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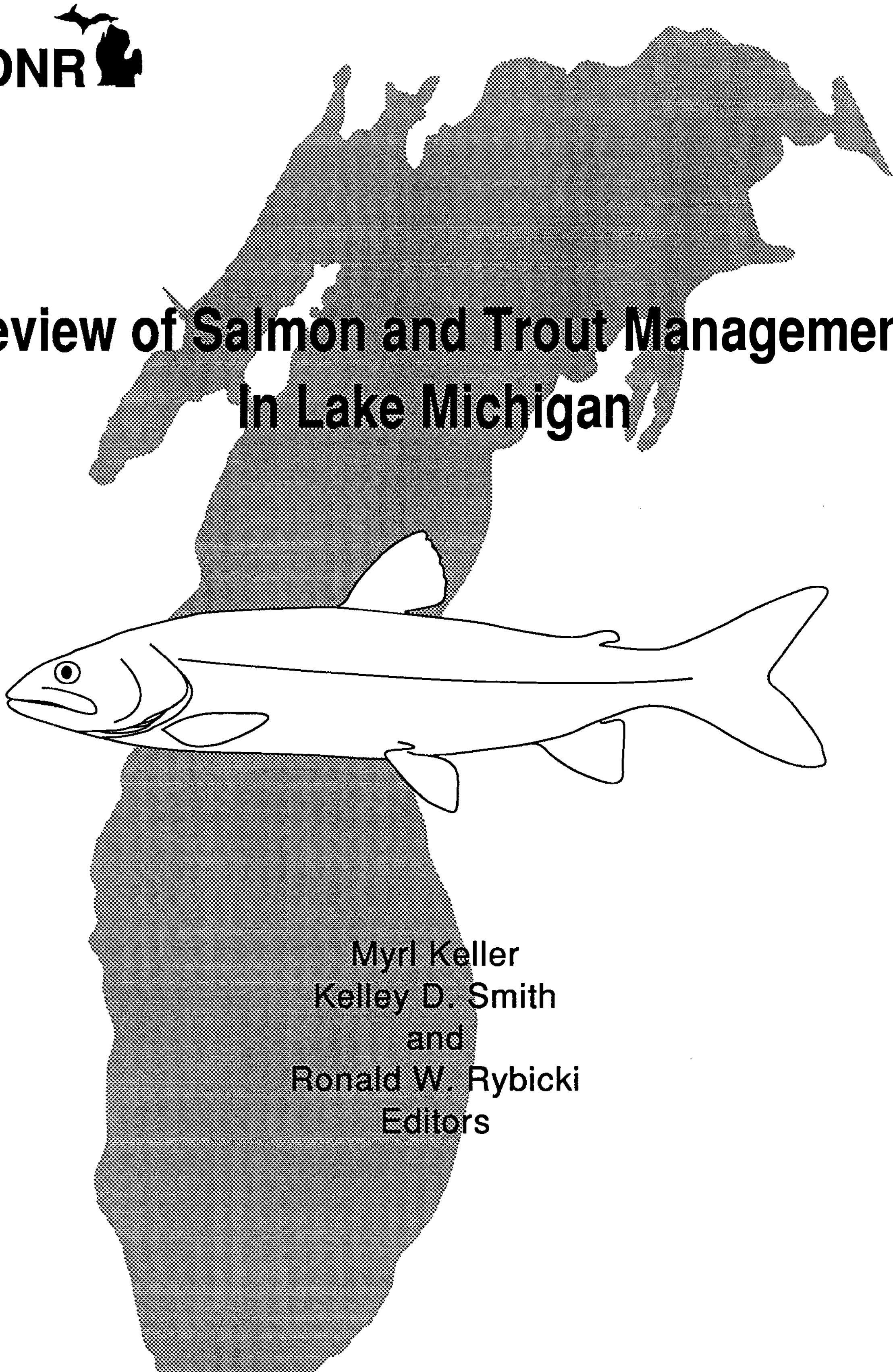
Review of Salmon and Trout Management In Lake Michigan



Myrl Keller
Kelley D. Smith
and
Ronald W. Rybicki
Editors

MICHIGAN DEPARTMENT OF NATURAL RESOURCES
FISHERIES DIVISION

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REVIEW OF SALMON AND TROUT MANAGEMENT IN LAKE MICHIGAN

Myrl Keller
Kelley D. Smith
and
Ronald W. Rybicki

Editors

Michigan Department of Natural Resources
Charlevoix Fisheries Station
Box 205
Charlevoix, Michigan 49720

LAKE MICHIGAN TASK FORCE

Cannon Downriggers
Lou Pomaville

Federation of Fly Fishers
James Schramm

Grand Traverse Bay Sportfishing Association
William Hicks   James Mattis

Great Lakes Fishery Advisory Committee
Alberta Bradford

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James Bedford

U. S. Advisor to the Great Lakes Fish Commission
Paul Wendler

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INTRODUCTION

Myrl Keller and Kelley Smith

The culture and natural environment of Michigan is strongly linked to the Great Lakes. Food fishing, agriculture, and logging were major industries that fostered the settlement of the Great Lakes area. All severely abused what appeared to be the inexhaustible resources of the region. However, through the years, Michigan, as a centerpiece of the Great Lakes region, has become a leader in the drive to protect, utilize, and develop properly its Great Lakes resources.

In 1964, the Michigan Department of Natural Resources (MDNR) made a major policy decision to launch a full-scale program to rehabilitate the fisheries resource of its Great Lakes waters. The successful introductions of Pacific salmon, increased plantings of rainbow (steelhead) and brown trout, controls on commercial fisheries, the Great Lakes Fishery Commission's (GLFC) efforts to control the parasitic sea lamprey, and increased plantings of lake trout by the U. S. Fish and Wildlife Service (USFWS), have improved ecological balances, resulting in the creation of a multimillion dollar sport fishery. These changes have been heralded as one of North America's most outstanding achievements in fishery management. A complex set of biological, political, economic, and social changes has occurred. The large human population (40 million) in or near the Great Lakes region has been the source of many environmental problems but also constitutes a very large recreational demand. This demand led Michigan fishery managers to shift the allocation of fish stocks away from commercial harvest and to maintain healthy salmonid sport fisheries by judicious plantings of hatchery-reared fish.

The MDNR has active fishery research and management programs on the lake. These programs include monitoring sport and commercial catches, marking principal species, stocking predatory species, and studying fish community interactions. The research is aimed at understanding long-term trends in fish population dynamics, thus allowing better management of our fish communities. Much of the work is coordinated through the Great Lakes Fishery Commission in cooperation with the other state, federal, and tribal fishery agencies bordering the lake. The MDNR also supports short-term university research on various phases in the life history of fishes.

The MDNR, along with the other states bordering the Great Lakes, continues to implement progressive fishery management programs. However, the 1987 salmonid sport fishery in Michigan waters of Lake Michigan was atypically poor and has prompted a review of current fisheries programs on Lake Michigan. This review of the fishery has been assigned to a task force consisting of Fisheries Division personnel and representatives from major user groups. The purpose of this report is to provide a data base combining all information available on the Lake Michigan salmonid fisheries. We will develop recommendations for future research and management of the stocks appropriate to maintaining the quality of the fishery.

A list of scientific names for species in this report is found in Appendix A. Appendix B is comprised of four maps. The first details state boundaries in Lake Michigan along with the zone designations used in this report (Appendix B-1). These zones are defined in the context of this report as a Southern zone (all waters south of and including the Montague-Whitehall area in Michigan to Port Washington, Wisconsin), a Northern zone (all waters north of and including Leland, Michigan to Sturgeon Bay, Wisconsin), and a Central zone (all waters between the Southern and Northern zone boundaries). The remaining three maps show hatchery and weir locations (Appendix B-2), creel survey ports (Appendix B-3), and lake trout refuge and treaty commercial waters as defined by the 1985 negotiated settlement (Appendix B-4). Appendix C contains two tables explaining commercial size limits by state and species (Appendix C-1) and gear and quota restrictions by state and species (Appendix C-2). Finally, Appendix D covers sportfishing regulations for lake trout by state (Appendix D-1) and sport regulations on the remaining salmonids by state (Appendix D-2).

The technique used for aging fish in the analyses described throughout the report follows one of two methods. The first describes the age of a fish as determined by the number of years in the stream (before smolting) followed by the number of years in the lake, separated by a decimal point. For example, an age-1.1 coho salmon has had one year of life in its natal stream (or hatchery) and 1 year of life in the lake environment, making the fish 2-years-old. This convention has been adopted by the MDNR in recent years to distinguish between stream and lake life. However, difficulties have arisen in the utilization of this method and it has been, at times, precluded for one reason or another. This aging procedure has been mainly used for chinook and coho salmon and, to some extent, on rainbow (steelhead) and brown trout. Although this age description may not be as important for short lived salmonids (e.g., coho salmon), it becomes very important for a species like rainbow (steelhead) trout which may spend 1 to 3 years in the stream before smolting. To understand both stages of this life cycle is very important in the management of these species. Therefore, in the future, this will be the primary means of representing the age of anadromous salmonids once all the problems in the actual aging process have been solved.

The second type of age description includes the actual number of annuli found on the scale. In this instance, the number of years in stream versus lake life was not determined for any number of reasons. Thus, an age-2 coho (no decimal point) is probably the same as the above age 1.1 fish, assuming that the individual remained in the stream for 1 year as expected.

The rule to remember throughout the report is if the age contains a decimal point, then the number before the decimal represents the number of years spent in the natal stream before smolting while the number after represents the number of years in the lake. If no decimal is present, then the age refers to the number of observable annuli, regardless of the life stage at which it was formed.

Recent studies of scale samples from the Lake Michigan fishery indicate that chinook salmon live to age 0.4 and 0.5. It has also been demonstrated that mature chinook never develop an annulus in their spawning year. This suggests that aging techniques used in the analysis of scales collected from the weirs before 1986 and from the sport fishery creel survey before 1987 may have been incorrect. These earlier aging data are probably biased towards younger fish because of the missing annulus. Thus, the results of analyses pertaining to growth patterns over time for chinook salmon must be interpreted with caution.

Description of Lake Michigan

Lake Michigan ranks sixth in size among the world's freshwater lakes, and is the only Great Lake entirely within the United States. The lake is bounded on the north and east by Michigan, on the west by Wisconsin, and on the south by Illinois and Indiana. The outlet is through the Straits of Mackinac into Lake Huron, with a mean discharge of 55,000 cubic feet per second (Powers and Ayers 1960) and a flushing rate of 99 years. Its surface area is 22,400 square miles and its mean depth is 276 feet. The length of the north-south axis is 307 miles, its east-west maximum width is 118 miles, and the shoreline length is 1,661 miles. The drainage basin, including the lake, covers 67,860 square miles (Beeton and Chandler 1963). The lake's elevation above sea level averages about 579 feet. The northern part of the watershed is forested, the central part is primarily farm-orchard land, and the southern part highly urbanized.

Lake Michigan proper is divided into two rather distinct basins, the southern basin with a relatively smooth, gently sloping bottom and depths to 550 feet, and the northern basin with steep slopes, irregular bottom, and depths to 923 feet. The northern basin has several islands, the most prominent of which are the Beaver group, Fox, and Manitous. Extensive glacial till or lake sediment covers most of the bedrock in the lake basin (Beeton 1969).

The only prominent bays are Green Bay in the northwest and Grand Traverse and Little Traverse bays in the northeast part of the lake. Green Bay is 118 miles long and averages 23 miles in width. It is divided into two sub-bays, Little and Big Bays de Noc. The physicochemical characteristics of Green Bay and the limited exchange of waters with the main lake make the bay almost a separate entity. In general, it is more eutrophic and productive than the rest of the lake (Wells and McLain 1973). Grand Traverse Bay is approximately 30 miles long and has an average width of 12 miles. The southern half is subdivided into the east arm and the west arm by a peninsula which extends northward 18 miles from the base of the bay. A relatively shallow shelf 7 miles wide extends across the mouth, separating the deeper portions (200-600 feet) of Grand Traverse Bay from the basin of Lake Michigan. The total area of the bay has been determined at 263.2 square miles (Lauff 1957).

Lake Michigan's annual water temperature cycle consists of a 5-month warming period from March to August, and a 7-month cooling period. Thermal stratification does not develop until after mid-May and is not stable until late June. The surface water temperatures peak in late July and early August and it is not until January-March that the lake again becomes vertically homothermous. A large portion of Lake Michigan remains ice free in winter, although Green Bay, Grand Traverse Bay, and the extreme northern part of the lake normally freeze over.

Lake Michigan waters are moderately hard. Total alkalinity ($CaCO_3$) is 113 parts per million (ppm) and the concentrations of calcium, magnesium, sodium, and phosphorus are 31.5, 10.4, 3.4, and 0.9 ppm, respectively. Dissolved oxygen content at all depths is near saturation throughout the year (Beeton and Chandler 1963).

The biological characteristics of Lake Michigan, except southern Green Bay, harbors, and areas around river mouths, are generally typical of that in North American oligotrophic lakes. Diatoms are the most abundant phytoplankton. Invertebrate fauna is characterized by such oligotrophic forms as the amphipod *Pontoporeia affinis* and mysid *Mysis relicta* (Beeton 1965; Wells and McLain 1973).

The historical fish fauna of Lake Michigan, which was of great importance in structuring the settlement of the area, was comprised of a wide array of species (Table 1). The lake whitefish, lake herring, and lake trout were most abundant. Many of the coregonines have become rare or extinct, five salmonines from outside the basin have been introduced, and lake trout have been reintroduced after extinction in the mid-1950s.

History of the Lake Michigan Fishery

Man's activities have caused great changes in the lake in the past 130 years. Although changes in both water quality and the lower biota have been generally modest except in local areas, those in fish communities have been vast. Historical (pre-1970) changes in fish community structure were summarized by Smith (1968) and Wells and McLain (1973). Commercial exploitation, invasion by or introduction of marine species, accelerated eutrophication in localized areas, and inadequate management of the resource have been contributing factors in bringing about a decline in abundance of native stocks, in some instances to extinction.

Within the native cold-water fish community, the major piscivores in the open lake were lake trout and burbot. Planktivores included a complex of up to seven species of cisco, two species of whitefish, lake herring, and the emerald shiner. Benthivores were principally lake sturgeon, four species of sculpin, and suckers. Most of these species, which made up a delicately balanced system for thousands of years, had declined in abundance or disappeared entirely by the 1960s.

Commercial exploitation, which began around 1843 in Lake Michigan, was largely responsible for the changes in the fish populations of high value before the introduction of smelt in 1912, the invasion of the parasitic sea lamprey in 1936, and the explosion of alewife in the mid-1950s (Van Oosten 1937; Wells and McLain 1973). Along with overfishing and eutrophication, the appearance of sea lamprey, smelt, and alewife greatly influenced the native stocks through predatory and competitive interactions. By the 1970s, the Lake Michigan fish communities had become dominated by non-endemic species that were either accidentally or purposefully introduced.

Effects of smelt on native stocks have not been well documented, but it is difficult to imagine that an exotic which reached the abundance of smelt in Lake Michigan would not have exerted at least some influence. The sea lamprey almost certainly has had a greater effect than any other invader on Lake Michigan's native species. Smith (1970) believed that the reduction of predatory lake trout and burbot by lamprey allowed the success of another marine exotic, the alewife. The alewife unquestionably has had a detrimental impact on native stocks. The major forces exerted by alewife, which helped restructure the biomass of Lake Michigan, were mainly through competition with juveniles for planktonic food sources and direct predation on eggs and young of the native fishes. However, smelt and particularly alewife have provided a foundation for the successful salmon fishery as the forage required to fuel the large salmonid stocking programs.

The early commercial fishery developed with settlement along the shoreline and grew very rapidly. It was conducted in shallow waters near shore with haul seines, but gill nets, pound nets, and trap nets soon replaced seines and were the principal gears (Koelz 1926). Trawls were introduced from the oceans to Lake Michigan in the late 1950s to harvest chubs and later alewives for animal food and industrial products.

Annual commercial production from Lake Michigan averaged 25 million pounds in 1879-92, 41 million in 1893-1908, 25 million in 1909-65, and 44 million in 1966-86 (Baldwin et al. 1979;

MDNR unpublished commercial fishing records). Annual commercial production from Michigan's waters averaged 8.5 million pounds from 1966 to 1986, which includes the tribal commercial catch since 1980. Catch of individual species has fluctuated much more widely than total production. Whitefish, lake trout, chub, lake herring, lake sturgeon, rainbow smelt, yellow perch, walleye, suckers, and alewife have been important species in the commercial catch.

The lake sturgeon was the first species affected by intensive exploitation. These large fish frequently damaged nets that were being fished for other more valuable species and, as a consequence, were purposely eliminated from the fishing grounds. Recorded commercial catches of sturgeon in the late 1800s exceeded 1 million pounds annually, but by 1900 the species was rare and has not recovered since. The sturgeon's prolonged period of immaturity reduced its chances of escaping nets before spawning age.

The lake whitefish was the backbone of the early fishery. It could easily be taken in large quantities near shore and its white flesh was favored by early immigrants. Catches peaked before the 1900s at 12 million pounds and have since fluctuated widely. A near collapse of whitefish stocks occurred in the mid-1950s, but they have recently increased in abundance due to both effective sea lamprey control and steps taken during the late 1960s by the MDNR to restructure the commercial fishery. Lake-wide production in the 1980s has averaged 4-5 million pounds annually, most of which has been from Michigan waters. Although present whitefish production is above the lake's average, we believe it is being maintained by recent increases in the efficiency and amount of gear (tribal and licensed-state fishermen combined) because some of the historical fishing grounds have not been reestablished with the species. For example, an 80-90% annual total mortality rate has been reported for whitefish in Green Bay during 1984-86 (R. Rybicki, MDNR, personal communication).

In the last decade a sport fishery for whitefish has been established in Grand Traverse Bay to a level that the species predominates in the salmonid catch. The combined open water and ice fishery catches were 90,000 and 54,000 fish in 1985 and 1986, respectively.

