they were first stocked inadvertently with American shad (fry of the two species are difficult to separate) in 1870 by the U.S. Fish Commission (Bean 1884, Miller 1957; Bailey and Smith 1981), or migrated from the Hudson River drainage into the lake through the Erie barge canal system (Smith 1970). A section of the Erie Canal between Lake Ontario (at Oswego, New York) and New York City (Atlantic Ocean) opened in 1819 and is most likely the route used by the fish to enter the lake (Smith 1970, Aron and Smith 1971). Miller (1957) did not rule out the use of the St. Lawrence River as a possible entry route, but it is generally considered unlikely because of the abundance of large piscivores such as Atlantic salmon and lake trout (Aron and Smith 1971). Alewives, like the lamprey, then could not enter other Great Lakes from Lake Ontario until the Erie and Welland canals were completed in 1825 and 1829, respectively. They were first reported in Lake Erie in 193 1 (Dymond 1932) and then spread rapidly into the other lakes (Miller 1957).

Alewife populations expanded rapidly in some lakes because the habitat was suitable and predators were too few to curb their expansion (lake trout were extirpated in all lakes except Superior by the 1960s). In some years, massive die-offs of alewives fouled recreational beaches and clogged municipal and industrial water intakes. Lake Michigan, for example, experienced a major die-off in 1967 (Brown 1968) and summer die-offs have occurred sporadically since 1890 in Lake Ontario (Rathbun 1895; Graham 1956). The alewife has been blamed for excessive competition with, and suppression of coregonines in all the Great Lakes (except Lake Superior), and yellow perch, *Perca flavescens,*

emerald shiners *Notropis atherinoides,* and rainbow smelt in Lake Michigan (Smith 1968a, 1970; Wells and McLain 1973; Wells 1977; Crowder 1980).

The abundance of alewives has fluctuated widely over the years in each lake. Some fishery biologists believe that such fluctuations have been caused by annual differences in spawning success (as related to food supplies and population densities), predation by introduced trout and salmon, or low-temperature stress during particularly harsh winters (Brown 1972, 1984; Colby 1973; Stewart et al. 1981).

In the early 1960s and 1970s, a commercial fishery was centered on alewives for use as fertilizer and animal feeds, but due to the high cost of production, low market value, and unacceptable levels of contaminants in some fish, there was little demand (Ragotzkie 1974). Despite large harvests from some lakes (e.g., about 22,000 metric tons from Lake Michigan in 1977), it appeared that commercial fishing had little effect on populations in the basin (Smith 1968b).

SEA LAMPREY

Petromyzon marinus (Linnaeus). It is not known when the sea lamprey first entered the Great Lakes basin. Before 1900, the sea lamprey was known only from Lake Ontario. Whether lampreys first recorded there in the 1830s (Lark 1973) were native (glacial relicts) or canal immigrants from the Atlantic drainage is not certain (Christie 1973). Sea lampreys are believed to have entered Lake Ontario through the Erie Canal (the same route used by the alewife), which opened to the Atlantic Ocean in 1819 (Aron and Smith 1971). Niagara Falls formed a natural barrier that prevented sea lampreys from migrating up the system from Lake Ontario until the Erie and Welland canals were completed. The Welland Canal is believed to be the main route used by sea lampreys migrating into Lake Erie (Trautman 1957; Lawrie 1970; Aron and Smith 197 1), although they could have entered the lake through the Erie Canal as well, but there is no evidence for or against this hypothesis. It has also been suggested that the sea lamprey might have been accidentally introduced into the Great Lakes (as ammocetes) by bait fisherman (Tibbles 1975), inadvertently with early plantings of elvers, or as adults carried in ballast water of upbound Atlantic Ocean vessels (Lamsa et al. 1980).

Sea lampreys were first reported in Lake Erie in 1921 (Dymond 1922). However, they never became abundant because the water was warm and most spawning tributaries were unsuitable (Applegate and Moffett 1955; Trautman 1957, Hartman 1973). Sea lampreys became common in Lakes Michigan and Huron during the 1930s. By the 1940s, they had seriously depleted populations of lake trout and some other species in lakes Huron and Michigan and eastern Lake Superior (Smith 1968a, 1972; Smith and Tibbles 1980).

After years of extensive research on the life cycle of the sea lamprey (Applegate 1950) and methods of control, the U.S. Fish and Wildlife Service, in the 1950s, tested and found a selective chemical toxicant, 3-trifluoromethyl& nitrophenol (TFM), that kills the stream-dwelling larvae before they transform

and move downstream to the lakes (Moffett 1958; Baldwin 1968). Control of the number of lampreys in the Great Lakes, requires repeated treatments of tributary streams with TFM (Smith and Tibbles 1980). This highly successful toxicant has reduced sea lamprey populations to about 10% of their pretreatment levels in the upper Great Lakes (Crowe 1975).

After 1971 sea lamprey control was extended to Lake Ontario, where the parasite has also seriously reduced fish populations (Christie 1974). Continued use of chemical lampricides and perhaps other control methods - e.g., physical barriers, sterilants, attractants, repellents, and other biological controls-will be required throughout the basin (Smith 1979; Lamsa et al. 1980; Smith and Tibbles 1980).

CHINOOK SALMON

Oncorhynchus tshawytscha (Walbaum). Chinook salmon were first planted in the Great Lakes in 1873 (Parsons 1973) and were the first of several species of Pacific salmon to be stocked in the basin. Various state agencies planted chinook salmon in each of the lakes except Superior. Between 1873 and 1933 many serious attempts were made to establish chinook salmon in the lakes, but all introductions failed.