The lake trout was the most valuable commercial species in Lake Michigan from the late 1800s until the mid-1940s. Beginning in 1890 the fishery was characterized by exceptional stability for several decades. In the 1890-1911 period, annual production averaged 8.2 million pounds. It dropped to an average of 7.8 million pounds in 1912-26, declined further to an average of 5.3 million pounds in 1927-39, and then increased to an average of 6.6 million pounds in 1940-44. The catch from Michigan waters generally was about half of the lake-wide production. The year 1945 marked the beginning of a precipitous decline that culminated in the annihilation of the species in 1956. We believe that the disappearance of the lake trout in Lake Michigan was a direct result of overfishing and sea lamprey predation.

For over 2 decades, lake trout populations in Lake Michigan have been artificially sustained by large plantings of hatchery-reared fish. This reconstruction has supported a highly successful sport fishery and, more recently, a tribal commercial fishery.

The collapse of the lake herring populations in Lake Michigan in the 1960s has been attributed to overfishing, the influence of smelt, and competitive effects of alewives. Herring production peaked in 1952 at 9.7 million pounds, declined to less than 1 million pounds by 1958, and finally became insignificant in the 1960s. Present day herring stocks in Lake Michigan exist only as traces in a few locations and are believed not to be sufficient in numbers to establish a resurgence of the species.

The seven species of deep-water ciscoes in Lake Michigan have supported a commercial fishery since at least 1869 (Koelz 1926). Although the seven species were morphometrically distinct from one another, they were similar in their choice of deep-water habitat and early fishermen grouped them together as chubs. Peak annual production of chubs was 12 million pounds in 1960-61 even though two of the larger species had by then become extinct from overexploitation (Wells and McLain 1973). Four other intermediate-sized species declined sharply in abundance between 1930-32 and 1960-61. For all practical purposes, six of the seven chubs are now extinct and the remaining species, the bloater, comprises about 75% of the Lake Michigan forage base (R. Argyle, USFWS, personal communication). Reasons for the depletion of the six species and the highly variable abundance of the bloater are complex, although it seems almost certain that overfishing, predation on the larger species by sea lamprey, and competition with alewives are responsible.

Yellow perch have been an important component of both the commercial and sport catches in nearly all shallow areas of Lake Michigan over the years. Peak commercial production was 6.3 million pounds in 1896 and 5.8 million pounds in 1964. Prior to 1966, Michigan waters produced an annual harvest of more than 1 million pounds for almost a decade. An abrupt decline, progressing from north to south, occurred in the mid-1960s and by the late 1960s the only substantial populations were in the extreme southeastern portion of the lake and in parts of Green Bay. This decline appears to have been caused by reproductive failure which, in turn, has been associated with both the build-up of the alewife population (Wells and McLain 1973) and intensive commercial exploitation. The fishery was closed in Michigan in 1970 with the advent of the zone management plan. Yellow perch stocks have since rebounded to near historic levels of abundance in Michigan waters of the main basin and have provided sport catches in excess of 2.9 million fish (870,000 pounds) in 1986 (Rakoczy and Rogers 1987).

The walleye, which has been concentrated mostly in Green Bay, was only moderately abundant until the late 1940s when a couple of successful year classes produced catches in excess of 1 million pounds during 1949-50. Since then it began an abrupt decline and was scarce until recent years. In 1978 the MDNR began annual stockings of 450,000 fingerling walleye in the Bays de Noc that have revived an active sport fishery. Walleye sport fisheries were also developed on the St. Joseph, Muskegon, and Grand rivers through stocking efforts. The walleye sport catch in Lake Michigan in 1986 was 37,000 fish.

The remaining principal species have been generally abundant in recent years. Commercial fishing for burbot, smelt, alewife, suckers, and carp, all of which are considered lower value commercial species, is primarily a function of market demand.

The Lake Michigan commercial catch has been shared by three Michigan tribes of Ottawa/Chippewa Indians since the March 28, 1985 negotiated settlement of the Treaty of 1836. The tribal fishery targets primarily for whitefish, chubs, yellow perch, and lake trout in the northern sector of the lake.

Lake Michigan's past recreational fishery is much more difficult to quantify than its commercial fishery. In the pioneer days, the idea of sportfishing was essentially nonexistent and angling occurred strictly as a means for gathering food. The day was still far distant when fishing would become a national recreation for millions.

Among the earliest references to sportfishing in Lake Michigan were statements by Smith and Snell (1891) that pleasure fishing was carried out by a great many people in the Chicago area in 1885. Yellow perch were caught from piers using hand lines baited with minnows which also were taken from Lake Michigan. Most breakwalls around the lake were often lined with anglers fishing for yellow perch, making it safe to assume that this species was the most important in the early sport fishery.

Other accounts indicate sportfishing for brook trout in streams tributary to Lake Michigan. By 1896, the Pere Marquette River was rated as one of the best trout streams in the United States. Michigan sportsmen, curious as to how western rainbow (steelhead) trout would fare in their favorite streams, were responsible for the first plantings in the late 1800s. The Michigan Fish Commission planted 67,000 fry in Michigan streams during the decade 1880-90. Rainbow (steelhead) trout, which was perceived as a species that would not migrate to any great extent, appeared in Lake Michigan about 1896. By 1898, the species had been permanently established and was becoming very popular as a game fish (Foster 1963). Between 1873 and 1947 many serious attempts were made to establish several species of Pacific salmon and the Atlantic salmon in Lake Michigan, but all of these early introductions failed (Emery 1985).

Brown trout, a native of Germany, was a newcomer to America when it was introduced in Michigan in 1883. Almost 2 million had been planted in streams by 1897 when propagation of the species was stopped because of adverse public opinion. By 1908, when a different species was needed to stock depleted brook trout streams, a new demand for the brown trout arose and they were again planted in 1909. The species later became known as a utility trout, as it was capable of living in waters where the brook and rainbow trout could no longer survive. Browns also migrated out of streams and provided limited sport fisheries around river mouths and shoreline areas.

The walleye also has been a favorite of sport fishermen. The major fishery for this species has been centered in Green Bay where it was harvested in huge numbers in the 1950s. Smallmouth bass have provided a lively sport fishery since at least the 1930s in certain shallow, rocky areas of Grand Traverse Bay, the famous Beaver Island group, and Waugoshance Point of northern Lake Michigan. Smelt are caught throughout the lake but mostly in the north during spring spawning runs. Deep-water trolling for lake trout was popular in Grand Traverse Bay before the collapse of the species in the late 1940s.

Prior to the mid-1960s, the various conservation agencies bordering the lake tended to regard the fisheries resources as more or less indestructible, regardless of exploitation levels. Furthermore, it was generally accepted that the commercial fishery should have the highest priority for utilization of these valuable fish populations. Exploitation of the fishery resource was open to all under an open access policy that failed to incorporate biologically meaningful controls for managing the important stocks. During this period, it was the view of some fishery managers that intensive exploitation had little effect on a population or group of populations (Regier et al. 1969). The catch and destroy management policy was pursued on most stocks until they collapsed. The obituaries of many species have been well documented; a major function for some scientists during this era of abuse.

In 1966, the MDNR broke from tradition and established a Great Lakes fishery policy which made recreational fishery management its primary goal and relegated commercial fishing to a secondary role. The aim of the policy was to manage the fisheries resource for maximum public benefit. The new fishery management initiative began with a series of sweeping changes. First, the commercial harvest of major sport species such as lake trout, walleye, and yellow perch was prohibited. Second, the commercial fishery was regulated by designating fishing areas, depths, and the type and amount of gear used, along with quotas on some species. The commercial fishery, except for the tribal fishery in the north, has been shifted to gear selective for those species unwanted by the sport fishers. Third, the MDNR rejected using low value commercial species (e.g., alewives, smelt, and chubs) as the base for an industrial fishery and aggressively launched a program of converting these species into a high value sport fishery. Finally, the number of state-licensed participants in Michigan's overcapitalized commercial fishery has been gradually reduced from 405 licenses in 1967 to 30 in 1987. However, the tribal commercial fishery in northern waters of Lake Michigan has been expanding for the last decade.

Along with these changes, plans were laid for the introduction of predatory Pacific salmon to make good use of the forage species in Lake Michigan which, at the time, consisted primarily of alewives. Coho salmon were first planted in the spring of 1966 and subsequently provided a most gratifying spawning run of adults in the fall of 1967. Chinook salmon were then introduced in 1967. The success of these plants caused the MDNR to implement plans for new hatchery construction. The subsequent increase in hatchery production has allowed the rejuvenation of salmonid populations to move forward at a rapid pace.

Currently, the salmonids occurring in Lake Michigan are comprised of primarily chinook salmon, coho salmon, lake trout, rainbow (steelhead) trout, brown trout, and, to a lesser degree, Atlantic salmon, brook trout, splake (lake trout x brook trout), and pink salmon. Pinks, which have never been planted in Lake Michigan, are believed to have immigrated from Lake Superior.

Total annual salmonid plantings by the various agencies bordering the lake have averaged about 15 million fish. In the 1980s, the estimated annual salmonid sport harvest from Lake Michigan has approached 2 million fish. This fact alone should make it obvious that the management practices utilized to date and the intensive stocking of salmonids have both been instrumental in creating the most spectacular sport fishery in Lake Michigan's history. However, past successes can fade quickly, and it is now mandatory that we determine where we have been, where we are going, and what knowledge is required to further maintain this quality fishery into the distant future.

Table 1. Historical fish species of Lake Michigan which were important in the early settlement of the region.

* Lake sturgeon	* Kiyi
Lake whitefish	* Shortnose cisco
Round whitefish	* Lake herring
* Blackfin cisco	* Lake trout
* Deepwater cisco	Walleye
* Longjaw cisco	Yellow perch
* Shortjaw cisco	Longnose sucker
Bloater	White sucker

*Presently rare or extinct.

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HATCHERY PRODUCTION AND PLANTING

*Harry Westers, William McClay, Charles Pecor,
Vernon Bennett, and John Driver*

History of the Broodstock

Lake trout.--Historically, lake trout was the major salmonid inhabiting Lake Michigan. It was very abundant and the dominant predator. After the collapse of the self-sustaining lake trout stocks, a multi-lateral effort was started to rehabilitate this species. Mr. Russell Robertson, former Superintendent of the MDNR Marquette Fish Hatchery, had the foresight to start a lake trout broodstock program at that facility (Figure 1). The initial strain of lake trout was obtained in 1948 from commercial fishermen, who gathered wild eggs from fish caught in the Marquette Harbor. They were of a lean variety and were successfully spawned in 1949. From the eggs taken in 1949, domestic broodfish were developed which began producing in 1954-58. In 1956, a strain of lake trout intermediate between leans and fats was taken from the Apostle Islands in Lake Superior. Additional broodstock were obtained from Copper Harbor in 1953 and 1955. In 1960, the lean variety of adult fish was again collected from the Marquette Harbor and used as broodfish.

Most of the Great Lakes rehabilitation stocking efforts have involved fish with a Lake Superior gene pool. The one exception is the Green Lake strain which was obtained from a deep spawning reef in central Lake Michigan and held in Green Lake, Wisconsin. These fish became Marquette Hatchery's 1958 and 1959 year classes.

Canadians used a strain from Clearwater Lake, Manitoba, to plant into the Great Lakes. Five yearly plants of this strain were made into Lake Michigan during the period 1959 to 1975.

Lake trout stocked today come from Marquette's domesticated stocks which have a predominantly Lake Superior gene pool. New stocks, such as the Jenny Lake, Wyoming and the Finger Lake, New York strains are being developed for future assessment.

Rainbow (steelhead) trout.--In 1876, Daniel C. Fitzhugh, Jr., of Bay City, supposedly brought the first rainbow (steelhead) trout into Michigan. They were received as eggs from the McLoud River, a tributary to the Sacramento River, in California. The fry which resulted from those eggs were released into the Au Sable River. In 1878, Frank N. Clark purchased 125 yearling McLoud River rainbow (steelhead) trout and raised them to maturity at the hatchery in Northville, Michigan. He, too, released their progeny as fry into the Au Sable River.

The Michigan Fish Commission first introduced rainbow (steelhead) trout in 1880. The eggs which they brought into Michigan also originated from the McLoud River in California. These were incubated and hatched at the Crystal Springs State Fish Hatchery at Pokagon. The 2,000 eggs produced 1,200 fry, of which one third were stocked into the North Branch of the Paw Paw River and one third into the Boyne River, both tributaries to Lake Michigan. The remaining one third was retained for production of future broodstock.

After these initial introductions, others followed rather rapidly and, by the end of 1890, Michigan had stocked 83,475 California trout. These plants increased to over 1 million in 1908, 2.6 million in 1909, and almost 5.0 million by 1914. Because of the success of these introductions, a program was implemented to collect eggs from fish in the Pine River below Stronach Dam, near Wellston. The rainbow (steelhead) trout was now a permanent member of the Lake Michigan fish community, with millions more planted during the next decade.

One may quite assuredly assume that the progeny of the McLoud or California trout are today's Lake Michigan steelhead. However, it is highly probable that their genetic makeup has been altered significantly through both natural selection and possibly hybridization with other strains of rainbow (steelhead) trout brought into Michigan. One such other strain, the summer steelhead, was released into Lake Michigan in 1975 by the State of Indiana. This fish, the Skamania steelhead from the State of Washington, migrates up river during the summer months. In 1984, Michigan introduced three additional strains of summer steelhead from Washington; the Rouge River, Siletz River, and Umpqua River strains. Since 1984, Michigan has annually received mature Skamania strain spawners from Indiana to continue the summer steelhead program. Nearly all the progeny of these fish are released into tributaries of Lake Michigan.

Chinook salmon.--Chinook salmon were first introduced into Lake Michigan between the years of 1873 and 1880. Michigan planted 13 different streams for 1 to 7 years while Wisconsin planted two streams for 2 years. The total number of chinook fry planted during this period was 842,000 (Parsons 1973). Few survivors were reported from these fry plants and the program was abandoned until the late 1960's.

In 1967, Michigan made the first successful plants of spring fingerling chinook smolts in two streams tributary to Lake Michigan. Wisconsin followed suit with a plant in 1969 and Indiana and Illinois in 1970. The source of the fall chinook eggs for the Michigan plants came from Oregon and Washington states. The first was a Tule strain which migrated up the Columbia River and the second was a Puget Sound strain from Washington's Green River Hatchery. After 3 years of successful plantings of smolts from these West Coast eggs, Michigan became self-sufficient in the collection of chinook eggs and was also able to supply other states with eggs.

After stocking two streams tributary to Lake Michigan for the first 3 years (1967-69), the number of Lake Michigan streams planted was increased to 6 in 1970 and to 14 in 1976. In 1988, 12 Lake Michigan streams were stocked with a total of 2.45 million chinook. The Michigan plants have also been supplemented with fish stocked by Indiana, Illinois, Wisconsin, and an undetermined amount of natural reproduction. The maximum number of chinook planted in Michigan streams tributary to Lake Michigan was 3.35 million in 1983.

The Little Manistee River serves as a broodstock river for chinook salmon. All chinook salmon eggs for Michigan are collected at the weir and egg-take facility located on this river. Chinook egg-takes at the Little Manistee have been as high as 25 million but currently run about 16 million, with 12 million being used for rearing chinook in Michigan.

The rearing of chinook in Michigan's hatcheries has proceeded very well and the fish have responded to the entirely freshwater environment. Chinook growth in the hatcheries is very good, with smolt size of 220 per kg (100 per pound) attained in approximately 6 months. Chinook are usually planted during the month of May.

Coho salmon.--Coho salmon were first planted in Lake Michigan in the spring of 1966. These smolts were produced in Michigan hatcheries from eyed eggs obtained during the fall of 1964 from the Columbia River at the Bonneville Dam, Oregon. The fry were reared until the spring of 1966 when 660,000 smolts were released in two Michigan streams tributary to Lake Michigan. During the fall of 1965, Michigan again received eyed eggs which were obtained from the Cascade River, Oregon and the Toutle River, Washington. Four Lake Michigan streams were planted in 1967 with 1.7 million of these smolts. Wisconsin, Illinois, and Indiana followed suit with coho plants in Lake Michigan in 1968, 1969, and 1970, respectively.

In 1967 and 1968, an Alaskan early run (August) strain of coho was imported into Michigan as eyed eggs. The smolts from these eggs were planted in Thompson Creek and a few other selected Lake Michigan streams in 1969 and 1970. The planting of this strain was continued until 1979 when it was determined the integrity of this strain was lost through inbreeding with the other coho strains in Lake Michigan. Further attempts to maintain this strain were discontinued.

Michigan became self-sufficient in the production of coho eggs in 1967 and was also able to supply other states with eggs after 2 years of successful plantings of smolts reared from West Coast and Alaska eggs. Platte River serves as a broodstock river for the Oregon and Washington strains and Thompson Creek served as a broodstock creek for the Alaskan strain. Platte River Hatchery's egg-take facility has collected all the coho eggs for Michigan and the other states boarding Lake Michigan since 1979, when planting of the Alaskan strain was stopped. Coho egg collections have been as high as 20 million but currently runs about 14 million, with 7 million being used to rear coho in Michigan.

After the initial stocking of the Platte River and Bear Creek in 1966, the number of streams planted increased to 4 in 1967, 10 in 1968, 14 in 1969, and reached a high of 16 in 1970. The number of coho planted reached a maximum in 1979 when 3.6 million were planted. In 1988, four Lake Michigan streams were planted with a total 1.7 million coho. Michigan plants are also supplemented with plants from Indiana, Illinois, Wisconsin, and natural reproduction. Naturally reproduced coho accounted for 9.3% of the coho catch in 1979 (Patriarche 1980).

The rearing of coho salmon in Michigan hatcheries was based on recommendations from West Coast hatcheries. Coho salmon grow well in Michigan and reach smolt size of 35 per kg (16 per pound) in about 18 months. Coho are usually planted during the months of March and April.

Atlantic salmon.--Atlantic salmon were on the preferred species list of the Michigan Fish Commission at the very onset. As early as 1875, Atlantic salmon were stocked into numerous waters, including tributaries to Lake Michigan. These were fry stockings but, because of poor survival and the small number of fish released, this species did not become established.

In 1972, Fisheries Division transported and stocked 20,000 Atlantic salmon smolts of the Cascapedia River strain from Quebec. These were planted in the Boyne River, Charlevoix County, and in the Au Sable River, Iosco County. In addition to these smolts, 500 3-year old fish were obtained from Quebec for use as future broodstock. Moderate numbers of smolts have been released since 1972, but the hatchery program never sustained high production levels due to an inadequate supply of quality eggs. A successfully reproducing population of Atlantic salmon did not develop and eventually the Quebec strain was lost.

In 1973, 10,000 Gullspang Atlantic salmon eggs were imported from Sweden. This landlocked strain grows to a large size. Two-year-old smolts of this strain (3,430 fish) were released into the Boyne River, Charlevoix County. In time, this strain was also lost.

Presently Michigan is embarking on an Atlantic salmon program involving the landlocked Sebago strain from the State of Maine (Grand Lake). Emphasis presently is on the establishment of a broodstock population in Gull lake, Kalamazoo County. The MDNR expects an egg take in the fall of 1988 and hopes to eventually produce 250,000 smolts annually. Once this level of production is achieved, Lake Michigan could once again become the recipient of an Atlantic salmon program, this time of a magnitude sufficiently large to enhance its success.

Rainbow trout (domestic).--Probably no other salmonid has undergone as much selection and domestication as the rainbow trout. Even today, the USFWS lists 57 domesticated and 41 feral strains of this species. For many years, Michigan maintained a captive broodstock and eventually designated it as the Harrietta strain. This was the old standby rainbow trout for Michigan's program. Because of the problems associated with keeping a specific pathogen free broodstock, the MDNR discontinued its own broodstock program for rainbow and brown trout and instead relied on the USFWS for certified eggs. Since 1983, Michigan has received predominantly the Shasta strain, but the McConaughy, White Sulphur, and Eagle Lake strains have also been used to some extent. At this point in time, no specific strain has been selected for use because the MDNR is depending on what is available and it is uncertain which strain is best suited for this State's program. The goal is to return to a broodstock program with strain(s) best suited to Michigan's needs as soon as capital outlay funds are available to rebuild the Oden Hatchery.

Brown trout.--Brown trout were introduced into the state by the Fish Commission in 1883 and a first release took place in a branch of the Pere Marquette River in 1884. These original fish came from Germany. A second shipment of eggs came from Loch Leven, Scotland and were stocked in a tributary to the Tobacco River. The brown trout program had its ups and downs until about 1920 when this species had become a highly important trout for Michigan's stream fishery.

As with rainbow trout, Michigan ultimately developed its own strain. It was also designated as a Harrietta strain (brown trout), named after the hatchery where, through many years of broodstock selection, this unique strain was born. However, it was lost after Michigan discontinued its own broodstock program in 1983. Since that time, the USFWS has provided Michigan with eggs from their Plymouth Rock strain as well as the White Sulphur Springs strain. Other strains have come from Wisconsin (Wisconsin strain), the State of Wyoming (Soda Lake strain), and from the private Plymouth Rock Trout Company in Massachusetts (domesticated Plymouth Rock strain). These strains now dominate Michigan's brown trout management program. At this time no definite selection has been made as to which strain is the most desirable for this State's program.

Characteristics of the Product

Salmonids are cold-water fish, tolerating temperatures down to 32°F and upwards to 70°F. However, the optimum temperature range is from 50°F to 58°F. Under these conditions they show the best performance in growth as well as in health and vitality. Within the optimum temperature range, salmonids can be expected to grow from 0.6 to 1.0 inches per month during their hatchery life, according to the equation:

Growth rate per month (cm) = C x 0.005 cm x 30 days

where C = average temperature in centigrade observed during the 30-day growing period.

Lake trout.--Lake trout are released as yearlings in the spring at about 5.0 inches. These fish are fall spawners, thus the fish spend about 18 months in the hatchery. All Michigan's lake trout are produced at the Marquette Hatchery. Until 1983 the facility was specific pathogen free but, since that time, high mortalities have been experienced in the young fingerlings. Recently these losses have been attributed to epizootic epitheliotropic virus disease (EED). The hatchery will undergo complete disinfection in the spring of 1988 in hopes of ridding the facility of this virus.

Rainbow (steelhead) trout.--Steelhead smolts show the best survival when liberated at 7 to 8 inches in size. In order to reach this length in 1 year, the fish must be reared in relatively warmwater (50°F or greater). This makes Wolf Lake Hatchery the only suitable facility. Steelhead are spring spawners, thus the fish remain in the hatchery only 12 months since they are released in the spring. The Wolf Lake Hatchery has been quite successful in producing a quality smolt, both of the Skamania strain (summer steelhead) and the Michigan strain (winter steelhead). The main disease problem has been recurring bouts with furunculosis (*Aeromonas salmonicida*). A disinfection project is again planned for the spring of 1988, to be followed with a predator-proof barrier (netting). It is assumed that previous attempts to keep furunculosis out failed because of bird predation, in particular blue herons.

Chinook salmon.--Chinook are released as spring fingerlings, 3 inches long. These fish spend only 6 months in the hatchery. They rank among the easiest fish to rear and are produced at Platte River, Wolf Lake, and Thompson hatcheries. Eggs are taken in the fall and usually show a 70% fertilization-eye-up success. Although low by western standards, it is easily compensated for by means of greater egg numbers.

Diseases have not been a problem. Chinook in Michigan hatcheries showed an abnormal mortality between the years of 1980 and 1983. This mortality was characterized by a spinning convulsive behavior just prior to or shortly after starting to feed and was similar to that experienced by coho salmon earlier and attributed to chemical residues. The mortality increased from 7% in 1980 to 20% in 1982, decreased to 8% in 1983, with a normal loss of 2-3% in 1984. All Michigan hatcheries experienced this mortality as did other states rearing chinook salmon from eggs obtained from Michigan. This mortality has not reoccurred and no other problems have developed.

Coho salmon.--Coho, another fall spawner, smolt at about 5 inches as yearlings. They remain in the hatchery for 18 months and are stocked in the spring. All coho are reared at the Platte River Hatchery. Since they remain there for 18 months, the fish are exposed during their hatchery existence to the extremely low (32°F) as well as the high (70°F) temperatures of the Platte River. Such conditions take their toll.

Diseases which have been or are still a problem in coho include furunculosis, bacterial kidney disease (*Renibacterium salmoninarum*), columnaris (*Flexibacter columnaris*), cold-water disease (*Cytophaga psychrophila*), IPN (infectious pancreatic necrosis), and VEN (viral erythrocytic necrosis). In addition to these diseases, coho also show a high incidence of corneal and lens cataracts just prior to smolting which can effect up to 50% of the hatchery population.

Coho salmon experienced an abnormal mortality starting with the fry from the first Michigan egg-take in 1967 and continuing until 1974. The mortalities peaked in 1973 with loses exceeding 20% but, by 1975, mortalities had decreased to less than 2%. The mortality started during the swim-up stage just prior to first feeding and was preceded by erratic spinning behavior. Pesticide poisoning was suspected as being the cause of the mortality. Since 1975 this type of mortality has been less than 1%.

Atlantic salmon.--Atlantic salmon smolts should ideally be 7 to 8 inches long (same as for steelhead). Only at the Wolf Lake Hatchery can this length be attained during the 18 month hatchery existence. This hatchery has had only limited numbers of fish and, unfortunately, Atlantic salmon are very susceptible to furunculosis. Since the bacterial disease is present at the Wolf Lake Hatchery, an effort will be made to eradicate the organisms along with measures to prevent reintroduction. Once the disease is eliminated, the Wolf Lake Hatchery should be an ideal Atlantic salmon smolt production facility.

Rainbow trout (domestic).--Rainbows are produced at Harrietta, Oden, and Thompson hatcheries. The fish are released as 6-inch yearlings in the spring after 18 months of rearing. Few problems, disease or otherwise, have plagued this species within their hatchery life. Dorsal fin erosion is the most common irregularity encountered. Little is known about what triggers it or about the effects it has on survival. It seems to be primarily a concern of aesthetics.

Brown trout.--Brown trout are also reared to yearlings, 6 inches long. This species is produced at Harrietta, Oden, and Thompson hatcheries. No particular problems have been encountered although this species is susceptible to furunculosis. Both the Harrietta and Oden hatcheries are specific disease-free. Thompson has occasional outbreaks of furunculosis but brown trout losses have not been excessive.

Stocking History

The Lake Michigan stocking history covered in this report includes chinook salmon, coho salmon, lake trout (including splake), rainbow trout (including steelhead), brown trout, Atlantic salmon, and brook trout (Tables 1-20). Future discussions of lake trout (or rainbow trout) will, by inference, assume splake (or steelhead) are included.

Data for all tables were obtained from the fish stocking records provided by management personnel in the various states (M. Hansen, Wisconsin Department of Natural Resources (WDNR); M. Conlin, Illinois Department of Conservation (IDC); G. Hudson, Indiana Department of Natural Resources (IDNR)) and from Annual Reports of the Great Lakes Fisheries Commission. The tables provide stocking data for each state and for all states combined in the order: Michigan, Wisconsin, Indiana, Illinois, and all states. All fish were obtained from state hatcheries except lake trout which are primarily from federal hatcheries of the USFWS.

The data are compiled by both period (1966-82 and 1983-87) and by Lake Michigan zone.

1966-82

During the period 1966-82, all jurisdictions stocked 78.8 million fingerling and 103 million yearling salmonids (Tables 5 and 10). Michigan and Wisconsin stocked 70.2 million fingerlings (Tables 1 and 2) and 94.4 million yearlings (Tables 6 and 7), representing 89% and 92% of all fingerlings and yearlings stocked respectively. Michigan waters received the most, 41 million fingerlings (52%) and 63 million yearlings (61%).

Chinook salmon accounted for 52.6 million (67%) of all the fingerlings stocked (Table 5). During the period l967-1982, Michigan stocked 30.2 million fingerlings (Table 1), while Wisconsin stocked 15.7 million (Table 2), representing 57% and 30% of the chinook stocked, respectively. The average annual stocking was 3.3 million fingerlings (1.9 million by Michigan, 1.0 million by Wisconsin, and 0.4 million by all other agencies).

Of the 103 million yearlings stocked lake wide from 1966 to 1982 (Tables 6-10), coho and lake trout (including splake) accounted for 81.3 million (79%), while rainbow and steelhead made up another 13.5 million (13%). During the same period, Michigan waters received 36.2 million coho, 18.7 million lake trout, and 6.5 million rainbow (Table 6), representing 60% of the total number of these yearlings stocked in Lake Michigan. The average annual stocking of coho salmon, lake trout, and rainbow trout by all agencies was 2.5 million [2.1 million (84%) in Michigan waters], 2.3 million [1.1 million (48%) in Michigan waters], and 0.8 million [0.38 million (48%) in Michigan waters], respectively.

The major trends in the number of fish stocked during the period 1966-82 were as follows, chinook increased, coho and lake trout yearlings remained fairly constant, and rainbow yearlings were highly variable (Tables 5 and 10). After initial introductions of chinook (1967-69), a moderate expansion of stocking occurred from 1970-77. However, beginning in 1978, a dramatic increase occurred. During the 5-year period 1973-77, 16.9 million chinook were stocked, compared with 27.3 million stocked in the 5-year period 1978-82, an increase of 61%. The average annual number stocked increased from 3,384,000 to 5,459,000.

1983-87

During the period 1983-87, 46.3 million fingerlings and 32.2 million yearling salmonids were stocked in Lake Michigan (Tables 15 and 20). Michigan and Wisconsin stocked 37.5 million fingerlings and 29.2 million yearlings, representing 81% and 91% of all fingerlings and yearlings stocked, respectively. Wisconsin waters received slightly more fingerlings than Michigan waters [19.9 million (43%) versus 17.5 million (38%)] although Michigan stocked more chinook salmon than Wisconsin (13.4 million versus 12.7 million). The Wisconsin fingerling brown trout program was larger than that of Michigan (3.2 million versus 1.7 million).

Of the 32.1 million yearlings stocked lake wide, coho and lake trout (including splake) again accounted for the majority (21.8 million or 68%), while rainbow and steelhead made up another 6.5 million (20%; Table 20). Michigan waters received the largest number of yearlings at 17 million fish (53%; Table 16). The average annual stocking of yearling coho salmon, lake trout, and rainbow trout by all agencies was 2.26 million [1.7 million (75%) in Michigan waters], 2.09 million (1.0 million (48%) in Michigan waters), and 1.31 million [0.53 million (40%) in Michigan waters], respectively.

When comparing the 5-year period 1978-82 to 1983-87, the trend during the latter period was to stock an average of 11.5% (953,000) more fingerlings annually, but 4.9% (330,000) fewer yearling size fish. The increase in fingerlings reflects an increase in the average annual number of chinook stocked by both Wisconsin (18.7% or 401,000) and Michigan (6.7% or 168,000). The decrease in yearlings is reflected in a lake wide decrease in the average annual number of coho stocked (16.5% or 447,000) and lake trout stocked (9.5% or 220,000) which more than offset an increase in the average annual number of rainbow stocked (35.6% or 343,000).

With the exception of lake trout, these trends reflect management decisions made by Michigan and Wisconsin. Reductions in lake trout occurred primarily in 1984, 1986, and 1987 as a result of reduced availability of fish from federal hatcheries due to reconstruction of the Iron River facility (Wisconsin), and major losses during the rearing cycle caused by disease.

Stocking Plans

In the early 1980s, the MDNR became concerned about perceived declines in the average size of sport caught salmonids and reports of significant changes in the forage base. Empirical evidence suggested that the escalating predator levels, which had occurred over the years in all states' waters, might have been responsible for an apparent negative impact on forage abundance and species composition. As a result of these concerns, Michigan conducted a review of its pre-1985 salmonid stocking program and determined it should reduce its overall stocking effort in Lake Michigan, beginning with the 1985 stocking year.

Michigan biologists estimated forage consumption rates for each size and species of salmonid stocked in terms of a common forage consumption unit called coho equivalents. On average, coho will consume 6.4 pounds of forage fish during a normal life span (D. Jester, Jr., MDNR, personal communication). Using this figure as an index (i.e., it assumes a standardized value of 1.0), all other salmonids can be ranked based upon the amount of forage they consume in a normal life time as compared to coho salmon. This allows adjustments in the stocking levels of various species to be related to forage availability in Lake Michigan. Forage consumption rates were equated as follows:

Species	Coho equivalents
Coho salmon, steelhead, rainbow trout, and brook trout (yearlings).	1.0
Lake trout (fall fingerlings).	1.2
Brown trout and lake trout (yearlings).	1.5
Chinook salmon (spring fingerlings).	2.0

As an example, this table implies that for each chinook salmon planted, two coho must be removed from the target stocking level if it is desired to maintain an overall constant consumption rate (i.e., keep the total withdrawal of forage fish from the lake by predators at some predetermined constant level). Based on this methodology, stocking records for the 5-year period 1980-84 were reviewed and the average number of fish stocked was calculated and expressed in terms of coho equivalents. The average annual stocking for Michigan waters was estimated at 10,775,000 million coho equivalents for this period.

The MDNR set a goal to develop a 5-year stocking program for Lake Michigan (covering the years 1985-90) which would reduce forage consumption rates by 10% (or 1.08 coho equivalents) as compared to the 1980-84 period. The final stocking plan achieved an estimated reduction in the total forage consumption rate of 8.5% (919,000 coho equivalents), representing a decrease from 10.8 million to 9.9 million coho equivalents (Table 21). The plan was implemented at the start of the 1985 stocking year and has been adhered to each year since. Some minor modifications to the plan will be made in 1988 and 1989, but these adjustments will not change the forage consumption rates. The principal change will come in stocking fewer but larger size steelhead, by eliminating the stocking of fall fingerling brown trout, and by slightly increasing the number of yearling brown trout stocked.

During this time, Wisconsin biologists were also hypothesizing that salmon size and condition were declining in Lake Michigan and that forage could be limiting salmon growth (Hansen 1986). Encouraged by the actions of Michigan in 1985, Wisconsin reduced their stocking effort beginning in 1987 by establishing target stocking goals for the same species-age combinations (except for lake trout) as Michigan (M. Hansen, WDNR, personal communication).

An analysis of the Wisconsin stocking data revealed that the target stocking levels (expressed in coho equivalents) for 1987 and beyond were reduced by 8.5% (655,000 coho equivalents) when compared to the averages for the pre-stocking plan period of 1982-86 (Table 21). When considering the Michigan and Wisconsin stocking programs together, both states have established target stocking levels which represent a 8.5% decrease in stocking rates (expressed in coho equivalents) from previous stocking levels.