In 1967 chinook salmon were reintroduced into the basin by the State of Michigan (Parson 1973). The objectives of introducing chinook and coho salmon and other salmonids were (1) to re-establish a multispecies complex that had been several disrupted by man, exotic invasions (e.g., alewife, sea lamprey), and other factors; (2) to use the expanding forage base, especially alewives in Lake Michigan; and (3) to develop a sport fishery (Tody and Tanner 1966; Great Lakes Fishery Commission 1967; Carter 1968).

In 1967-84 millions of chinook salmon were stocked annually. The fish grew well, ate alewives, and provided an important sport fishery in Lakes Michigan and Huron. Although some natural reproduction has been recorded, the sport fishery depended almost entirely on stocking.

RAINBOW TROUT

Salmo gairdneri Richardson. Rainbow trout were first stocked in the Great Lakes in a tributary to Lake Huron in 1876 (Smedley 1938). They were first reported in the lakes in 1895 and 1896, when individual fish were captured on two occasions by commercial fishermen in Lake Superior (Whitaker et al. 1897). It was not long before self-sustaining, resident rainbow trout populations became widely distributed in colder tributaries and inshore waters of Lakes Michigan, Huron, and Superior. Early plantings consisted primarily of progeny of nonmigratory rainbow trout until the late 1890s, when some hatcheries replaced their brood stock with anadromous (steelhead) trout from the West Coast (MacCrimmon and Gots 1972).

In the years after the initial stocking in 1876, millions of rainbow trout were stocked in the Great Lakes. Michigan, in fact, continued stocking rainbow trout

annually after the late 1800s. As an example of the magnitude of the stocking effort, Michigan plantings averaged nearly 2 million fish annually from 1880 to 1961 (Holcomb 1964), and almost 1 million fish annually from 1962 to 198 1.

During the 1960s and 1970s a large steelhead trout sport fishery developed in tributaries to Lakes Superior, Michigan, and Huron. From 1970 to 1983 the estimated sport catch of steelheads (including rainbow trout) in Michigan exceeded 300,000 fish annually (G. Jamsen, Michigan Department of Natural Resources, personal communication). The continuation of quality sport fishing for rainbow trout in the Great Lakes appeared to be dependent on sustained stocking to augment natural reproduction.

GOLDFISH

Carassius auratus (Linnaeus). Specific introductions of goldfish into the basin are unrecorded. Their occurrence could be the result of (1) direct stocking many years ago by the Great Lakes states, (2) the escape of goldfish from private ponds, or (3) the release of aquarium goldfish by persons unknown.

It is also difficult to determine when goldfish were first introduced into North America (McCrimmon 1968; Scott and Crossman 1973). One of the earliest introductions was in 1878, when the U.S. Fish Commission received a shipment (Smith 1924; Hodge and Derham 1926; Quast 1929) for propagation in ponds in Washington, D.C. (Baird 1879, McDonald 1885a, Holcomb 1964). Progeny from these fish were distributed in small numbers to applicants throughout the United States (McDonald 1885b). Great Lakes states were among early applicants who received fish (Jerome 1879), but records are not clear about stocking localities within the states (Hazzard and Eschmeyer 1938).

Goldfish have been reported in each of the Great Lakes, but are primarily in the southern half of the drainage and are most abundant in the shallow western portion of Lake Erie (Hubbs and Lagler 1970; Emery 1976).

Generally, goldfish are of little value in the Great Lakes. However, they hybridize readily with common carp, and the hybrids are marketed commercially with carp.

COMMON CARP

Cyprinus carpio Linnaeus. The introduction of common carp into the basin was most likely the result of an importation of 345 fish from Germany by the U.S. Fish Commission in 1877 (Baird 1879; Gottschalk 1967). Progeny from these fish were distributed in small numbers from ponds in the Baltimore, Maryland, and District of Columbia areas to applicants in Illinois, Indiana, Michigan, New York, and Ohio in 1879 (Baird 1883; McDonald 1884a), and into Ontario, Canada in 1880 (Mackay 1963, McCrimmon 1968).

Common carp were introduced into North America in 1831 by a private citizen for propagation as a food fish (McCrimmon 1968). The first introductions into the Great Lakes basin were usually made into artificial or natural ponds, but in later years stocking was widespread (Whitaker et al. 1897; Hacker 1983).

Stocking was severely reduced in the late 1890s because of growing public disapproval of the species (Davis et al. 1899; McCrimmon 1968; Nelson 1973). Even then, some states continued to plant carp until 1921 (Holcomb 1964). As late as 1850 statutes were passed making destruction of carp a misdemeanor punishable by a fine (Lachner et al. 1970).

Common carp are present in each of the Great Lakes. An average of 1,874 metric tons were harvested annually from Lake Erie in 1914-81 (Baldwin et al. 1979). The commercial fishery could be expanded to other lakes if the demand increased. However, the low market value has made expansion unlikely.

Common carp are aggressive omnivores that uproot plants and roil the water while they feed. These habits frequently deteriorate habitat by increasing turbidity and destroying aquatic vegetation used by fish and waterfowl for food and cover (Berry 1983). The turbid waters are unfavorable for sight-feeding predatory fish, allegedly destroy eggs through siltation, and limit light penetration necessary for photosynthesis. Common carp are prolific in suitable habitats, and as they increase in numbers they compete for food and space with other more desirable fish species (Pflieger 1975; Rosenthal 1980). No extensive sport fishery for carp developed in the Great Lakes. The failure of this species to be accepted as a sport fish or as a food species has cost millions of dollars in eradication efforts over the years. Carp have never attained a favorable reputation in the Great Lakes and remain a costly problem fish throughout the basin.