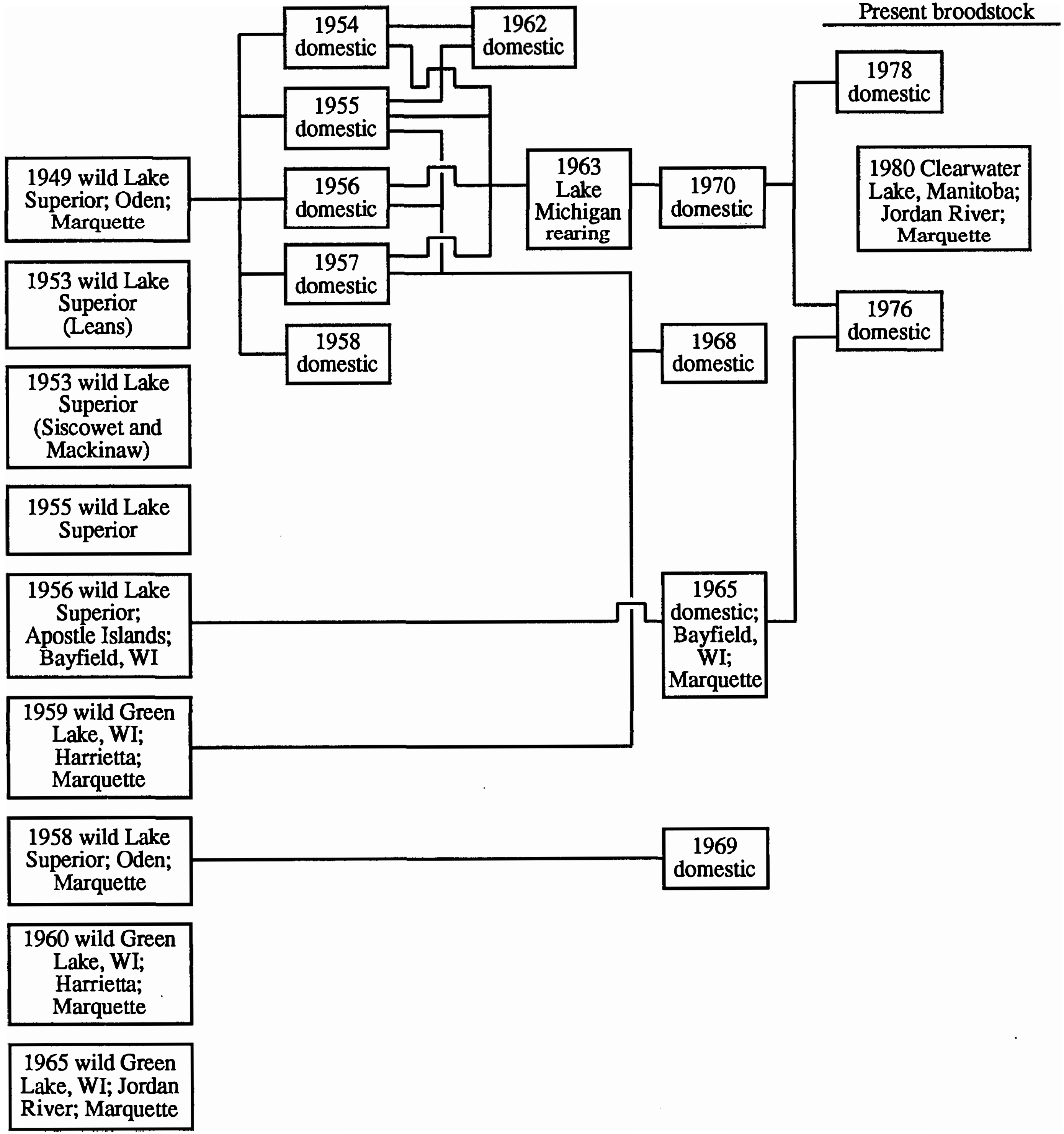
Present broodstock
1954 domestic
1962 domestic
1955 domestic
1978 domestic
1949 wild Lake Superior; Oden; Marquette
1956 domestic
1963 Lake Michigan rearing
1970 domestic
1980 Clearwater Lake, Manitoba; Jordan River; Marquette
1957 domestic
1953 wild Lake Superior (Leans)
1976 domestic
1958 domestic
1968 domestic
1953 wild Lake Superior (Siscowet and Mackinaw)
1955 wild Lake Superior
1956 wild Lake Superior; Apostle Islands; Bayfield, WI
1965 domestic; Bayfield, WI; Marquette
1959 wild Green Lake, WI; Harrietta; Marquette
1958 wild Lake Superior; Oden; Marquette
1969 domestic
1960 wild Green Lake, WI; Harrietta; Marquette
1965 wild Green Lake, WI; Jordan River; Marquette

Figure 1. Historical origin and development of the Marquette lake trout broodstock.

Table 1. Number of salmonid fingerlings (thousands) stocked during the period 1966 to 1982 in Michigan waters of Lake Michigan.

Year	Brook trout	Brown trout	Chinook salmon	Coho salmon	Lake trout (splake)	Rainbow trout (steelhead)	Total
1966	0	0	0	0	0	50	50
1967	0	0	802	0	0	30	832
1968	0	0	687	0	0	0	687
1969	0	0	652	0	0	0	652
1970	0	0	1,674	0	0	322	1,996
1971	0	479	1,764	0	0	644	2,887
1972	0	0	1,691	0	0	126	1,817
1973	0	753	2,115	0	0	1,264	4,132
1974	0	75	2,046	0	0	1,125	3,246
1975	0	0	2,812	0	0	486	3,298
1976	61	211	1,947	208	0	0	2,427
1977	0	0	1,458	0	0	0	1,458
1978	0	75	2,523	0	0	896	3,494
1979	0	151	2,307	394	59	851	3,762
1980	3	105	2,903	0	127	920	4,058
1981	0	0	2,255	0	116	110	2,481
1982	0	306	2,584	0	334	685	3,909
Total	64	2,155	30,220	602	636	7,509	41,186

Table 2. Number of salmonid fingerlings (thousands) stocked during the period 1966 to 1982 in Wisconsin waters of Lake Michigan.

Year	Brook trout	Brown trout	Chinook salmon	Coho salmon	Lake trout (splake)	Rainbow trout (steelhead)	Total
1966	0	16	0	0	0	31	47
1967	0	13	0	0	285	44	342
1968	0	172	0	0	0	0	172
1969	0	47	66	0	0	22	135
1970	0	93	119	0	0	40	252
1971	0	45	264	0	0	40	349
1972	10	723	317	0	204	338	1,592
1973	0	340	757	313	200	305	1,915
1974	4	293	616	0	125	137	1,175
1975	0	52	825	60	100	205	1,242
1976	0	177	1,176	145	0	393	1,891
1977	525	362	873	0	48	138	1,946
1978	30	792	2,017	0	65	349	3,253
1979	0	449	2,063	0	61	604	3,177
1980	0	508	2,429	75	142	539	3,693
1981	89	455	1,849	0	314	574	3,281
1982	193	1,198	2,345	0	275	582	4,593
Total	851	5,735	15,716	593	1,819	4,341	29,055

Table 3. Number of salmonid fingerlings (thousands) stocked during the period 1966 to 1982 in Indiana waters of Lake Michigan.

Year	Brook trout	Brown trout	Chinook salmon	Coho salmon	Lake trout (splake)	Rainbow trout (steelhead)	Total
1966	0	0	0	0	0	0	0
1967	0	0	0	0	0	0	0
1968	0	0	0	0	0	0	0
1969	0	0	0	0	0	0	0
1970	0	0	100	0	0	0	100
1971	0	0	180	0	0	0	180
1972	0	0	107	0	0	0	107
1973	0	0	0	0	0	0	0
1974	0	0	159	0	0	0	159
1975	0	20	156	0	0	0	176
1976	0	0	38	0	0	0	38
1977	0	0	141	0	0	0	141
1978	0	0	213	0	0	0	213
1979	0	69	531	118	0	114	832
1980	0	116	621	169	0	70	976
1981	0	58	263	101	48	98	568
1982	0	0	313	160	63	116	652
Total	0	263	2,822	548	111	398	4,142

Table 4. Number of salmonid fingerlings (thousands) stocked during the period 1966 to 1982 in Illinois waters of Lake Michigan.

Year	Brook trout	Brown trout	Chinook salmon	Coho salmon	Lake trout (splake)	Rainbow trout (steelhead)	Total
1966	0	0	0	0	0	0	0
1967	0	0	0	0	0	0	0
1968	0	0	0	0	0	0	0
1969	0	0	0	0	0	0	0
1970	0	0	10	0	0	0	10
1971	0	0	8	0	0	0	8
1972	0	0	24	0	0	0	24
1973	0	0	174	0	0	0	174
1974	0	0	757	0	0	0	757
1975	0	0	381	0	0	0	381
1976	0	0	142	0	0	0	142
1977	0	0	347	0	0	0	347
1978	0	0	611	0	0	39	650
1979	0	0	183	0	0	15	198
1980	0	24	152	0	0	91	267
1981	0	65	339	0	49	73	526
1982	0	18	793	85	52	27	975
Total	0	107	3,921	85	101	245	4,459

Table 5. Number of salmonid fingerlings (thousands) stocked during the period 1966 to 1982 in all waters of Lake Michigan.

Year	Brook trout	Brown trout	Chinook salmon	Coho salmon	Lake trout (splake)	Rainbow trout (steelhead)	Total
1966	0	16	0	0	0	81	97
1967	0	13	802	0	285	74	1,174
1968	0	172	687	0	0	0	859
1969	0	47	718	0	0	22	787
1970	0	93	1,903	0	0	362	2,358
1971	0	524	2,216	0	0	684	3,424
1972	10	723	2,139	0	204	464	3,540
1973	0	1,093	3,046	313	200	1,569	6,221
1974	4	368	3,578	0	125	1,262	5,337
1975	0	72	4,174	60	100	691	5,097
1976	61	388	3,303	353	0	393	4,498
1977	525	362	2,819	0	48	138	3,892
1978	30	867	5,364	0	65	1,284	7,610
1979	0	669	5,084	512	120	1,584	7,969
1980	3	753	6,105	244	269	1,620	8,994
1981	89	578	4,706	101	527	855	6,856
1982	193	1,522	6,035	245	724	1,410	10,129
Total	915	8,260	52,679	1,828	2,667	12,493	78,842

Table 6. Number of salmonid yearlings (thousands) stocked during the period 1966 to 1982 in Michigan waters of Lake Michigan.

Year	Atlantic salmon	Brook trout	Brown trout	Coho salmon	Lake trout (splake)	Rainbow trout (steelhead)	Total
1966	0	49	0	660	956	167	1,832
1967	0	24	15	1,732	1,118	0	2,889
1968	0	24	0	1,159	855	286	2,324
1969	0	0	0	3,054	876	263	4,193
1970	0	32	25	3,156	875	191	4,279
1971	0	24	14	2,405	1,195	538	4,176
1972	10	35	114	2,270	1,422	571	4,422
1973	15	0	382	2,003	1,204	1,190	4,794
1974	22	0	221	2,788	1,070	547	4,648
1975	19	0	115	1,930	1,126	215	3,405
1976	20	0	239	2,061	1,254	593	4,167
1977	19	0	206	2,314	1,057	305	3,901
1978	46	0	75	1,802	1,253	254	3,430
1979	0	0	38	3,273	1,117	130	4,558
1980	0	0	0	2,243	1,248	390	3,881
1981	20	8	32	1,707	1,118	447	3,332
1982	45	0	0	1,645	971	381	3,042
Total	216	196	1,476	36,202	18,715	6,468	63,273

Table 7. Number of salmonid yearlings (thousands) stocked during the period 1966 to 1982 in Wisconsin waters of Lake Michigan.

Year	Atlantic salmon	Brook trout	Brown trout	Coho salmon	Lake trout (splake)	Rainbow trout (steelhead)	Total
1966	0	0	22	0	761	28	811
1967	0	9	36	0	845	40	930
1968	0	25	79	25	817	104	1,050
1969	0	34	84	175	884	147	1,324
1970	0	18	90	332	900	103	1,443
1971	0	69	163	265	945	128	1,570
1972	0	60	89	258	1,080	280	1,767
1973	0	50	217	257	970	356	1,850
1974	0	30	142	318	846	358	1,694
1975	0	61	310	392	954	303	2,020
1976	0	19	121	522	1,045	618	2,325
1977	0	98	436	492	922	534	2,482
1978	0	213	436	500	929	268	2,346
1979	0	185	505	320	972	529	2,511
1980	0	186	555	417	1,114	628	2,900
1981	0	111	559	318	649	392	2,029
1982	0	51	643	216	747	462	2,119
Total	0	1,219	4,487	4,807	15,380	5,278	31,171

Table 8. Number of salmonid yearlings (thousands) stocked during the period 1966 to 1982 in Indiana waters of Lake Michigan.

Year	Atlantic salmon	Brook trout	Brown trout	Coho salmon	Lake trout (splake)	Rainbow trout (steelhead)	Total
1966	0	0	0	0	0	0	0
1967	0	0	0	0	87	0	87
1968	0	0	0	0	100	0	100
1969	0	0	0	0	119	0	119
1970	0	0	0	48	85	0	133
1971	0	0	0	68	103	0	171
1972	0	0	0	96	110	0	206
1973	0	0	0	0	105	0	105
1974	0	0	0	125	180	0	305
1975	0	0	0	46	186	217	449
1976	0	0	199	179	164	217	759
1977	0	0	109	102	177	48	436
1978	0	0	131	105	175	130	541
1979	0	0	0	0	176	68	244
1980	0	0	0	0	174	0	174
1981	0	0	0	0	124	132	256
1982	0	0	0	0	152	131	283
Total	0	0	439	769	2,217	943	4,368

Table 9. Number of salmonid yearlings (thousands) stocked during the period 1966 to 1982 in Illinois waters of Lake Michigan.

Year	Atlantic salmon	Brook trout	Brown trout	Coho salmon	Lake trout (splake)	Rainbow trout (steelhead)	Total
1966	0	0	0	0	0	0	0
1967	0	0	0	0	90	0	90
1968	0	0	0	0	104	0	104
1969	0	0	0	9	121	0	130
1970	0	0	0	0	100	0	100
1971	0	0	0	5	100	0	105
1972	0	0	0	0	110	0	110
1973	0	0	0	5	105	0	110
1974	0	0	0	0	176	0	176
1975	0	0	0	0	186	0	186
1976	0	6	94	80	160	45	385
1977	0	0	42	103	166	276	587
1978	0	5	13	279	116	0	413
1979	0	8	1	289	162	200	660
1980	0	19	0	39	87	22	167
1981	0	0	0	324	124	113	561
1982	0	0	0	73	151	142	366
Total	0	38	150	1,286	2,058	798	4,250

Table 10. Number of salmonid yearlings (thousands) stocked during the period 1966 to 1982 in all waters of Lake Michigan.

Year	Atlantic salmon	Brook trout	Brown trout	Coho salmon	Lake trout (splake)	Rainbow trout (steelhead)	Total
1966	0	49	22	660	1,717	195	2,643
1967	0	33	51	1,732	2,140	40	3,996
1968	0	49	79	1,184	1,876	390	3,578
1969	0	34	84	3,238	2,000	410	5,766
1970	0	50	115	3,536	1,960	294	5,955
1971	0	93	177	2,743	2,343	666	6,022
1972	10	95	203	2,624	2,722	851	6,505
1973	15	50	599	2,265	2,384	1,546	6,859
1974	22	30	363	3,231	2,272	905	6,823
1975	19	61	425	2,368	2,452	735	6,060
1976	20	25	653	2,842	2,623	1,473	7,636
1977	19	98	793	3,011	2,322	1,163	7,406
1978	46	218	655	2,686	2,473	652	6,730
1979	0	193	544	3,882	2,427	927	7,973
1980	0	205	555	2,699	2,623	1,040	7,122
1981	20	119	591	2,349	2,015	1,084	6,178
1982	45	51	643	1,934	2,021	1,116	5,810
Total	216	1,453	6,552	42,984	38,370	13,487	103,062

Table 11. Number of salmonid fingerlings (thousands) stocked during the period 1983 to 1987 in Michigan waters of Lake Michigan by zone.

Year	Brook trout	Brown trout	Chinook salmon	Coho salmon	Lake trout (splake)	Rainbow trout (steelhead)	Total
Southern							
1983	0	153	1,318	0	0	259	1,730
1984	0	88	1,450	0	90	762	2,390
1985	0	28	832	0	510	260	1,630
1986	0	28	857	0	218	0	1,103
1987	0	19	910	0	0	4	933
Total	0	316	5,367	0	818	1,285	7,786
Central							
1983	0	80	1,187	0	0	0	1,267
1984	0	51	1,231	0	44	0	1,326
1985	0	50	857	0	0	0	907
1986	0	50	845	0	59	0	954
1987	0	28	824	0	0	5	857
Total	0	259	4,944	0	103	5	5,311
Northern							
1983	0	213	470	0	0	0	683
1984	0	200	670	0	60	20	950
1985	0	289	569	0	0	60	918
1986	0	256	700	0	0	0	956
1987	0	191	695	0	0	72	958
Total	0	1,149	3,104	0	60	152	4,465
Lake wide							
1983	0	446	2,975	0	0	259	3,680
1984	0	339	3,351	0	194	782	4,666
1985	0	367	2,258	0	510	320	3,455
1986	0	334	2,402	0	277	0	3,013
1987	0	238	2,429	0	0	81	2,748
Total	0	1,724	13,415	0	981	1,442	17,562

Table 12. Number of salmonid fingerlings (thousands) stocked during the period 1983 to 1987 in Wisconsin waters of Lake Michigan by zone.

Year	Brook trout	Brown trout	Chinook salmon	Coho salmon	Lake trout (splake)	Rainbow trout (steelhead)	Total
Southern							
1983	20	322	672	0	0	465	1,479
1984	9	155	749	0	216	201	1,330
1985	22	115	736	0	453	0	1,326
1986	14	72	300	0	0	29	415
1987	32	72	357	0	0	0	461
Total	97	736	2,814	0	669	695	5,011
Central							
1983	152	328	960	0	0	336	1,776
1984	67	367	1,324	133	0	312	2,203
1985	154	284	1,157	0	0	0	1,595
1986	12	128	1,050	113	267	35	1,605
1987	0	180	990	126	0	0	1,296
Total	385	1,287	5,481	372	267	683	8,475
Northern							
1983	38	410	801	0	31	258	1,538
1984	9	200	819	150	14	140	1,332
1985	0	232	848	0	35	0	1,115
1986	0	134	1,028	0	172	0	1,334
1987	6	233	917	0	0	0	1,156
Total	53	1,209	4,413	150	252	398	6,475
Lake wide							
1983	210	1,060	2,433	0	31	1,059	4,793
1984	85	722	2,892	283	230	653	4,865
1985	176	631	2,741	0	488	0	4,036
1986	26	334	2,378	113	439	64	3,354
1987	38	485	2,264	126	0	0	2,913
Total	535	3,232	12,708	522	1,188	1,776	19,961

Table 13. Number of salmonid fingerlings (thousands) stocked during the period 1983 to 1987 in Indiana waters of Lake Michigan by zone.

Year	Brook trout	Brown trout	Chinook salmon	Coho salmon	Lake trout (splake)	Rainbow trout (steelhead)	Total
Southern							
1983	0	0	238	128	0	291	657
1984	0	0	928	156	36	147	1,267
1985	0	0	762	156	0	280	1,198
1986	0	0	698	133	0	319	1,150
1987	0	0	569	165	0	209	943
Total	0	0	3,195	738	36	1,246	5,215

Table 14. Number of salmonid fingerlings (thousands) stocked during the period 1983 to 1987 in Illinois waters of Lake Michigan by zone.

Year	Brook trout	Brown trout	Chinook salmon	Coho salmon	Lake trout (splake)	Rainbow trout (steelhead)	Total
Southern							
1983	0	51	534	0	0	0	585
1984	0	88	538	0	0	165	791
1985	0	115	195	0	194	146	650
1986	0	59	215	0	202	152	628
1987	0	88	539	187	25	91	930
Total	0	401	2,021	187	421	554	3,584

Table 15. Number of salmonid fingerlings (thousands) stocked during the period 1983 to 1987 in all waters of Lake Michigan by zone.

Year	Brook trout	Brown trout	Chinook salmon	Coho salmon	Lake trout (splake)	Rainbow trout (steelhead)	Total
Southern							
1983	20	526	2,762	128	0	1,015	4,451
1984	9	331	3,665	156	342	1,275	5,778
1985	22	258	2,525	156	1,157	686	4,804
1986	14	159	2,070	133	420	500	3,296
1987	32	179	2,375	352	25	304	3,267
Total	97	1,453	13,397	925	1,944	3,780	21,596
Central							
1983	152	408	2,147	0	0	336	3,043
1984	67	418	2,555	133	44	312	3,529
1985	154	334	2,014	0	0	0	2,502
1986	12	178	1,895	113	326	35	2,559
1987	0	208	1,814	126	0	5	2,153
Total	385	1,546	10,425	372	370	688	13,786
Northern							
1983	38	623	1,271	0	31	258	2,221
1984	9	400	1,489	150	74	160	2,282
1985	0	521	1,417	0	35	60	2,033
1986	0	390	1,728	0	172	0	2,290
1987	6	424	1,612	0	0	72	2,114
Total	53	2,358	7,517	150	312	550	10,940
Lake wide							
1983	210	1,557	6,180	128	31	1,609	9,715
1984	85	1,149	7,709	439	460	1,747	11,589
1985	176	1,113	5,956	156	1,192	746	9,339
1986	26	727	5,693	246	918	535	8,145
1987	38	811	5,801	478	25	381	7,534
Total	535	5,357	31,339	1,447	2,626	5,018	46,322

Table 16. Number of salmonid yearlings (thousands) stocked during the period 1983 to 1987 in Michigan waters of Lake Michigan by zone.

Year	Brook trout	Brown trout	Coho salmon	Lake trout (splake)	Rainbow trout (steelhead)	Total
Southern						
1983	0	40	400	473	215	1,128
1984	0	75	455	250	251	1,031
1985	0	66	400	0	258	724
1986	0	75	390	0	335	800
1987	0	75	404	0	320	799
Total	0	331	2,049	723	1,379	4,482
Central						
1983	0	31	1,383	323	85	1,822
1984	0	55	1,489	80	129	1,753
1985	0	43	1,193	288	63	1,587
1986	0	55	1,094	220	108	1,477
1987	0	55	938	0	88	1,081
Total	0	239	6,097	911	473	7,720
Northern						
1983	0	67	99	276	195	637
1984	8	60	100	61	130	359
1985	9	30	100	1,015	134	1,288
1986	9	35	95	1,104	170	1,413
1987	0	48	80	805	193	1,126
Total	26	240	474	3,261	822	4,823
Lake wide						
1983	0	138	1,882	1,072	495	3,587
1984	8	190	2,044	391	510	3,143
1985	9	139	1,693	1,303	455	3,599
1986	9	165	1,579	1,324	613	3,690
1987	0	178	1,422	805	601	3,006
Total	26	810	8,620	4,895	2,674	17,025

Table 17. Number of salmonid yearlings (thousands) stocked during the period 1983 to 1987 in Wisconsin waters of Lake Michigan by zone.

Year	Brook trout	Brown trout	Coho salmon	Lake trout (splake)	Rainbow trout (steelhead)	Total
Southern						
1983	0	95	252	502	204	1,053
1984	0	53	109	0	348	510
1985	0	95	216	0	119	430
1986	12	60	0	0	162	234
1987	11	33	199	714	130	1,087
Total	23	336	776	1,216	963	3,314
Central						
1983	62	180	105	111	86	544
1984	45	212	159	499	150	1,065
1985	67	212	307	775	180	1,541
1986	106	259	154	684	370	1,573
1987	29	141	259	0	275	704
Total	309	1,004	984	2,069	1,061	5,427
Northern						
1983	25	254	0	202	55	536
1984	94	199	0	40	232	565
1985	64	233	0	380	117	794
1986	45	233	0	387	188	853
1987	17	179	40	351	137	724
Total	245	1,098	40	1,360	729	3,472
Lake wide						
1983	87	529	357	815	345	2,133
1984	139	464	268	539	730	2,140
1985	131	540	523	1,155	416	2,765
1986	163	552	154	1,071	720	2,660
1987	57	353	498	1,065	542	2,515
Total	577	2,438	1,800	4,645	2,753	12,213

Table 18. Number of salmonid yearlings (thousands) stocked during the period 1983 to 1987 in Indiana waters of Lake Michigan by zone.

Year	Brook trout	Brown trout	Coho salmon	Lake trout (splake)	Rainbow trout (steelhead)	Total
Southern						
1983	0	0	0	157	87	244
1984	0	0	0	108	137	245
1985	0	7	0	0	284	291
1986	0	0	0	0	296	296
1987	0	0	0	0	302	302
Total	0	7	0	265	1,106	1,378

Table 19. Number of salmonid yearlings (thousands) stocked during the period 1983 to 1987 in Illinois waters of Lake Michigan by zone.

Year	Brook trout	Brown trout	Coho salmon	Lake trout (splake)	Rainbow trout (steelhead)	Total
Southern						
1983	0	0	0	166	0	166
1984	0	0	277	100	0	377
1985	0	0	305	185	0	490
1986	0	0	312	100	0	412
1987	0	0	0	102	0	102
Total	0	0	894	653	0	1,547

Table 20. Number of salmonid yearlings (thousands) stocked during the period 1983 to 1987 in all waters of Lake Michigan by zone.

Year	Brook trout	Brown trout	Coho salmon	Lake trout (splake)	Rainbow trout (steelhead)	Total
Southern						
1983	0	135	652	1,298	506	2,591
1984	0	128	841	458	736	2,163
1985	0	168	921	185	661	1,935
1986	12	135	702	100	793	1,742
1987	11	108	603	816	752	2,290
Total	23	674	3,719	2,857	3,448	10,721
Central						
1983	62	211	1,488	434	171	2,366
1984	45	267	1,648	579	279	2,818
1985	67	255	1,500	1,063	243	3,128
1986	106	314	1,248	904	478	3,050
1987	29	196	1,197	0	363	1,785
Total	309	1,243	7,081	2,980	1,534	13,147
Northern						
1983	25	321	99	478	250	1,173
1984	102	259	100	101	362	924
1985	73	263	100	1,395	251	2,082
1986	54	268	95	1,491	358	2,266
1987	17	227	120	1,156	330	1,850
Total	271	1,338	514	4,621	1,551	8,295
Lake wide						
1983	87	667	2,239	2,210	927	6,130
1984	147	654	2,589	1,138	1,377	5,905
1985	140	686	2,521	2,643	1,155	7,145
1986	172	717	2,045	2,495	1,629	7,058
1987	57	531	1,920	1,972	1,445	5,925
Total	603	3,255	11,314	10,458	6,533	32,163

Table 21. Comparison of pre-plan and post-plan stocking effort in Lake Michigan (expressed in terms of coho equivalents) by Michigan and Wisconsin.

	Michigan		Wisconsin
Pre-plan 5 year average[1]	10,775,000		7,424,000
Goal[2]	9,856,000		6,769,000
Reduction in coho equivalents	919,000 (8.5%)		655,000 (8.5%)
Total reduction for both states combined		1,574,000 (8.5%)	

[1]Michigan pre-plan period, 1980-84. Wisconsin pre-plan period, 1982-86.

[2]Established in 1985 by Michigan and in 1987 by Wisconsin.

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STREAM MANAGEMENT

Ralph Hay and Walter Houghton

The introduction of Pacific salmon into the Great Lakes began a new era in stream fisheries management, especially the streams that emptied into the Great Lakes. Bear Creek (Manistee County), Platte River (Benzie County), and the Big Huron River (Baraga County) were selected to receive the first coho salmon yearlings in the spring of 1966 because of their similarities to streams of the Pacific northwest. The following year (1967) chinook salmon fingerlings were planted in the Big Huron River, Little Manistee River (Manistee County), and Muskegon River (Newaygo County).

The success of the initial plant of coho salmon became evident in the fall of 1966 when thousands of coho jacks returned to Platte River and Bear Creek. These fish ranged in size from 2 to 7 pounds after just 4 months in Lake Michigan.

Weirs

In anticipation of the adult run in 1967, fish blocking weirs were quickly constructed on the Bear, Platte, Big Huron, and Little Manistee rivers. These weirs were initially built to trap the returning adult salmon for egg collection. This was paramount, since the continuation of the program has, and still does, depend upon the propagation of hatchery fish. Secondary to egg-take operations was the collection of biological data and assessment of the runs.

In the fall of 1967, the first run of adult coho was in excess of the most optimistic predictions. The coho craze gripped Michigan anglers. Thousands of people came to witness the large fish in Michigan streams. Everybody wanted coho salmon. Since there were fish surplus to the egg-take requirements at the weirs, several thousand adults were transported to 14 streams around the state. This transfer was not intended to provide a put-and-take fishery but to try and establish a natural run of wild fish in these waters. Some fish were also passed upstream of the weirs for the same reasons.

Despite these transfers, fish were still continuing to accumulate below the weirs. It was during this period of the run that controversy began to creep into the picture. Public pressure was increasing for passage of these coho upstream of the weir. The result would be a snag fishery that was in conflict with the desire of the MDNR to maintain the traditions of conventional hook and line fishing. On the other hand, the MDNR did not want large numbers of salmon dying and littering the streams. Thus, the decision was made to harvest surplus salmon at the weirs and either make them available to state institutions free of charge or sell them to local commercial fishermen for a flat rate of 10 cents per pound. However, the MDNR was not fully prepared for the intense amount of labor needed to remove and distribute the fish. Many commercial fishermen arrived and some only brought pickup trucks for a few hundred pounds. Quality control was inadequate. This was a time of rapid fire decision making and turmoil. Plans would have to be in place to deal with the even larger run in 1968. Because of the overwhelming success of the salmon plants, it was mandatory to immediately upgrade the salmon program from an experimental basis to full-scale management.

Fish harvested at the weirs in 1968 were sold to the highest bid commercial contractor (Blackport Packing Company of Grand Rapids) for canning and human consumption. This eliminated the problems of dealing with many different vendors. In February of 1969, the Michigan Department of Agriculture withheld sale of canned salmon due to dieldrin contamination and, in March, a large amount of frozen coho was seized by the United States Food and Drug Administration (FDA) because of high levels of DDT (13-19 ppm) in the flesh. These developments culminated in the FDA setting an interim DDT tolerance limit of 5 ppm which allowed only for the sale of salmon intrastate, with the eggs being sold for caviar and bait.

In 1969 and 1970, to provide salmon to people near the major salmon streams, fish were given to anglers free. Any licensed angler could receive a freshly iced coho at designated locations. These popular fish "give-aways" were conducted at Manistee and the lower Platte River harvest weir. This program was stopped after the 1970 season because fish exceeded the FDA tolerance limits for PCB, and the Michigan Attorney General considered the salmon distribution as a sale at zero cost, hence illegal.

Snagging

By 1968, refinements were made in the salmon management plan to address two key areas, 1) to maximize angler opportunities and harvest and 2) to minimize destruction of habitat by intense angler use.

With very large numbers of salmon in many of the smaller streams, anglers became extremely frustrated at their inability to catch salmon. There was intense pressure put upon the MDNR to legalize snagging. In order to maximize angling opportunities and harvest, the MDNR did not object to the snagging of salmon. After all, snagging began (illegally) with the 1967 run in Bear Creek. The sudden staggering abundance of salmon made foul-hooking inevitable and snagging easy. Although snagging was illegal (Act 165, PA 1929) and considerable enforcement effort was expended, it could not be controlled and the enforcement caused considerable public outcry. Fishermen reasoned that the salmon were going to die anyway and they saw nothing morally or ethically wrong with snagging. Besides, it was believed that the salmon would not bite using normal fishing techniques. Fishermen attracted to the dense schools of coho caused trespass problems on private land, littered fishing sites, and caused habitat damage by trampling banks and removing stream cover to take the fish. Bear Creek was closed to fishing on October 7, 2 weeks after the first fish came in, because of habitat damage and concern for survival of enough salmon for an egg source. As the salmon program expanded, the scenario of problems was repeated to some degree whenever large numbers of fish were concentrated. Following are some key dates in the history of salmon snagging in Michigan.

1969	Snagging permitted in all rivers from August 1 through December 31.
1972	Restrictions imposed, only seven locations allowed.
1974	Snagging permitted at eight locations.
1975	Number of snagging sites increased to 16.
1977	Temporary blocking weirs installed on the Pere Marquette, Van Etten, Jordan, and Bear Creek in an attempt to reduce snagging.
1978	Started reducing the number of snagging sites and shortened seasons. Gear restrictions imposed.
1983	Began a phase out of snagging at the five remaining sites.
1984	Legislation (Act 118, PA 1984) authorizing snagging at four locations.

In the above chronology of events, it can be seen that shortly after the first runs entered the rivers, the MDNR was pressured into legalizing the snagging of salmon. Beginning in 1969, snagging was permitted in all salmon rivers from August 1 to December 31. In 1972, area restrictions were imposed and snagging was only allowed at seven designated locations. The number of locations was increased to 8 in 1974 and 16 in 1975.

In 1977, then MDNR Director Howard Tanner requested Fisheries Division to install blocking weirs to stop salmon migrations on the Jordan River, Bear Creek, Pere Marquette River, and Van Etten Creek. He also ordered that only the unavoidable minimum of salmon be passed through the lower weir on Platte River, that the MDNR seek legislation making the collection and sale of salmon eggs a state monopoly to achieve control over egg sales, and that fishing regulations be vigorously enforced. These were the first steps taken to address problems of illegal fishing methods, trespass, littering, environmental damage, and a profit motive (egg sale) injected into the sport fisheries for salmon, most of which were associated with the large numbers of highly visible salmon concentrated in fragile trout streams.

Since 1978, the Michigan Natural Resources Commission (MNRC) has continuously reduced the number of liberalized fishing sites, shortened the season, and placed restrictions on the type of snagging gear. The MNRC order pertaining to liberalized fishing in 1983 called for a complete phase-out of snagging at the remaining five sites in 1984 and 1985. However, before snagging could be eliminated, the pro-snagging forces sought and received legislation to continue the practice of snagging. Act 118, PA 1984 authorized snagging of Pacific salmon from September 10 to October 25 in a portion of the Muskegon (Newaygo County), Pere Marquette (Mason County), Big Manistee (Manistee County), and Big Sable (Mason County) rivers. The MNRC order to end snagging on the Au Sable River after the 1985 season was allowed to stand. Finally, it was ruled that an angler had to purchase a salmon snagging stamp in addition to the trout and salmon stamp to snag salmon in these sections of river.

The issue of snagging continues to be a topic of debate in Michigan. The economic impact to communities near the snagging sites are significant and, with existing legislation, snagging will continue on the above mentioned rivers. However, combined with the increased open-water catch, reduced snagging sites, anglers learning stream salmon will strike, weir harvest, and controls on salmon egg sales, the adverse impacts to salmon streams have been greatly reduced.

Snagging has been synonymous with salmon in Michigan. Although snagging has existed for 20 plus years, it is unfortunately a fishery that has been poorly documented with the exception of the snag fishery at the Big Sable River near Ludington. This river is the outlet for Hamlin Lake, Mason County, is approximately 1 mile in length, and lies completely within Ludington State Park. A dam at the outlet of Hamlin Lake blocks salmon from further upstream movement.

Because of the short river length and relatively large salmon stocking rates, this river has attracted large numbers of salmon snaggers. Crowd control became a problem for the State Park in the early 1970s. Since access could be controlled, the park responded by initiating a limited access permit program in 1975 which used a lottery to select successful anglers. The structure of the permit program has changed over the years but, since 1980, has remained fairly stable. Fishing is allowed between 7:30 am and 5:00 pm. There are two morning and two afternoon shifts, with 125 permits issued per shift by lottery drawing. The single exception to this program structure occurred in 1981 when snagging was only authorized on odd-numbered days. On even-numbered days only conventional fishing techniques were allowed.

Anglers are required to report their catch to Park personnel at the conclusion of each shift. Compliance is excellent and virtually all harvested salmon are counted. Unfortunately, Park personnel are unable to make reliable identifications of chinook and coho salmon and, therefore, salmon species composition is unknown as are the size and age distributions of this harvest.

The number of chinook salmon harvested from the Big Sable River has decreased significantly over the years (Table 1). Although the stocking of coho salmon was discontinued in 1983 due to poor returns, the number of chinook salmon stocked has been relatively constant (ranging from 100,000 to 300,000 spring fingerlings annually). The annual target stocking rate for the Big Sable River is now 200,000 fish.

The majority of chinook return as age-0.3 and age-0.4 fish. The relatively small plants of chinook in 1976-77 provided a good fishery in 1979-81. As the plants were increased to a maximum of 300,000 in 1980, the catch improved and remained high through 1984. Although the plants remained near 200,000 from 1982 through 1987, both the total catch and catch rate decreased. It appears that with the increased open-water catch, fewer fish are left to run the rivers.

To minimize habitat destruction by both salmon and anglers in the smaller streams, plants were shifted to include larger rivers only. Several of these larger rivers were only marginal for trout and the introduction of salmon created an otherwise nonexistent fishery. Also, these rivers were of sufficient size to handle the additional fishing pressure. Since many of these streams lack good spawning habitat in the lower reaches, it has been necessary to continue annual plants. In order to extend the range of these fish, it was also necessary to either remove dams or provide fish passage over old dams on many rivers.

Dam removal

Expansion of anadromous fishing through dam removal has been done at two sites, Newaygo dam on the Muskegon River in 1969 and the Homestead dam on the Betsie River in 1974. The removal of these two dams opened up 14 and 40 miles of stream, respectively. Not only did removal of these two dams open additional waters for fishing but it opened many miles of good spawning habitat. The Homestead dam was replaced with a low head dam designed to physically block the upstream migration of adult sea lamprey without inhibiting anadromous fish runs.