BROWN TROUT

Salmo trutta Linnaeus. Brown trout (called Von Behr trout [from Germany] and Loch Leven trout [from Scotland] in early planting records) were first planted in the basin in 1883 (Mather 1893). Eggs were sent from Germany to New York (Mather 1886, 1893) and, in turn, forwarded from New York to Federal hatcheries at Northville, Michigan, and Caledonia, New York. Michigan planted brown trout fry in the Pere Marquette River, a tributary to Lake Michigan, in spring 1883 (Clark 1885). During the same year, some of the fry raised at the Calendonia hatchery accidentally escaped into the Genessee River, a tributary to Lake Ontario (Mather 1889).

Eventually, brown trout were stocked by all states bordering the Great Lakes and by Canada (MacCrimmon and Marshall 1968; MacCrimmon et al. 1970). Some states (e.g., Michigan) continued stocking brown trout sporadically after the late 1800s; self-sustaining populations have become widely distributed in suitable tributaries and shoreline waters of the lakes.

In the 1960s and 1970s a sport fishery for brown trout developed in suitable tributaries of all the Great Lakes and along some shorelines of the upper lakes. As with rainbow trout, the maintenance of a quality sport fishery seems to require stocking to augment natural reproduction.

RAINBOW SMELT

Osmerus mordax (Mitchill). It is not known when rainbow smelt first entered the basin. The 1912 stocking of smelt eggs in Crystal Lake, Michigan, which drains

into Lake Michigan, is credited with the establishment of the species in Lake Michigan (rainbow smelt were first reported in Lake Michigan in 1923), and eventually in the other lakes, except Lake Ontario (Van Oosten 1937; Mackay 1963; Scott and Crossman 1973). The origin of smelt in Lake Ontario has been controversial (Greeley 1939, Christie 1973, Scott and Crossman 1973). Hubbs and Lagler (1970) believed that rainbow smelt were endemic to Lake Ontario, and this hypothesis was also favored by Mackay (1963) and Smith (1968a). Scott and Crossman (1973), however, believed that smelt most likely migrated into the lake by way of the extensive canal system in New York (Cayuga Lake to Cross Lake to Seneca River to Oswego River) that was connected to the Atlantic Ocean drainage.

Although the 1912 stocking is credited with establishing smelt in the upper lakes, Michigan stocked smelt eggs in the St. Marys River as early as 1906 with the intention of ultimately providing forage for Atlantic salmon planted earlier by the state (Bower 1909; Creaser 1926). Michigan made additional smelt plantings (as eggs) in the St. Marys River in 1909, 1914, 1916, and 1921, but these introductions were considered failures (Creaser 1926; Van Oosten 1937; Dymond 1944).

Rainbow smelt are now abundant in all the Great Lakes, particularly in Lake Erie where a successful commercial trawl fishery developed in Canadian waters in the 1950s. About 9,096 metric tons of smelt were produced annually from 1960 to 1981 (Baldwin et al. 1979). Relatively large numbers of smelt are also harvested with dipnets during their spawning migration into tributaries and along shorelines of the lakes (Great Lakes Commission 1975).

Although the rainbow smelt is a valuable sport, commercial, and forage fish, it is blamed for excessive competition with, and predation on, young bloaters *(Coregonus hoyi)* and lake herring *(Coregonus artedii)* in the upper lakes (Smith 1970; Anderson and Smith 197 1; Christie 1974)) and for the decline of lake herring in Lake Ontario (Christie 1972, 1973, 1974); it may also have played a role in the extinction of blue pike *(Stizostedion vitreum glaucum)* in Lake Erie (Reiger and Hartman 1973; Ver Duin 1984b).

Despite wide population fluctuations in each of the lakes in the past (Smith 1972), the populations of smelt in each of the lakes later became relatively stable.

MOSQUITOFISH

Gambusia affinis (Baird and Girard). Mosquitofish, natural inhabitants of southern Illinois and Indiana, were first introduced into the Great Lakes drainage in 1923 at Whitman's Pond (Cook County) near Winnetka, Illinois (Krumholz 1944, 1948). They were later widely disseminated throughout the Chicago area (including waters in the drainage area of the Chicago River) for mosquito control. Progeny from the Cook County brood stock were introduced into Michigan, Wisconsin, Ohio, New York, and Ontario in 1941 to control mosquitoes and reduce the malaria hazard (Krumholz 1948). Michigan, for example, introduced the mosquitofish into inland ponds and lakes throughout the lower peninsula from Ann Arbor to the Straits of Mackinaw. Some of the fish are known to have

escaped into the Clinton and Huron Rivers (Lake Erie drainage) in southeastern Michigan, but apparently they never became established (Krumholz 1944). It is uncertain whether any mosquitofish planted in the other states or Ontario escaped into the Great Lakes. The mosquitofish became established in the Great Lakes basin in Cook County, Illinois, and in a few ponds in Washtenaw County, near Ann Arbor, Michigan (Latta 1974). No collections were recorded from the Great Lakes.

Redear Sunfish

Lepomis microlophus (Gunther). The redear sunfish probably entered the Great Lakes drainage in 1928 when Indiana first propagated the species and stocked it in northern lakes and streams of the state (Gerking 1945, 1953). It was later widely introduced into other Great Lakes states, but became established only in inland lakes (Fukano et al. 1964; Latta 1974) within the basin and not in the Great Lakes proper.