Fish ladders

When dam removal was not possible or desirable, the next best alternative was to construct fish ladders. Most of the ladders to date have been built on large southern Michigan rivers.

Six fish ladders were constructed on the Grand River. This allowed salmon and rainbow (steelhead) trout to migrate inland through 155 miles of mainstream and 270 miles of tributaries. The cost of these structures was about $2.4 million.

The St. Joseph River has a fish ladder at Berrien Springs. Fish ladders are planned for the Buchanan and Niles dams with completion scheduled for 1989. As part of the cooperative fishery management plan with the State of Indiana, two ladders are planned for dams on the St. Joseph River in Indiana that will greatly extend the range of anadromous fish into Michigan.

A fish ladder was constructed at the Union Street dam on the Boardman River. This ladder was also designed to prevent the upstream migration of adult sea lamprey. It was operational by the fall of 1987. Fish passage at the Union Street dam opens about two additional river miles of stream for fishing. This was built in conjunction with a fish trap and transfer, harvest weir complex downstream from the dam. Total cost of these projects was about $1.0 million.

Trap and transfer operations

None of the current facilities is designed to allow for transfer of adult salmonids. In the past, the practice has been to hold fish in ponds and then sort fish to be transferred. The fish are then loaded manually into fish transport units.

As mentioned earlier, some adult coho from the first runs were transferred to other streams. Adult coho and chinook have also been transferred to the Ludington Pump Storage Facility for research on the effects of pumping on adult salmonids. Adult rainbow (steelhead) trout have been transferred to the Pine and Big Manistee rivers to establish naturally reproducing populations in these areas.

Sea lamprey control

Sea lamprey are native to the Atlantic Ocean and gained initial entry into Oneida Lake and the Finger Lakes in the mid-1800s, probably through the Erie Canal. They moved into Lake Ontario where they became common in the 1880s. Niagara Falls, a natural barrier to the migration of lamprey into the other Great Lakes, was bypassed by the Welland Canal and the first lamprey was found above the falls in 1921. By the mid-1930s, sea lamprey reached lakes Huron and Michigan where food supplies were abundant and stream conditions ideal for reproduction and survival. In 1938, sea lamprey were discovered in Lake Superior, completing their establishment in all five Great Lakes.

The sea lamprey was a major cause of the severe damage done in the 1940s and 1950s to populations of lake trout, whitefish, and chubs. The loss of predatory species set the stage for invasion of the upper lakes by alewives that exploded to super-abundance in lakes Michigan and Huron.

Restoration of Great Lakes fish populations in the 1950s and 1960s was based on finding a method of lamprey control. Early efforts to manage lamprey involved the use of mechanical and electrical barriers to capture spawning adults when they migrated into streams. The barriers were effective but undependable during flooding and expensive to maintain. Also in the early 1950s, scientists began searching for a chemical that would kill sea lamprey during their vulnerable larval stage in the streams without harming other fish. In 1957, after screening over 6,000 chemicals, 3-trifluoromethyl-4-nitrophenol (TFM) was found to effectively kill larval lamprey in the streams. TFM is the primary chemical used in sea lamprey control today. A second compound, Bayer 73, is sometimes used in combination with TFM or where TFM applications are not feasible.

Presently lamprey populations are reduced to less than 10% of pretreatment levels. At this level of control, acceptable survival and growth of desirable fish species has been achieved. Although the population has been reduced, lamprey remain a constant threat and are still an important factor in fish mortality, especially on lake trout.

Although treatment of streams with TFM is the major control method, low-head barriers provide control on selected streams. Additional methods of management are being developed to reduce the dependency on chemicals. Redesigned electric barriers are being constructed and tested. The release of sterile males to reduce the number of young produced is being explored.

Rainbow (steelhead) trout fishery

Steelhead, or migratory rainbow trout, were first introduced into Michigan in 1876 from California. By the early 1900s, they were well established in the State's waters. Originally rainbow (steelhead) trout were believed to be strictly a stream fish but it was soon realized that these fish did, in fact, migrate into Lake Michigan where they attained a large size. However, their expansion in Michigan met two setbacks. First, rainbow (steelhead) numbers were reduced because of the construction of hydro dams on major spawning streams (the Muskegon, Manistee, and Au Sable rivers) during the early 1900s. However, rainbow (steelhead) fishing remained good until the second problem, sea lamprey, caused a further decline in the late 1940s and early 1950s. Sea lamprey, which are selective for the larger members of any species, all but eliminated the large spawners. During this period, a 5-pound rainbow (steelhead) was worthy of mention in local newspapers when taken from streams in northwest lower Michigan which were, historically, famous for large rainbow (steelhead).

Chemical control of sea lamprey was extended to Lake Michigan in the early 1960s and rainbow (steelhead) quickly recovered. Spawning runs in indicator streams (the Platte and Little Manistee rivers) doubled and redoubled for four successive years. Prior to 1950, runs of adults in the Little Manistee and Platte rivers, based on records from MDNR weirs, numbered about 1,000-3,000 fish annually. In 1969-70, the run on the Little Manistee was 17,000 fish, while the runs during 1980-86 have varied from 7,000-19,000. Although the MDNR began stocking substantial numbers of rainbow (steelhead) smolts in 1968, most of the initial resurgence of these fish in Michigan can be credited to sea lamprey control.

The rainbow (steelhead) trout is managed primarily for a stream fishery. Management procedures on Michigan's top quality wild steelhead rivers is aimed at maintaining moderate runs that can normally be sustained by natural reproduction through habitat protection and angling regulations. Excessively large spawning runs of steelhead attract large numbers of anglers that cause crowded fishing conditions and streambank damage. Angling quality suffers under such circumstances. Supplemental plantings are made in those streams that lack adequate natural reproduction. Stocking is now made with yearling fish at a size of six per pound (7 to 8 inches). Expansion of the steelhead program has been achieved through 1) stocking rivers that have dams which block fish from spawning areas, 2) supplemental stockings in waters which only have limited natural reproduction, and 3) through dam removal or ladders around dams so as to open new fishing waters and spawning areas.

Although the majority of rainbow (steelhead) are caught in streams or estuaries, the open-water catch is increasing and requires watching. Until recently, steelhead were not targeted out in the lake and were taken incidentally while anglers were trolling in the open water for other species. Now they are being targeted offshore at the scum line (the surface temperature break that occurs with offshore winds). This has increased the Great Lakes harvest of steelhead and the developing fishery should be monitored closely. The Lake Michigan catch of steelhead in 1987 was nearly 50,000 fish and is expected to increase in the future.

Water management

Dams continue to limit further expansion of inland anadromous fisheries. However, hydroelectric dams on most of Michigan's streams are regulated by the Federal Energy Regulatory Commission (FERC). Through the 1960s, licensing focused on the most efficient production of power. The scope of licensing has broadened considerably because of increased national awareness of environmental issues. Through the FERC licensing process and agreements with the hydroelectric plant owners, it has been possible to provide minimum flows which reduce streambank erosion and to develop access sites and parking areas for the developing fisheries.

Changes in the licensing procedures now require FERC to give equal consideration to fish and wildlife values. Thus, it should be easier to mitigate the adverse impacts that power dams have on the aquatic environment, especially the fisheries interests. In addition to minimum water flows and parking areas, attention will be given to boat launching facilities, shoreline access for the nonboaters, and coolwater draw from the larger impoundments.

Table 1. Chinook salmon plantings, harvest, angler trips, and catch rates (fish per angler trip) for the Big Sable River salmon snagging fishery during 1976-87.[1]

Year	Number planted	Number[2] harvested	Angler trips	Catch rate
1976	101,101	8,872	12,274	0.72
1977	150,048	19,521	17,915	1.09
1978	218,000	8,894	17,466	0.51
1979	200,000	14,428	16,850	0.86
1980	300,150	26,513	18,210	1.46
1981	100,000	17,775	14,275	1.25
1982	200,284	21,815	20,861	1.05
1983	200,000	30,860	19,121	1.61
1984	200,170	22,161	20,046	1.11
1985	185,014	11,792	17,224	0.68
1986	199,990	8,471	15,571	0.54
1987	199,150	7,391	11,290	0.65

[1]Harvest and angler trip data provided by MDNR Ludington State Park personnel.

[2]Total chinook salmon harvest was calculated by subtracting the estimated coho harvest from the total salmon harvest. The coho harvest estimate was based on a 1981 survey of the Big Sable River salmon fishery conducted by MDNR District 6 Fisheries personnel. In that year, the adult coho salmon harvest represented 3% of the yearlings stocked the previous year. Coho stocking in the Big Sable River was eventually eliminated in 1983 because of consistently poor return rates.

SALMONID HARVEST

Gerald Rakoczy and Donald Nelson

Catch and Effort Sampling

The MDNR has monitored Lake Michigan's sport fishery through the use of a contact creel survey since 1983. The objective of the program is to obtain a continuous record of sport catch, catch rates, and catch composition from the open waters of the Great Lakes and important anadromous river fisheries. Data collected from this program will be used to develop, test, and improve decision models to aid in determining strategies for managing Lake Michigan's sport fishery.

Boat, shore, and pier anglers were contacted at 26 sites along the Lake Michigan shoreline from New Buffalo to Harbor Springs in the Lower Peninsula and from Manistique to Menominee in the Upper Peninsula. In order to compare annual trends in these data, the areas sampled on Lake Michigan were combined into a southern, central, and northern zone. Within each zone, only those sampling areas which were monitored consistently during the period 1985-87 have been included in the analysis for this report.

The southern zone includes the ports of New Buffalo, St. Joseph, South Haven, Saugatuck, Holland, Port Sheldon, Grand Haven, and Muskegon. The central zone includes the ports of Pentwater, Ludington, Manistee, Frankfort, and Platte Bay. The northern zone includes Leland, Grand Traverse bays, Charlevoix, Petoskey, Harbor Springs, Manistique, Little Bay de Noc, Cedar River, and Menominee. Estimates of effort and harvest are based solely on these sample areas for both individual zone and lake wide totals.

No rigorous statistical testing was performed on these data to determine year-to-year differences in zone or lake wide estimates for a given confidence level. However, it was assumed that non-overlapping error bounds implied significant differences in such estimates between years, although the confidence level is really unknown. In the context of this report, error bounds are defined as two standard errors of the mean (2 times the square root of the variance of an estimate) and approximate true 70-95% confidence limits, depending on sample size.

Estimates of total angler harvest for boat, shore, and pier fisheries combined at all sites sampled each year (1985-87) and age distributions from the sport catch were used to calculate the percent return to the sport fishery of chinook salmon, coho salmon, rainbow (steelhead) trout, lake trout, and brown trout. These analyses did not address possible contributions to the sport fishery from harvest in the river fisheries, natural reproduction, or fish stocked by other agencies. Estimated returns of Atlantic salmon, brook trout, and splake were not calculated due to a lack of sample data on these species. Pink salmon were also excluded from the analysis as this species is not stocked by any Great Lakes agency.

Biologists from the Wisconsin Department of Natural Resources (WDNR), Illinois Department of Natural Resources (IDC), and Indiana Department of Natural Resources (IDNR) were contacted regarding the sport harvest in their State's waters. Complete sport harvest data from all agencies bordering Lake Michigan were only available for 1985.

The harvest of salmonids by Michigan's charter-boat fleet were not separated from the total catch figures presented in this report. The charter-boat data were combined with all other boat data each year because few charter interviews were collected and counts were not separated into charter and non-charter to enable the estimated harvest to be apportioned. In addition, harvest data for the charter fishery were not available from Indiana. Reports were available for the Illinois charter fleet for the 1976-84 seasons (T. Trudeau, IDC, unpublished data) and the Wisconsin charter fishery for the 1976-87 seasons (WDNR, unpublished data). Size at age data for salmonids taken by charter fisheries were not available.

Angler Effort

Over 90,000 Lake Michigan anglers were interviewed at the end of their fishing trips during 1985-87. Fishing pressure for all zones ranged from 5,509,023 (±382,775) angler hours in 1987 to 6,594,922 (±488,582) angler hours in 1986 (Table 1). Estimated angler effort during 1985 (6,297,541 ± 291,913 angler hours) was not significantly different than the figure estimated for 1986. Total estimated angler effort decreased in 1987 by 16% compared to 1986, and by 13% compared to 1985. Angling effort broken down by mode of fishing each year was approximately 86% boat, 12% pier, and 2% shore.

The estimated number of individual fishing trips ranged from 1.22 million in 1987 to 1.46 million during 1986. A recent GLFC survey indicated that the average Great Lakes angler expended $36.50 per fishing trip (Talhelm 1987). Based on these data the Lake Michigan sport fishery at the ports which were sampled may have been worth $44-53 million to the State's economy during this period.

Anglers fishing in the southern zone of Lake Michigan accounted for 47-53% of the total estimated effort in all zones during the 1985-87 seasons. The southern zone was the only area where a significant decrease in total fishing pressure occurred between years. Total estimated angler effort for the period April through October in the south during 1987 decreased 20% and

22% compared to 1985 and 1986, respectively. During 1985 and 1986, 45-50% of the total angler effort in the southern zone occurred during July and August. Angler effort in these 2 months decreased by 51% and 46% compared to 1985 and 1986. The amount of fishing pressure during the spring fishery (April-June) was not significantly different during 1987 when compared to 1986.

Approximately 31-36% of the 1985-87 angler effort in all areas occurred in the central zone. During 1985 and 1986, about 55% of the fishing pressure in the central zone occurred during July and August. Fishing pressure shifted in 1987, with 59% of the angler effort occurring during August and September. Estimated angler effort during the 1987 spring and early summer fishery (April-July) decreased 42% compared to 1986.

The remainder of the total estimated angler effort (15-17%) occurred in the northern zone during 1985-87. As was the case in the southern and central zones, approximately half the fishing pressure was observed during July and August. Estimated effort for all months was not significantly different when comparing 1987 to the previous 2 years.

Chinook Salmon

Angling success.--Chinook salmon are the most important salmonid in the Lake Michigan sport fishery in terms of numbers and pounds of fish harvested (Rakoczy and Rogers 1987). Chinook have made up 50-58% of all the salmonids harvested during 1985-87 (Figure 1). The total estimated harvest for all zones combined ranged from 347,012 (±60,915) fish in 1987 to 513,780 (±96,387) fish in 1986 (Table 2).

The majority of chinook salmon (47-56%) were harvested in the central zone. Total harvest in this zone has ranged from 191,906 (±49,268) fish in 1987 to 285,880 (±87,905) fish during 1986. No significant change in total seasonal (April-October) catch has occurred between years (1985-87) in the central zone. However, the monthly distribution of the catch in the central zone during 1987 was different than the previous 2 years. During 1985 and 1986, 43-54% of the chinook salmon harvest occurred during April through July. In 1987, only 23% of the chinook harvest occurred during that same period.

Harvest of chinook in the southern zone has ranged from 110,537 (±35,038) fish in 1987 to 194,760 (±37,299) in 1986. The south zone was the only one to show a significant change in the total seasonal (April-October) chinook harvest between years. Total estimated harvest decreased 43% in 1987 compared with the 2-year average noted for 1985-86. The bulk of this decrease occurred during May, 1987 when 80% fewer chinook were harvested compared to the average number for the previous 2 years.

In the northern zone the sport harvest of chinook salmon increased, although not significantly, during 1987 compared to 1985-86. The chinook catch in this zone ranged from 33,140 (±13,105) fish in 1986 to 44,569 (±7,462) in 1987. The monthly distribution of the chinook harvest showed that many more chinook were caught during June 1987 than during June of 1985-86. Since angler effort during June 1987 was 19% less than the previous 2 year average, it is possible that chinook salmon abundance was higher in the northern portion of the lake during 1987 compared to 1985 or 1986.

Catch rates (angler success) for chinook salmon for all the zones combined during 1987 decreased 9% and 19% compared to 1985 and 1986, respectively (Table 3). However, these decreases were not significant. The estimated catch rates for chinook decreased in both the southern and central zones of the lake in 1987. In the southern zone, the 1987 catch rate of 4.3 (±1.4) fish per 100 angler hours was 27% less than the previous 2-year average. The central zone had the greatest chinook salmon catch rates for each of the 3 years sampling took place. In the central area the 1987 catch rate of 9.6 (±2.8) chinook per 100 angler hours was 15% less than the previous 2-year average.

Catch rates for chinook were up 38% during 1987 in the northern zone compared to the previous 2-year average. It is possible that chinook salmon were distributed differently on a geographic basis during 1987 as compared to 1985 and 1986. Angler harvests of chinook were reported at Cedar River, Manistique, and Charlevoix as much as 1 month earlier in the season (late May and early June) during 1987 than in previous years.

Number and percent return.--Biological data collected from the Lake Michigan sport fishery since 1983 indicated that age-0.3 chinook were the most numerous age group in the catch, making up 40-54% of the sport catch in the areas sampled (Table 4). Age-0.2 and age-0.3 chinook made up an average of 74% of the total harvest during 1983-86.

Using the estimated harvest and age distribution data from 1985-87, the number and percent return of various chinook salmon year classes were calculated (Table 4). Catch estimates for the Lake Michigan sport fishery have not been made for enough years to follow one cohort (year class) through the fishery. A minimum of 4 years harvest data are required. Three years of data are available for the 1983 and 1984 year classes of chinook. The percent return of the 1983 year class totaled 19.1% for age groups 0.2 through 0.4. If the return of the 1983 year class chinook at age-0.1 was similar to the 1984-86 year classes at that same age, then the total return over 4 years would be approximately 21%. Total return of the 1984 year class over 3 years (ages 0.1 through 0.3) was 9.8%. Using the average return of 0.4-year-old fish from the 1981-83 year classes would give a total return of approximately 13% for the 1984 year class.

The percent return of the 1984 year class at age 0.3 was much lower than the return of the 1982 and 1983 year classes at that same age. The poor representation of the 1984 year class may have contributed to the decrease in harvest and catch rate of chinook during 1987. The representation of the 1985 and 1986 year classes at age 0.1 and 0.2 in the sport fishery appears to be similar to that observed for the 1984 year class, implying possible problems with survival of these later groups also.