Orangespotted Sunfish

Lepomis humilis (Girard). The orangespotted sunfish was first recorded in the basin in 1929 when it was collected in the eastern outlet of Lake St. Marys (Grand Lake), Ohio, a part of the Lake Erie drainage system (Trautman 1957). How it was introduced into Lake St. Marys is uncertain, but by the 1940s it had invaded the Maumee River and other river systems of Lake Erie in Ohio (Trautman 1957). Its range northward is limited to northern Ohio and extreme southeastern Michigan (Hubbs and Lagler 1970; Van Meter and Trautman 1970). The orangespotted sunfish was reported in Lake Erie marshes and other tributary streams in the vicinity of Cleveland, Ohio, in 1975 (White et al. 1975), which represented a significant extension of its range eastward in Ohio and for the basin (Trautman 1981).

Coho Salmon

Oncorhynchus kisutch (Walbaum). There is some uncertainty about when coho salmon were first introduced into the Great Lakes. They may have been stocked inadvertently with early plantings of chinook salmon in 1873. Many references credit the stocking of coho salmon in Lake Erie by the Ohio Division of Conservation in 1933 as the first introduction of the species into the Great Lakes (Slastenenko 1958; Scott 1967; Parsons 1973). From 1933 to 1935, some 3-to 5-pound (6.6-11 kilogram) salmon were recovered from the lake, but the introduction was considered unsuccessful (Scott and Crossman 1973).

In 1966 West Coast coho salmon were reintroduced into the Great Lakes by Michigan and Ohio (Parsons 1973). Those introductions were successful, and millions of coho salmon have been stocked annually since 1966. A highly successful sport fishery developed, particularly in Lake Michigan. The fish grew well and ate alewives as forage. Although some natural reproduction occurred,

the sport fishery and continued presence of the coho salmon have depended primarily on continued stocking in the basin.

ORIENTAL WEATHERFISH

Misgurnus anguillicaudatus (Cantor). The oriental weatherfish, a native of eastem Asia (Sterba 1962, Okada 1966), was brought into Michigan from Kobe, Japan, in 1939 by an aquarium supply house and apparently escaped into the Shiawassee River, Michigan, where it was first discovered in 1958 (Schultz 1960; Latta 1974). The range of the species appeared to be confined to a small section of the headwaters of the Shiawassee River (Schultz 1960). The introduction of oriental weatherfish into the Shiawassee River marked the first successful introduction of any species of the family Cobitidae into the New World (Latta 1974). No attempts were made to eradicate the species from the stream, and presumably it did not spread from the Shiawassee River. Fish collections in 1973 indicated that the population had remained stable (G. Smith, University of Michigan, personal communication). The effect of the oriental weatherfish on native species has not been assessed. Its survival in the basin has remained a curiosity.

MARGINED MADTOM

Noturus insignis (Richardson). The margined madtom was first reported in the basin by Greeley (1928) and Eaton (1928). They found a few individuals in streams and lakes within the Oswego River drainage system, a Lake Ontario drainage. The introduction was apparently accidental and occurred when a Susquehanna stream was diverted into the Oswego drainage. Hubbs and Lagler (1947) listed the margined madtom as present in southern tributaries to Lake Ontario and it is unclear whether they referred to Greeley's listing, or to other tributaries along the southern shore of the lake. Crossman and Van Meter (1979) were unable to find any margined madtoms in surveys of streams along the southern shores of Lake Ontario.

The margined madtom is a native of Atlantic coastal streams (Taylor 1969) and its occurrence in other areas of the country is usually believed to be the result of accidental introductions with plantings of bait or game fish (Rubec and Coad 1974). The margined madtom has been a popular bait fish used by fishermen to catch largemouth *(Micropterus salmoides)* and smallmouth bass *(Micropterus dolomieui).*

Because of its size and habits, and because it is relatively difficult to identify, the margined madtom commands little attention from the public. It was thus not surprising that its presence in the basin went unreported until it was found in 1966 in an isolated inland lake in Michigan's Upper Peninsula (Latta 1974) and in 1979 in an inland site at the extreme eastern part of the Lake Ontario watershed (Crossman and Van Meter 1979). It appears that both reports represented isolated populations; further expansion in the basin seems unlikely.

KOKANEE

Oncorhynchus nerka (Walbaum). The kokanee-a landlocked form of sockeye salmon-was first introduced into the basin in 1950, when New York stocked fingerlings into the headwaters of Lake Ontario tributaries (Parsons 1973). Other Great Lakes states later experimented with kokanees, but did not stock them into the Great Lakes proper (Crossman and Van Meter 1979).

A major program of kokanee introduction was initiated in Lakes Ontario and Huron by the Ontario Ministry of Natural Resources in 1964-72 (Collins 1971; Great Lakes Fishery Commission 1976). About 17 million fish were stocked in the two lakes before the stocking program was terminated in 1972 (Great Lakes Fishery Commission 1976). Initially some fairly large spawning runs (9,000 or more fish) were noted in Lake Huron on Manitoulin Island (Collins 1971) but the number of returning fish declined annually over the years. A small resident population remained in Lake Huron in 1979; small numbers of fish (about 50) were observed entering Manitoulin Island streams to spawn in 1979 (J. Collins, Ontario Department of Natural Resources, personal comunication). It is difficult to estimate how long the small Lake Huron population will continue to exist, much less expand its range.

WHITE PERCH

Morone americana (Gmelin). White perch are believed to have invaded the basin in about 1950, when they apparently gained access to Lake Ontario by way of the Oswego River (Scott and Christie 1963). Their movement into the lake was the result of an expanding Hudson River population that moved through the Mohawk River Valley and the Erie Barge Canal into the lake (Scott and Crossman 1973). White perch were first reported in Lake Ontario in 1952 (Christie 1973, 1974), and by 1960 had become the dominant species in the Bay of Quinte region (Scott 1963; Scott and Christie 1963; Christie 1972, 1973).