Size at age of fish harvested.--Mean total lengths of chinook salmon by age taken in the sport fishery have changed significantly since 1983. Mean lengths of chinook ranged from 18.1 (±0.6) to 20.6 (±0.8) inches for age 0.1, 25.5 (±0.6) to 27.8 (±0.6) inches for age 0.2, 32.1 (±0.2) to 33.3 (±0.2) for age 0.3, and 34.8 (±0.2) to 36.4 (±0.4) inches for age-0.4 fish during 1983-87 (Figure 2).

Chinook salmon growth in Lake Michigan may be at equilibrium with the present lake environment. Year to year changes in size at age may be dependent on seasonal weather patterns and annual fluctuations of the forage base. The relationship of winter weather patterns and rainbow (steelhead) trout growth was investigated by Seelbach (1986). He found that the degree of winter severity had a direct effect on the size of rainbow (steelhead) trout smolts.

Mean round weights of chinook by age ranged from 2.4 (±0.4) to 3.7 (±0.4) pounds for age 0.1, 6.3 (±0.2) to 9.3 (±0.4) pounds for age 0.2, 11.9 (±0.2) to 14.6 (±0.2) pounds for age 0.3 and, 15.5 (±0.4) to 18.1 (±0.4) pounds for age 0.4 during 1983-87. Mean weights of chinook salmon taken from the sport fishery have not changed significantly over the past 4 years (1984-87, Figure 3). A significant decrease in mean weights of age 0.2-0.4 chinook occurred between 1983 and 1984. Hansen (1986) found that mean weights of all chinook salmon in Wisconsin's sport fishery during the period 1969-84 did not change significantly. He did, however, find that mean length of trophy size chinook declined in the southern basin of Lake Michigan beginning in 1975. Trophy-size chinook were defined as those fish with a weight greater than or equal to the 95th percentile of the estimated weight distribution.

Length-frequency distributions of chinook salmon by month have not changed appreciably since 1983. Most chinook under 20 inches were observed each year in the June and July harvest (Figure 4). The April and May harvest consisted mainly of fish in the 22 through 35 inch size range. These data indicate that a season closure during April and May would do little to prevent smaller chinook from being harvested by the sport fishery.

Sport harvest in other states.--An estimated 922,157 chinook salmon were harvested by the sport fishery from areas sampled on Lake Michigan in all state jurisdictions during 1985 (Table 5). The percent of the total catch harvested by state was 55% Michigan, 36% Wisconsin, 7% Illinois, and 2% Indiana.

An approximation of the percent return in relation to each State's mean annual stocking rate indicates that Michigan anglers accrued the greatest percent return (18.3%) of the four states. Wisconsin and Illinois returns were 13.8% and 11.7%, respectively. The total return for all states combined was 15.0%.

Charter harvest.--The number of charter-boat operators in Michigan, Illinois, and Wisconsin has steadily increased since 1976. Michigan's Lake Michigan charter fleet accounts for 60-65% of all the charter operations licensed by Michigan (J. Ward, MDNR, personal communication). The charter fleet in Michigan's waters of Lake Michigan has grown from 177 to 639 operators during 1976-86 (Table 6). The charter fleets of all jurisdictions, except Indiana, have grown from 415 to 1,197 during 1976-84.

The Illinois charter harvest has increased from 146 fish in 1976 to 9,109 during 1984 (Table 7). Chinook catch rates for Illinois charter fishermen have increased over 500%, from 1.0 to 6.2 fish per 100 hours, during that same period. Chinook salmon have become more important to the Illinois charter fishery over the past decade, accounting for as much as 20% of the total charter harvest in 1983.

Wisconsin's charter harvest has grown from approximately 3,000 chinook during 1976 to over 76,000 during 1987 (Table 7). During 1985, 17% of all the chinook harvested in Wisconsin waters were taken by that State's charter fleet. The contribution of chinook salmon in the charter salmonid harvest has grown from 16% during 1976 to over 50% during 1986-87. During this same period, chinook catch rates have steadily increased from 4.5 to 16.6 fish per 100 angler hours. Charter fishermen in Wisconsin waters had catch rates 2.6 times greater than the rate calculated for Michigan's average angler.

Coho Salmon

Angling success.--Coho salmon made up 13-20% of the salmonid harvest during 1985-87 (Figure 1). The total estimated harvest for all zones combined ranged from 99,842 (±14,252) fish in 1985 to 138,627 (±27,864) in 1987 (Table 8). Approximately 49-57% of the total estimated harvest during 1986-87 was taken in April and May. During 1985, the April and May harvest accounted for only 30% of the total for that year. A large percentage of the coho harvest (32-44%) occurred during August and September of 1986-87. June and July were not important months for the sport harvest of coho salmon.

No significant change in total harvest from all zones has occurred between years (1985-87) during April through October. The majority of coho (50-58%) were harvested in the southern zone. Total harvest in this zone ranged from 49,643 (±12,195) fish in 1985 to 78,074 (±18,669) during 1986. The 1985 catch estimate was 17% lower than the average catch during 1986-87. Most of the spring coho fishery during 1985 and 1986 occurred at the extreme southern end of the zone between New Buffalo and St. Joseph. During 1987, the estimated coho salmon catch for New Buffalo and St. Joseph was approximately 75% less than in 1986. However, harvests in the Holland and Grand Haven areas combined were up 400% over 1986. Therefore, it is possible that coho salmon were distributed a little further north in this zone during 1987 than they were the previous 2 years.

The coho harvest in the central zone ranged from 45,153 (±6,945) fish in 1985 to 65,598 (±17,581) in 1987. Most of the harvest (71-87%) occurred during August and September. The number of coho taken by the sport fishery in the northern zone was very small compared to the other two zones.

Catch rates for coho for all areas combined ranged from 1.6 (±0.2) fish per 100 angler hours during 1985 to 2.5 (±0.5) during 1987 (Table 3). No significant change occurred in catch rates between 1986 and 1987 or 1985 and 1986. However, coho catch rates were 56% greater during 1987 when compared to the 1985 season.

No significant differences in coho salmon catch rates could be detected between years within either the southern or central zones. Catch rates were in general lower during the 1985 season in the southern zone when compared to 1986-87. The poor chinook fishery in the southern zone during 1987 was partially offset by a better than average coho fishery.

Number and percent return.--Biological data collected from the Lake Michigan sport fishery since 1983 indicated that age-1.0 coho made up 7-8% of the sport catch, while age-1.1 coho accounted for 92-93% of the annual total harvest.

Estimated harvest by age group was calculated using the age distribution data gathered during 1985-86. These data were then used to calculate the percent return of various year classes by age group (Table 9). The percent return to the sport fishery of age-1.0 coho ranged from 0.5-0.8% during 1985-87. The percent return of age-1.1 coho salmon ranged from 5-8%. Two year classes (1984 and 1985) of coho salmon have completed their cycle in the Lake Michigan sport fishery since catch estimates were first made in 1985. The sport fishery in Michigan waters took 8.5% of the 1984 year class, and 8.7% of the 1985 year class.

Size at age of fish harvested.--Mean total lengths of coho salmon by age taken in the sport fishery have not changed significantly since 1983 (Figure 5). Mean total lengths of age-1.0 coho ranged from 15.3 (±1.4) to 17.0 (±0.5) inches. Mean lengths of age-1.1 coho ranged from 22.4 (±0.4) to 23.9 (±0.4) inches.

Mean round weights of age-1.0 coho have not changed during 1983-86 (Figure 6). Age-1.0 fish have averaged 2.0 (±0.2) to 2.4 (±1.9) pounds while mean weights of age-1.1 coho have fluctuated from 3.9 (±0.2) to 5.1 (±0.2) pounds. Hansen (1986) found no change in annual mean weights of coho salmon in Wisconsin waters of Lake Michigan during 1969-84.

Monthly length and weight frequency distributions for coho during April through September have not changed during 1983-86.

Sport harvest in other states.--A total of 448,288 coho salmon were estimated harvested by the sport fishery from the areas sampled on Lake Michigan during 1985 (Table 10). The percent of the total catch harvested by state was 37% Wisconsin, 35% Illinois, 25% Michigan, and 3% Indiana.

An approximation of the percent return to the sport fishery of each State's coho plants, based on the 1983 year class, indicated that Wisconsin and Illinois achieved the greatest return. The State of Illinois has not stocked coho salmon since 1982, yet anglers in that State's waters harvested over 150,000 coho during 1985. Fisheries biologists in Illinois (R. Hess, IDC, personal communication) and Wisconsin (P. Schultz, WDNR, personal communication) feel that this fishery is dependent on Michigan stocked fish. A return of over 60% to Wisconsin anglers also indicated the possibility that a large number of Michigan stocked coho are harvested in waters outside Michigan. If a 10% return for plants made in other jurisdictions was assumed, over 300,000 Michigan stocked coho could have been harvested in other states. This is over 250% greater than the estimated coho harvest in Michigan waters. During recent years, coho salmon which were stocked in Michigan waters of Lake Superior at Marquette and Black River Harbor were taken in the sport fishery near Kenosha and Racine, Wisconsin (P. Schultz, WDNR, personal communication).

During 1985, the Lake Michigan sport fishery in all state waters took 18.4% of the total number of coho stocked during 1984. This compares well with the 15.2% return calculated for chinook salmon.

Charter harvest.--Coho salmon are a very important component of the Illinois charter harvest. During 1976-84, coho have made up an average of 72% of that state's total charter catch (Table 11). The Illinois charter harvest has increased from 3,100 fish in 1976 to 35,800 during 1984. Over 40,000 coho were taken by the Illinois charter fleet during 1981 and 1982. Catch rates for charter anglers in Illinois waters were phenomenal, ranging from 12.1 to 29.3 fish per 100 angler hours during 1976-84.

The State of Wisconsin's charter harvest of coho has increased from around 3,000 fish in 1976 to 20,000 during 1987 (Table 11). During the last 5 years, coho salmon have made up about 18% of all the salmonids taken by charter anglers. Wisconsin charter anglers took 13% of the total coho harvest in that state's waters in 1985. Catch rates for coho in the Wisconsin charter fishery have fluctuated from 1.6 to 9.0 fish per 100 angler hours since 1976. During 1987, the catch rate for coho in Michigan waters was 2.5 (±0.5) compared to 4.1 for the Wisconsin charter angler.

Rainbow (Steelhead) Trout

Angling success.--Rainbow (steelhead) trout have made up only a small portion (4-8%) of the Lake Michigan salmonid harvest during 1985-87 (Figure 1). The total estimated harvest for all zones combined ranged from 35,071 (±13,531) fish in 1986 to 46,282 (±10,188) in 1987 (Table 12). No significant difference in total catch between years could be detected during 1985-87.

The monthly harvest statistics for rainbow (steelhead) appear to be quite variable. Most of the rainbow (steelhead) trout harvest (59-68%) in 1985 and 1987 occurred during September and October. During 1986, only 29% of the total catch occurred in those 2 months, probably as a result of poor weather conditions.

An offshore boat fishery has developed for rainbow (steelhead) trout on Lake Michigan during the past several years. This fishery occurs during June through August and has caused some anglers to be concerned about possible overharvest of this species. In 1985-87 11,000-17,000 rainbow (steelhead) trout were harvested annually by all modes of fishing during these months. Most of the harvest came from the boat fishery.

During 1985-87, 15-50% of the estimated rainbow (steelhead) trout harvest in all areas occurred in the central zone. The harvest ranged from 14,819 (±5,178) fish in 1986 to 35,035 (±9,782) in 1987. The 1987 catch was 69% and 137% greater than the 1985 and 1986 harvest estimates, respectively. The increase in the 1987 rainbow (steelhead) catch was mainly due to above average angler success in the pier and shore fisheries during September and October. The estimated harvest during these months was 83% and 362% greater than in 1985 and 1986, respectively.

Anglers in the southern zone also harvested 15-50% of all rainbow (steelhead) trout caught during 1985-87. The estimated harvest was 13,634 (±2,554), 17,639 (±12,444), and 7,083 (±2,434) fish in 1985-87, respectively. The 1987 catch was 48% less than the 1985 harvest estimate. It is possible that the unusual weather conditions during 1987 may have caused rainbow (steelhead) trout to be distributed further north in the lake compared to the two previous years. This may explain the significant increase in the rainbow (steelhead) harvest in the central zone during 1987.

The remainder of the rainbow (steelhead) harvest (7-17%) occurred in the northern zone during 1985-87. No significant changes in total harvest occurred between years during 1985-87.

Catch rates for rainbow (steelhead) in all zones combined ranged from 0.5 (±0.2) to 0.8 (±0.2) fish per 100 angler hours during 1985-87 (Table 3). No significant change has occurred in lake-wide catch rates between years. The greatest catch rates for rainbow (steelhead) trout occurred in the central zone. Since 1985, anglers have harvested rainbow (steelhead) in the central zone at a mean rate of 0.6 (±0.2) to 1.8 (±0.6) fish per 100 angler hours. The 1987 catch rate for rainbow (steelhead) in this zone was 200% greater than in 1986.

Number and percent return.--Biological data collected from the Lake Michigan sport fishery indicated that rainbow (steelhead) of ages 1 through 8 were present in the harvest. Ages 2, 3, and 4 were the most numerous age groups in the harvest. These age groups made up an average of 24%, 30%, and 23% of the annual harvest.

The estimated number of rainbow (steelhead) harvested by age and year class were calculated using the harvest and age distribution data from 1985-87 (Table 13). At this time it is difficult to make a fair assessment of the percent return to the sport fishery of various year classes of rainbow (steelhead) trout plants. This is due to the fact that only 3 years of catch estimates are available for a species which is exploited by the sport fishery for 8 years. Secondly, many year classes of rainbow (steelhead) trout have been stocked as both fall fingerlings and yearlings. Finally, the level of natural recruitment is unknown for Lake Michigan. However, mortality rates on fingerling and yearling plants are known to be quite different (Seelbach 1985). In light of this, it is not surprising that the percentage of rainbow (steelhead) harvested by age and year class varies widely. For example, the percentage of the 1983, 1984, and 1985 year classes of rainbow (steelhead) harvested at age 2 was estimated at 2.4%, 0.7%, and 2.1%, respectively. For the same three year classes harvested at age 3 the estimates were 1.8%, 3.7%, and 1.4%, respectively. Several more years of catch estimates are needed to carry this analysis further.

Size at age of fish harvested.--In general, mean total lengths and round weights of rainbow (steelhead) by age have not changed significantly during 1983-86 (Figures 7 and 8). It is difficult to get a true picture of differences in size at age utilizing the number of scale annuli. Seelbach (1986) found that rainbow (steelhead) trout growth is affected by the number of years spent in the stream versus the lake environment.

During the period 1983-86, the average total length of all rainbow (steelhead) trout (all age groups) taken by the sport fishery were 24.6 (±0.6), 24.4 (±0.4), 25.2 (±0.2), and 25.4 (±0.4) inches, respectively. Corresponding mean round weights for these same years were 7.0 (±0.4), 6.3 (±0.2), 5.6 (±0.2), and 6.5 (±0.2) pounds, respectively. The average rainbow (steelhead) trout in the 1986 harvest was not significantly different in mean length or weight than fish taken

5 years earlier. Hansen (1986) did not find any significant change in mean weights of rainbow (steelhead) trout in Wisconsin's waters of Lake Michigan during 1969-84.

Sport harvest in other states.--A total of 100,361 rainbow (steelhead) trout were harvested by sport anglers from areas sampled on Lake Michigan during 1985 from all states (Table 14). The percent of the harvest by state was 47% Michigan, 24% Wisconsin, 20% Indiana, and 9% Illinois.

An approximation of the percent return to the sport fishery of each state's 1981-84 average rainbow (steelhead) plants indicates that Michigan (7.0%) and Indiana (6.8%) had the greatest returns. The poor return (2%) in the Wisconsin sport fishery relative to the other states may be a result of the high percentage of fingerling fish that state has planted during 1981-84. Of the 4.78 million rainbow (steelhead) trout planted by Wisconsin during 1981-84, 62% were fingerlings. It has been shown that fingerling plants have very high mortality rates in some years compared to yearling plants (Seelbach 1985). As a result, fingerling plants may not add much to the sport harvest.

The return for the entire Lake Michigan fishery was estimated to be around 4.3%. Michigan's stream harvest of rainbow (steelhead) trout is probably as large as the estimated lake catch (40,000-45,000 fish) from the Michigan waters of Lake Michigan. Wisconsin's stream fishery for rainbow (steelhead) is not substantial because of a lack of good stream systems (P. Schultz, WDNR, personal communication).

Charter harvest.--Wisconsin's charter fleet during 1976-86 harvested an average of 2,070 rainbow (steelhead) trout per year (Table 15). During 1987, Wisconsin's charter anglers harvested over 15,000 rainbow (steelhead), 7.5 times the previous 11-year average. Catch rates for the same 11-year period averaged 1.2 rainbow (steelhead) per 100 angler hours. The 1987 catch rate for rainbow (steelhead) in the Wisconsin charter fishery was 3.4 fish per 100 angler hours, or 2.8 times higher than the 11-year average and over four times greater than the rate (0.8) calculated for Michigan anglers during 1987. Rainbow (steelhead) accounted for 10% of the entire 1987 Wisconsin charter harvest, up from 2-3% the previous five years.

The large increase of rainbow (steelhead) in the Wisconsin charter fishery during 1987 may be attributed to the increased awareness of the offshore rainbow (steelhead) fishery during the summer months by charter captains, and to a rejuvenated stocking program during the past few years by the State of Wisconsin (M. Hansen, WDNR, personal communication).

The Illinois charter fleet harvest of rainbow (steelhead) has increased from 115 fish in 1976 to 2,634 during 1984 (Table 15). Catch rates for rainbow (steelhead) taken by the Illinois charter fishery have ranged from 0.8 to 1.8 per 100 angler hours during this same time period. Rainbow (steelhead) have made up approximately 4% of that state's charter harvest over the 9-year period.

Lake Trout

Angling success.--Lake trout have been called the bread and butter fish of the Lake Michigan sport fishery. The overall role of lake trout in the sport fishery has decreased over the last 10 years because of increasing angler success in catching chinook salmon throughout the spring and summer months. Lake trout are, however, very important during periods of the angling season when chinook are not available.