It is generally accepted that white perch expanded their range from Lake Ontario into Lake Erie through canals. Both the Welland and the Erie canals provided entry routes, but the Erie Canal was the most likely route just as it was for populations entering Lake Ontario (Radonski 1983). White perch were first collected in Lake Erie in 1953 (Larsen 1954), but were not reported again until 1973. By 1975, however, they had become firmly established in the shallow, warmer western end of the lake (Busch et al. 1977). They have not become as abundant in Lake Erie as in Lake Ontario, possibly because of the greater abundance of piscivorous fish-particularly walleye-in Lake Erie (Busch et al. 1977). Negative impacts on native species, particularly yellow perch, have not been determined (Carline 1983). Some commercial and sports fishermen are worried about the effects an expanding white perch population might have on sport and other commercially important species present in the lakes (Ver Duin 1984c; Shepherd 1985). White perch were captured in 1977 in Canadian waters of Lake St. Clair where they continued to increase over the years (Ontario Ministry of Natural Resources 1983). In 1983, adults were captured in trap nets

set by commercial fishermen in Saginaw Bay, Lake Huron (J. Weber, Michigan Department of Natural Resources, personal communication; Ver Duin 1984c). Continued expansion into the upper Great Lakes is probable, primarily into the shallower, warmer areas of the lakes such as Green Bay and other smaller bays along the shores (the species prefers water that reaches 24°C in summer).

White perch became an important sport and commercial fish in Lakes Erie and Ontario.

PINK SALMON

Oncorhynchus gorbuscha (Walbaum). Pink salmon were first introduced into the Great Lakes in 1956 when the Ontario Department of Lands and Forests released about 21,000 fingerlings into the Current River, a tributary to Lake Superior, and a small number (300-350) near Pie Island in Lake Superior (Nunan 1967; Collins 1975). The introduction was essentially accidental; the fish were not intentionally planted to create a fishery, but were discarded from the Port Arthur Hatchery (Ontario, Canada) into a sewer that emptied into the Current River (Nunan 1967). There has been much unwritten discussion by fishery biologists about this introduction because it was seemingly unauthorized. Apparently the pink salmon were excess hatchery stock (three troughs containing about 7,000 fingerlings each) left over from fish reared for planting in the Hudson Bay area. Although the Hudson Bay introductions failed to produce the intended sport and commercial fishery for the Indians in the area, the Great Lakes introduction was highly successful, and pink salmon became the only self-sustaining species of salmon in the lakes (other than the much more limited and declining kokanee in Lake Huron).

A few prespawning pink salmon taken in Minnesota waters of Lake Superior in 1957 were the first recorded specimens produced by natural reproduction (Schumacher and Eddy 1960; Schumacher and Hale 1962). The species spread throughout Lake Superior and into northern Lake Huron by 1969 and into Lake Michigan by 1973 (Collins 1975; Wagner and Stauffer 1975). Extension of the range into the lower lakes was slow (Parsons 1973). However, by 1979, the range had been expanded to include all of the Great Lakes (Emery 1981).

Pink salmon became most abundant in Lake Superior, where spawning migrations into some streams along Michigan's Upper Peninsula exceeded 10,000 fish in 1979 (Wagner and Stauffer 1982). Pink salmon were noticeably absent in southern portions of Lakes Michigan and Huron. Their expansion into Lakes Erie and Ontario will be watched closely by scientists and sport fishermen (Dermott 1982). Pink salmon were usually not observed in any of the lakes until they entered tributaries to spawn (Honsowetz 1978). Little is known about their behavior in the open lakes.

Pink salmon adapted well to the Great Lakes environment (Kwain and Lawrie 1981). Their normal life span is two years (Gilbert 1914; Anas 1959; Bilton and Ricker 1965; Bailey 1969). Since they were introduced as fingerlings in an even-numbered year (1956), spawning first occurred only in odd-numbered

years (Collins 1975). However, some fish lived to he three years old before they spawned (Wagner and Stauffer 1980). These three-year-olds produced a population that spawned in even-numbered years (Kwain 1978; Kwain and Chappel 1978; Wagner and Stauffer 1980). The development of a strong even-year spawning population of pink salmon in Lake Superior, in conjunction with expanding odd-year spawning populations into the other Great Lakes, could expand the recreational sport fishery for this species (Huggler 1979), and perhaps lead to the development of a commercial fishery in certain areas of the Great Lakes. The pink salmon competes with other introduced and native species for food and space, and it is still too early to determine if their introduction will ultimately be judged favorably or unfavorably. No matter how it is judged, this species has become a firmly established resident of the Great Lakes.

UNSUCCESSFUL INTRODUCTIONS

The 17 species considered unsuccessful are a diverse mixture, most of which were the focus of considerable effort expended toward establishing them in the basin. The American eel, Atlantic salmon, Arctic grayling, and grass carp differ from the others discussed in this section in that they did not, or could not, produce offspring to sustain a population. For example, the American eel reproduces only in the Sargasso Sea and the status of the grass carp in the basin remained undertermined. The Atlantic salmon and Arctic grayling once flourished in parts of the basin but populations did not persist and reintroductions of both species failed.

AMERICAN SHAD

Alosa sapidissima (Wilson). American shad were first introduced into the basin in 1870, when New York (one of 19 states that were involved in fish culture and in restoring depleted fisheries before the U.S. Fish Commission was established in 1871 [Bowen 1970]) planted about 5,000 in the Genessee River, a tributary to Lake Ontario (Baird 1874; Smith 1892; Evermann and Kendall 1902). Other plantings were made in the drainages of lakes Erie and Michigan in 187 1, when Seth Green, New York Fish Commissioner, planted small numbers at Cleveland and Toledo, Ohio, and Chicago, Illinois (Milner 1874a). These fish were part of a larger shipment en route from the East Coast to the Pacific Coast. American shad were planted in Lake Huron in 1873 (Jerome 1875). These early plantings were all experimental and were part of the first efforts by the U.S. Fish Commission to solve the problem of decreasing catches of food fish along the Atlantic Coast and in the Great Lakes (Baird 1874; Milner 1874a).

Nearly 3.5 million American shad were stocked in the Great Lakes in the 1870s and early 1880s (Baird 1874, 1876, 1880, 1884, 1887; Milner 1876, 1880; Anonymous 1883; McDonald 1884b; Smiley 1884). Few were ever recovered (Baird 1874; Milner 1874a; Smith 1892), and stocking in the Great Lakes was discontinued in the early 1880s (Post 1894).

American shad were last reported in Lake Ontario in 1931 (Greeley and Bishop 1931); these fish were probably stragglers moving to the lake from the lower Ottawa River (Dymond 1939; Radforth 1944; Miller 1957; Scott and Crossman 1973).

American Eel

Anguilla rostrata (LeSueur). The natural distribution of the American eel in the basin was limited to Lake Ontario until completion of the Erie Canal in 1825 and the Welland Canal in 1829 (Aron and Smith 1971). Like the sea lamprey, the American eel is believed to have entered the upper lakes through the Welland Canal (Trautman 1981). It is unknown when eels were first reported into Lakes Erie, Huron, and Superior. One of the early migrants was captured in a Lake Erie tributary in 1856 (Trautman 1981). The first eel caught in Lake Michigan (1871) was believed to be from a private planting (Milner 1874b).

The U.S. Fish Commission began stocking eels in Lake Michigan in 1873 (Goode 1882), although private citizens frequently transplanted the eels from Lake Ontario before the Commission began a stocking program. The Michigan Fish Commission was one of the first state agencies to transfer eels to the basin, stocking more than 2 million eels (obtained from the Hudson River, New York) into Michigan ponds, lakes, and streams between 1877 and 1891 (Holcomb 1964). It was also common practice for eels transported aboard vessels upbound from Lake Ontario to be haphazardly released into Lake Erie (Milner 1874b). Live eels kept for food by crew members were thrown overboard when other edible fish species were obtained.

Many plantings were made in the basin before Schmidt (1922) completed his classical life history study on eels. Because little was known about their life history (Wergeland 1880; Jacoby 1882; Benecke 1885), eels were planted everywhere within the basin, including inland lakes and other unfavorable sites. Under these conditions, successful plantings were impossible because the eels were unable to migrate out of the Great Lakes to their spawning grounds in the Atlantic Ocean southwest of Bermuda.

Occasional eels caught in the upper Great Lakes are undoubtedly stray immigrants from Lake Ontario. Eels remained most abundant in Lake Ontario, where they continued to support a commercial fishery (Emery 1976; Baldwin et al. 1979). About 149 metric tons of eels were harvested annually from 1960-1983. In recent years the fishery has been closed to all but foreign markets because of the high levels of contaminants (e.g., mercury, mirex) found in the fish.

Arctic Char

Salvelinus alpinus (Linnaeus). The Arctic char was known by a variety of names in the late 1800s and, depending on the source, was called Swiss lake trout, European charr, saibling, or charr (Michigan State Board of Fish Commissioners 1888). A small shipment of Arctic char from England was stocked in Lake

Ontario near New Castle, Ontario, in 1871 (Goode 1882), and a few char (reported as Swiss lake trout) were stocked by the State of Michigan in an inland lake in 1890 (Michigan State Board of Fish Commissioners 1890). These first two introductions into the basin were apparently failures and no other plantings were reported by the U.S. Fish and Fisheries Commission after 1897 (Ravenal 1898). Introductions of Arctic char into southern Ontario in 1954 (Scott 1957, 1963) and into the Finger Lakes, New York, in 1967 (Martin 1967) were also failures.

ATLANTIC SALMON

Salmo salar Linneaus. The Atlantic salmon was endemic only to Lake Ontario, where populations once flourished (Webster 1982). Between 1867 and 1884, about 5 million fry and fingerlings from native stocks in Ontario were stocked into Lake Ontario by Canada in an attempt to save the populations from extirpation. However, the restoration attempts failed, and Atlantic salmon became extinct in the lake in the 1890s (Parsons 1973).

In 1873 Atlantic salmon were introduced into the four other Great Lakes. Stocks came from landlocked and anadromous forms collected in the New England states. Between 1873 and 1947, stocking of these two forms totaled about 1 million and 1.9 million fish, respectively (Parsons 1973). Few fish were recovered and the introductions were considered failures.

After 1953 New York continued to stock Atlantic salmon in several lakes in the upper reaches of the drainage system of Lake Ontario (Parsons 1973; T. Eckert, New York Department of Environmental Conservation, personal communication). These introductions have supported a small sport fishery in the lakes, but the survivors have not reproduced.

Atlantic salmon were reintroduced into Lakes Superior, Huron, and Michigan in 1972 when Michigan and Wisconsin stocked fish obtained from Quebec (Great Lakes Fishery Commission 1982). A total of 276,000 fish were planted in these lakes in 1972-80 by Michigan, Wisconsin, and Minnesota; however, success (e.g., establishment of a sport fishery or natural reproduction) has been poor or lacking (Great Lakes Fishery Commission, unpublished reports).

GERMAN WHITEFISH

Coregonus maraena (Bloch). The German whitefish (also referred to as the European cisco [whitefish?] or moranke) was obtained from Germany in the late 1800s by the Federal Fish Hatchery at Northville, Michigan, for propagation and stocking in the northeastern states (Baird 1887). The U.S. Fish and Fisheries Commission reported that small numbers of German whitefish (reported as moranke) were stocked in the Great Lakes between 1872 and 1882 (Baird 1887). However, the year of planting and the water into which these first introductions were made were not recorded by the Commission. One of the early introductions was an experimental stocking made by Michigan in inland waters of that state in 1877 (Baird 1879; Jerome 1879). The Michigan stocking was apparently un-

successful and no other introductions into the Great Lakes were recorded (Post 1894; Hubbs and Lagler 1970; Van Oosten 1957).

Striped Bass

Morone saxatilis. Striped bass were first introduced into the basin in 1878 when 140 fish from the Hudson River were stocked into the Genessee River, a tributary to Lake Ontario (Green 1879; Crossman and Van Meter 1979). Only one fish (a "6-pounder" [14.5 kilograms]) was recovered from this introduction (Mather 1881) and no other introductions into the basin have been attempted.

Some Great Lakes states and the U.S. Fish and Wildlife Service evaluated striped bass for reintroduction into the Great Lakes (Parsons 1974), but no plantings were made.

Arctic Grayling

Thymallus arcticus (Pallus). The Arctic grayling was historically present in Michigan drainages of Lakes Superior, Michigan, and Huron (Milner 1874c; Goode 1884, 1903; Jordan and Everman 1896; Hubbs and Lagler 1970). Its rapid decline in the late 1800s (Whitaker 1887; Brice 1897; Vincent 1962) stimulated propagation of the species (Goode 1884; Clark 1886; Baird 1887; Henshall 1898; Bowers 1899). The extermination of grayling is believed to have been the result of overfishing, habitat destruction, adverse effects of logging on eggs, and predation by brook trout, whose range was greatly expanded by Michigan plantings that began in 1879 (DeClaire [1974] stated brook trout plantings began in 1877) (Michigan State Board of Fish Commissioners 1905, Taylor 1954). In 1889 the first grayling from Montana were stocked in Michigan drainages of Lakes Michigan and Huron (Ravenel 1900).

The Michigan Fish Commission continued stocking Montana grayling in Michigan waters intermittently until 1941 (Westerman 1941), but no self-sustaining populations resulted (Creaser and Creaser 1935; Leonard 1939); by the mid-1930s, the grayling was extinct in Michigan and the basin (Scott and Crossman 1973; DeClaire 1974; Latta 1974; Westers and Stauffer 1974).

Attempts to establish the grayling in the Michigan and Ontario drainages of the Great Lakes during the 1950s and 1960s were also failures (Ontario Department of Lands and Forests 1962, 1968; Scott 1963; Fukano et al. 1964; Scott and Crossman 1973). Michigan is considering an experimental reintroduction of Arctic grayling into two streams within the Pictured Rocks National Lakeshore National Park, in the Upper Peninsula, but had not begun efforts in 1985 because a suitable egg source had not been located (D. Reynolds, Michigan Department of Natural Resources, personal communication).

Cutthroat Trout

Salmo clarki Richardson. Michigan was the first state to propagate cutthroat trout, a native Western North American species, and stock it into waters of the

basin. The federal fish hatchery at Leadville, Colorado, began active propagation of the species in 1889 and was primarily responsible for distribution of cutthroat trout to various state fish commissions (McDonald 1893, 1894). The Federal Fish Hatchery at Northville, Michigan, was an early recipient of fish from Leadville, and had 940 cutthroat trout on hand in 189 1 (Worth 1895). In 1892, the Minnesota and Wisconsin Fish Commissions both received small numbers of fish from Leadville (McDonald 1895). Although most cutthroat trout produced went to western states, the Leadville Hatchery also distributed small numbers of fish and eggs to various state fish commissions in the Great Lakes basin until the early 1900s, but whether any of these states, besides Michigan, stocked cutthroat trout in the Great Lakes or in the basin is uncertain.

In 1895 the Michigan Fish Commission began planting cutthroat trout in the south branch of the Pere Marquette River, a tributary to Lake Michigan (Michigan State Board of Fish Commissioners 1897). Michigan continued to stock cutthroat trout in state waters from 1895 to 1940. A total of 105,000 fish were stocked by Michigan, but apparently all introductions failed because no fish were reported caught from waters of the upper Great Lakes basin (Holcomb 1964).

Cutthroat trout may also have been introduced into Canadian waters of Georgian Bay, but the year or years of introduction and the outcome were not reported (McAllister and Crossman 1973).

TENCH

Tinca tinca (Linnaeus). Tenth were accidentally introduced into the basin in 1898 when a freshet caused the escape of a few fish from an artificial lake on the campus of Ohio State University, Columbus, Ohio, into the Olentangy River (Osburn 1901; Baughman 1947). Although the river lies outside the basin, extensive canal systems in Ohio at the time, and frequent flooding, made it possible for tenth to reach the Great Lakes drainage. Tenth were first raised with common carp as a food fish (Benecke 1885; Nicklas 1886) by the U.S. Fish Commission in the 1800s, but in later years were stocked primarily as ornamental fish with golden ide *(Leuciscus* idus) - also called ide or golden orfe - and goldfish (Baird 1879; Ravenel 1900). Many Great Lakes states received small numbers of tenth but their distribution was unclear. Attempts to verify the survival of tenth in Ohio waters were unsuccessful (Baughman 1947) and the introduction was considered a failure.

CHAIN PICKEREL

Esox niger LeSueur. The chain pickerel, a native of eastern Lake Ontario drainages in New York and the eastern seaboard states (Weed 1927), was propagated successfully in the early 1900s as a game fish for stocking in inland waters of northeastern Pennsylvania (Meehan 1906; Kendall 1919). Chain pickerel are often cited as being introduced into New York drainages of Lake Erie (Slastenenko 1958; Hubbs and Lagler 1970; Scott and Crossman 1973). However, these reports may have been a misinterpretation of Greeley's (1929) early survey

work done on the Erie-Niagara watershed, which listed the chain pickerel as a native species.

The most verifiable Great Lakes introduction of the chain pickerel was in 1907, when Pennsylvania stocked chain pickerel fry into Lake Erie at Presque Isle Bay, Erie, Pennsylvania (Hartman 1908). There were no records of recoveries, and the introduction was apparently unsuccessful. Ohio intermittently stocked chain pickerel in isolated lakes, impoundments, and in the upper reaches of small streams in the Lake Erie drainage after 1954 (Trautman 1981), with moderate success, but discontinued the program in 1982.

MOUNTAIN WHITEFISH

Prosopium williamsoni (Girard). The mountain whitefish, a native of western North America, was introduced into Michigan waters in 1920 as part of the propagation of game and food fishes for inland waters (Baird 1922). This was the only Great Lakes stocking recorded, and it apparently failed (Van Oosten 1957).

BULLHEAD MINNOW

Pimephales vigilax (Baird and Girard). The bullhead minnow (range generally restricted to the Mississippi drainage) has been reported twice in the Great Lakes basin. It was first reported in 1927 by Cahn (1927) in the Wisconsin drainage of Lake Michigan, but the authenticity of its identification was questioned (Hubbs and Black 1947). It is uncertain whether the minnow invaded from the West or was released accidentally by bait fishermen. Inasmuch as the Wisconsin collection came from an area of many stream cross-overs, the fish may have entered the Great Lakes basin during a period of high water.

The other report for the Great Lakes basin was made by Hubbs (1930), who reported that the bullhead minnow was collected by Milton Trautman (Ohio State University) in Lake St. Marys (Grand Lake), an Ohio lake within the Lake Erie drainage. Its presence in the lake is believed to have been the result of accidental introductions by bait fishermen (Hubbs and Black 1947). There have been no other reports of this species in the basin and it is believed that all introductions failed.

MASU SALMON

Oncorhynchus masou Brevoort. A few masu salmon (also called cherry salmon) from Japan were stocked in a Michigan tributary of Lake Michigan in 1929 (Westerman 1930; Parsons 1973). No further information about this introduction was reported; apparently there were no survivors (Scott and Christie 1963; Parsons 1973). In 1966 the Ontario Department of Lands and Forests experimentally planted small numbers of masu salmon in a small inland lake near the western boundary of Algonquin Park, Ontario, outside the Great Lakes basin (Christie 1970). Although these fish grew moderately well, the project was terminated and no plantings were made in the Great Lakes basin.

White Catfish

Ictalurus *catus* (Linnaeus). The white catfish, a native of southeastern Atlantic coastal states, was introduced into Lake Erie in about 1939 by a commercial fisherman (Trautman 1981). For a number of years, individual fish escaped from holding pens into the lake, where they were captured until 1953; however, none were reported later, and presumably the species did not become established in the basin (Van Meter and Trautman 1970).

Chum Salmon

Oncorhynchus keta. The chum salmon was introduced into the basin in 1945 (Fukano et al. 1964; Holcomb 1964; Latta 1974). Michigan planted a few of these fish (4 or 185-depending on the source of information) as fingerlings in an inland lake (Deep Lake) in Oakland County, Michigan. There is some question whether these fish were chum salmon or misidentified coho or chinook salmon planted at the same time. No chum salmon were recovered and no other plantings in the basin were reported.

Alaska Blackfish

Dallia pectoralis Bean. The Alaska blackfish was introduced into the basin in 1956 when fish from Alaska were stocked in a few farm ponds in Ontario (Crossman 1968; Scott and Crossman 1973). It is a small fish similar to the central mudminnow *(Umbra limi)* in form and habits. It was hoped that the Alaska blackfish could survive winter oxygen depletions and create a recreational fishery in the shallow ponds, but the attempt failed.

Grass Carp

Ctenophalyngodon idella (Valenciennes). Grass carp were first brought into the United States from Malaysia in 1963 by the U.S. Fish and Wildlife Service for experimental research at Auburn University, Auburn, Alabama, and at the Service's Fish Farming Experimental Station, Stuttgart, Arkansas (Roberts 1973; Guillory and Gasaway 1978). Grass carp were tested for potential use in aquatic weed control. The carp did not prove to be the panacea for aquatic weed control (it does not confine its diet to vegetation), and many states later banned its importation (Courtenay and Robins 1972; Rosenthal 1980; Hacker 1983).

The introduction of grass carp into the Great Lakes region was prohibited by regulations in each of the Great Lakes states and Canada, but in 1975 it was discovered that private citizens in Wisconsin and Michigan had illegally obtained and stocked grass carp in private ponds within the basin in 1974 (Anonymous 1975; Mainville 1975; Michigan Department of Natural Resources 1975). Persons responsible for the introductions cooperated with state officials in eradicating the stocks. However, some ponds allowed direct access to the Great Lakes and state biologists are uncertain if any fish or eggs escaped into connecting

streams or lakes. Despite repeated importations of the species into the basin (Guillory and Gasaway 1978) there was no evidence that any introductions were successful (Bailey and Smith 1981).

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