Lake trout made up 16-19% of the salmonid harvest during 1985-87 (Figure 1). The total estimated harvest for all zones combined ranged from 127,506 (±17,166) fish in 1985 to 139,888 (±44,890) in 1986 (Table 16). No significant change in the estimated lake wide harvest for all areas sampled has occurred during 1985-87.

During 1985-87, 43-52% of the total lake trout harvest for all areas occurred in the southern zone. The harvest has averaged 60,800 fish over the last 3 seasons. No significant difference was noted between years. The greatest monthly harvest occurred in May. The May, 1987 harvest made up 50% of the total catch for the southern zone.

The annual average harvest from the central zone was 44,700 lake trout during 1985-87. This was 28-41% of the total estimated lake wide harvest of lake trout in Michigan waters of Lake Michigan. No significant difference in harvest between years was noted in this zone. The greatest monthly harvest in 1986-87 occurred during June. In 1985, July had the greatest monthly harvest.

The lake trout harvest in the northern zone ranged from 37,682 (±10,041) fish in 1985 to 20,889 (±3,915) in 1987. The northern zone was the only area to show a significant change in estimated harvest between years. The lake trout harvest decreased 43% and 45% during 1986 and 1987, respectively, compared to 1985. Most of the decrease in harvest came from a decline in the Charlevoix-Petoskey areas of the northern zone. Gill-net fisheries are probably responsible for the decrease in the angler harvest in these areas. The combined tribal and sport harvest of lake trout in the Charlevoix-Petoskey area has exceeded the total allowable catch (TAC) for this species each year since 1985 (R. Hatch, USFWS, personal communication).

Catch rates for lake trout for all zones combined have ranged from 2.6 (±0.4) fish per 100 angler hours in 1985 to 3.5 (±0.9) in 1987 (Table 3). No significant differences were noted in the lake-wide catch rates between years. During 1987, lake trout catch rates were the greatest in the southern zone of Lake Michigan. Compared to 1985 and 1986, these catch rates were 85% and 54% greater, respectively. These differences, however, were not significant. The increase in catch rates may have been due to the fact that anglers were targeting for lake trout more during 1987 than in previous years because of the poor spring chinook fishery.

Lake trout catch rates between years in the central and northern zones have not changed significantly during 1985-87. The point estimates of lake trout catch rates in the north have decreased over 35% during 1986 and 1987 compared to 1985. Again, this may be a result of the gill-net fisheries in the Charlevoix-Petoskey areas.

Number and percent return.--Biological data collected from the Lake Michigan sport fishery since 1983 indicated that 10 age groups (ages 3-12) of lake trout were present in the sport harvest. Age groups 5 and 6 were the most numerous in the catch. These two groups comprised 48-66% of all lake trout harvested during 1983-86.

It is impossible to follow one year class of lake trout through the sport fishery since only 3 years of harvest data are available. A minimum of 10 years of harvest data would be needed. However, estimated harvest by year class was calculated for 3 years (1985-87, Table 17). The percent return of these year classes of lake trout to the Lake Michigan sport fishery by age varied widely. A total of 7.6% of the 1980 year class were harvested at ages 5 and 6 in comparison to 5.5% of the 1981 year class at those same ages. If the percent returns by age are averaged for the 3 years for which data are available, the approximate total return was about 13%.

Size at age of fish harvested.--Mean lengths of lake trout in the sport catch ranged from 24.5 (±0.2) to 25.8 (±0.2) inches during 1983-86. Mean total lengths of lake trout in age groups 6, 8, and 9 harvested by the sport fishery have not changed significantly since 1983 (Figure 9). However, age-7 fish captured in 1986 were smaller than those harvested in the previous 2 years. Mean lengths of age-4 and age-5 lake trout decreased following the 1983 season.

Mean round weights of lake trout taken by the sport fishery have ranged from 5.5 (±0.2) to 6.3 (±0.2) pounds during 1983-86. Mean round weights of age groups 5, 6, 8, and 9 have not changed significantly during this period (Figure 10). Again, as for length, age-7 fish captured in 1986 showed a significantly lower weight than in 1984 or 1985. The decrease in round weight of age-4 fish following the 1983 season may be due to sampling bias, since age-4 lake trout are not fully recruited to the sport fishery.

Length and weight frequency distributions of lake trout by month have not changed appreciably since 1983. The modal length of lake trout taken during the season was 23-25 inches (Figure 11). The length frequency data indicates that raising the legal size limit to 18-20 inches would have little overall impact on the sport fishery since very few lake trout under 20 inches are harvested.

Sport harvest in other states.--An estimated 237,369 lake trout were harvested by the sport fishery during 1985 from all states (Table 18). The percentage of the total catch harvested by state was 60% Michigan, 34% Wisconsin, 5% Illinois, and 1% Indiana. In addition to the sport fishery, significant numbers of lake trout were harvested by various gill-net fisheries in Indiana, Illinois, Wisconsin, and Michigan.

An approximation of the percent return to the sport fishery of each state's average annual (1977-81) lake trout plants indicated that Michigan (11.7%) and Illinois (10.0%) had the greatest return. The return for the entire Lake Michigan fishery was estimated to be about 9.2%.

Charter harvest.--The Wisconsin charter fishery during 1976-87 harvested an average of 22,000 lake trout each year (Table 19). During the past 5 years (1983-87), the average annual harvest has increased to over 33,000 fish. During 1976-84, lake trout comprised over 40% of all the salmonids taken in the charter fishery annually. In the last 3 years (1985-87), lake trout abundance in the harvest has decreased to about 23% of the total charter harvest in Wisconsin. In general, catch rates for lake trout in the Wisconsin charter fishery have decreased since the mid to late 1970s. During 1976-80, charter anglers harvested 12.2 lake trout per 100 hours while in the last 5 years (1983-87) the rate has declined to 8.9. The 27% decrease in catch rates for lake trout can be attributed to several factors. One major assumption is that charter captains during the last 5 years have been spending more time target fishing for other species, such as chinook salmon. Catch rates for lake trout in Michigan waters of Lake Michigan for all modes of fishing ranged from 2.6 (±0.4) to 3.5 (±0.9) fish per 100 angler hours. Wisconsin charter angler's catch rate for lake trout during 1987 was two times greater than the rate estimated for Michigan's non-charter anglers.

The Illinois charter fleet harvest of lake trout ranged from 71 fish in 1976 to 13,045 in 1983. Except for 1 year (1983), lake trout have played a minor role in the Illinois charter fishery. Lake trout have usually made up less than 10% of the total charter harvest in that state's waters. During the period 1976-84, lake trout catch rates in the Illinois charter fishery averaged 2.9 fish per 100 angler hours.

Brown Trout

Angling success.--Brown trout made up 4-8% of the Lake Michigan salmonid harvest during 1985-87 (Figure 1). The total estimated harvest for all zones combined ranged from 27,722 (±6,515) fish in 1987 to 73,768 (±16,136) in 1986 (Table 20). The year to year variation in the lake-wide brown trout harvest was large. The 1987 estimated harvest declined 62% and 39% compared to 1986 and 1985, respectively. The largest harvest, which occurred in 1986, was 65% greater than that estimated for the previous season. A large part of the brown trout harvest was taken during April and May, with 45-75% of the total annual harvest taken during these 2 months in 1985-87.

Most of the early spring fishery for brown trout occurs in shallow near-shore waters where browns congregate presumably due to warmer water temperatures and forage availability (G. Rakoczy, MDNR, personal observation). The 62% decline in the brown trout harvest during 1987 compared to 1986 was possibly due in part to the mild winter and early spring weather. Brown trout inhabit the near-shore waters during late February and early March before most anglers begin fishing. By April, most of these fish disperse (D. Johnson and R. Hay, MDNR, personal communication). Also, some early angler activity during February for brown trout in the Berrien County (southeastern Lake Michigan) area was missed by the creel sampling program (D. Johnson, MDNR, personal communication).

The majority of the lake wide harvest (53-74%) of brown trout came from the central zone during 1985-87. The 1987 harvest of 15,678 (±5,089) fish was 71% less than that estimated for 1986 (54,747 ± 14,858). Most of this decline occurred during April and May. The estimated harvest during these months in 1987 was 7,743 (±3,433) fish compared to 42,238 (±12,615) fish in 1986. There was no significant difference in harvest during the entire season comparing 1987 to 1985.

The estimated brown trout harvest in the southern zone ranged from 6,430 (±3,821) fish in 1987 to 15,929 (±6,217) in 1986. There were no differences in harvest levels between years (1985-87).

The northern zone brown trout harvest was estimated at 5,614 (±1,401) fish in 1987, virtually unchanged from the 5,906 (±1,633) estimated for 1985. However, the 1987 harvest was 82% greater than that estimated for 1986. The northern zone was the only area of Lake Michigan to show a significant increase in brown trout harvest comparing 1987 to 1986.

Lake-wide catch rates for brown trout decreased 55% in 1987 compared to 1986, but were not significantly different than rates calculated for 1985 (Table 3). The central zone was the only area of the lake to show a significant decline in catch rates for brown trout between years. Catch rates during 1987 in the central zone declined 65% compared to 1986, but were not significantly different than 1985.

Number and percent return.--Generally 5-6 age groups (ages 1-6) of brown trout were present in the sport harvest. During 1983-86, 2- and 3-year-old trout were the most numerous in the catch, averaging 43% and 39% of the annual harvest, respectively. Brown trout were fully recruited to the sport fishery at age 2 during 3 out of the 4 years for which biological data were collected.

The estimated number of brown trout harvested by age and year class were calculated using the harvest and age distribution data collected during 1985-87 (Table 21). The MDNR did not stock any brown trout in Lake Michigan in 1981, yet fish from this year class were noted in the catch during 1983-86. These fish may have resulted from either natural reproduction or were stocked in other states' waters.

Since one cohort of brown trout can be expected to contribute to the sport fishery for 5-6 years, it is impossible at this time to follow a year class through its entire life history. Three years (1985-87) of harvest data indicated that the percent return to the sport fishery of Michigan stocked (fingerling and yearling) brown trout has varied widely (Table 21). For example, the percent return for age-2 brown trout from the 1983-85 year classes ranged from 2.9-8.9%. Age-3 brown trout from the 1982-84 year classes ranged from 1.8-3.6%. If the percent returns by age are averaged for the 3 years for which data are available, the approximate total return was about 10.6%.

Results of research studies being conducted on lakes Huron and Superior regarding the return to the sport fishery of yearling and fingerling stocked brown trout conflict. Lake Huron results indicate that the return of brown trout stocked as fingerlings is very poor compared to yearlings (Weber 1987). However, Peck (1987) found that 54% of hatchery origin brown trout taken in the sport fishery at Marquette were from fall fingerling plants and only 15% were planted as yearlings.

Size at age of fish harvested.--Mean total length of 2- and 3-year-old brown trout taken in the sport fishery have increased slightly during 1983-86 (Figure 12). No significant differences between years in mean lengths of age-4 browns were noted. Too few brown trout greater than age 4 were sampled to conduct a meaningful analysis. Mean total lengths of all brown trout in the harvest ranged from 19.4 (±0.4) to 20.8 (±0.2) inches during 1983-86.

Mean round weights of age-2 brown trout in the sport harvest also have increased slightly during the 4-year sampling period (Figure 13). No significant change in round weights of older browns was noted. Mean round weights of all brown trout in the sport harvest ranged from 4.1 (±0.2) to 4.7 (±0.2) pounds during 1983-86.

Insufficient data were collected on brown trout during 1983-84 to determine if changes in monthly length or weight frequency distributions occurred. However, during 1985-86, no differences in monthly frequency distributions between years were noted. The modal length of brown trout increased as the season progressed. During April, 1985, the modal length of brown trout in the sport harvest was 18 inches. By July the mode increased to 20 inches, and by September the modal length in the harvest was 23 inches (Figure 14).

Sport harvest in other states.--An estimated 125,718 brown trout were harvested by the Lake Michigan sport fishery in all state waters during 1985 (Table 22). The percentage of the total harvest by jurisdiction was 56% Wisconsin, 39% Michigan, 3% Illinois, and 2% Indiana.

An approximation of the percent return to the sport fishery of each states average annual brown trout plants indicated that Michigan anglers had the greatest return. During the period 1980-81, 58% of Wisconsin's annual brown plants have been fingerlings. All brown trout stocked by the states of Indiana and Illinois during this period have also been fingerlings. In light of the possible poor performance of fingerling brown trout plants, it is not surprising that the approximate return to other states' sport fisheries are relatively low (4.5-8.5%).

The total Lake Michigan harvest of brown trout during 1985 was 7.1% of the annual number of brown trout stocked by all states during 1980-84.

Charter harvest.--The available data for brown trout from Wisconsin and Illinois charter operations on Lake Michigan indicated that harvest of this species was minimal. During the period 1983-87, the Wisconsin charter fleet's average annual harvest has been around 4,700 brown trout (Table 23). This species has only made up 3-5% of the total salmonid harvest by the charter fishery in Wisconsin. The Illinois charter harvest was less than 1,000 fish during the past several years. Brown trout have only made up 1-2% of that state's total salmonid harvest by the charter fishery.

Catch rates for brown trout by charter anglers in Wisconsin and Illinois waters were not significantly different than the rates estimated for Michigan anglers during 1985-87 (Table 3).

Other Salmonids

Angling success.--Small numbers of pink salmon, Atlantic salmon, brook trout, and splake are harvested each year by Lake Michigan anglers. These species, in combination, make up less than 1% of the total salmonid harvest in Michigan waters.

The greatest estimated sport harvest of pink salmon (3,325 ± 2,084) from Lake Michigan occurred during 1987 (Table 24). The estimated catch during 1985-86 was less than 500 fish. Fishable populations of pink salmon normally occur every 2 years because this species matures after only 2 years of life. In general, the majority of pink salmon were harvested in the northern zone of Lake Michigan during 1985-87.

The lake-wide Atlantic salmon harvest in Michigan waters has generally been less than 1,000 fish, except for 1985 when an estimated 1,256 (±1,442) were harvested (Table 24). During 1985-87, most of the Atlantic salmon harvest occurred in the southern and central sections of Lake Michigan.

During 1985-86, the brook trout and splake harvest have each been less than 500 fish per year. Most brook trout and splake that were harvested came from the northern zone of Lake Michigan.

Sport harvest in other states.--During 1985 no Atlantic salmon, pink salmon, or splake were reported harvested in the Wisconsin, Illinois, or Indiana waters of Lake Michigan. A total of 6,200 brook trout were harvested in Wisconsin. Brook trout were not reported in the Illinois or Indiana harvest.

Charter harvest.--Atlantic salmon, pink salmon, brook trout, and splake were not reported in the charter harvest of Wisconsin or Illinois. The charter harvests in Michigan and Indiana are not known, but probably are very small.

Weir Harvest

Originally, Great Lakes anglers were poorly prepared and equipped to harvest salmon in the open water of Lake Michigan. As a result, large numbers of salmon returned to the rivers and streams where they had been planted several years before. In a desire to harvest these fish, many anglers abandoned traditional fishing techniques and instead relied upon such illegal methods as intentional foul hooking, hand netting, spearing, and, in some cases, clubbing. In addition, crowd control became a problem. Trespass was common and, in areas of salmon concentrations, stream banks and in-stream habitat structures were destroyed. From a biological viewpoint, there was concern about the potential impact of interspecific competition between Pacific salmon and resident trout populations.

Fortunately, some of these problems had been anticipated. Since West Coast states had used harvest weirs for many years to reduce or eliminate surpluses of salmon, these devices were included in Michigan's original plan. In addition, harvest weirs were needed to provide the eggs to maintain the salmonid stocking program.

In Michigan, harvest weirs and egg-taking facilities were constructed on the Little Manistee River and at the Platte River Hatchery. Today, all of Michigan's chinook and coho salmon eggs come from these two facilities, respectively. Later, another permanent harvest weir was constructed on the Platte River, downstream from the hatchery weir, to remove the portion of the coho salmon run which was not required for the stream fishery or for egg production. In Wisconsin, a chinook salmon weir and egg-take facility was constructed on Strawberry Creek.

Fish harvested at these harvest weirs were disposed of in several manners. Originally, they were sold on an annual contract basis to the highest bidder. Later, contaminant problems made such sales impractical or illegal, and both processed and unprocessed fish were buried. And finally, fish were given away in some years to persons possessing a valid Michigan fishing license.

These procedures continued through the 1970s. Then, in 1983, the MDNR made several changes in their salmon management plan. Noting that the Great Lakes open-water fisheries were not created by specific stocking sites, the 1983 plan sought to stock most northern Lake Michigan salmon at only certain northern sites. The sites so chosen were selected on the basis of being efficient harvest sites. In principle, open-water fishing in the northern portion of the lake would not be affected while the problems associated with returning salmon would be restricted to only a few highly controllable streams.

In addition to the permanent harvest weirs already described, permanent weirs were also constructed on Medusa Creek (Charlevoix County) in 1985 and the Boardman River (Grand Traverse County) in 1987. The target salmon stocking rates for these primary salmon harvest rivers are listed in Table 25.

In certain years since 1983, temporary weirs were also used on the White and Jordan rivers. Although neither of these rivers are presently stocked with salmon, both have relatively large runs of naturally reproduced chinook salmon. The purpose of the Jordan River weir was to limit salmon access to this relatively small, blue ribbon trout stream. Over the years, salmon and salmon anglers have caused stream habitat destruction and chinook salmon are thought to compete with resident trout populations. Unfortunately, the temporary weir was never successful and a permanent blocking (versus harvest) weir has now been placed near the mouth of the river. On the White River, illegal foul-hooking fisheries developed in several small tributaries and at the first upstream dam on the mainstream. A temporary weir was installed in 1983 to intercept a portion of these returning fish to reduce the law enforcement problems. Again, the temporary structure was not successful and its use was discontinued.

Number and percent return.--The total pounds of chinook salmon harvested at Lake Michigan weirs fluctuated from a low of 407,038 pounds in 1986 to a high of 724,049 pounds in 1987 (Table 26). However, the actual returns (versus harvest) may have been more consistent than represented by these values. The highest 1987 value included the first major returns from the relatively new weirs on the Boardman River and Medusa Creek. Conversely, during the fall 1986 salmon harvest, unusually high precipitation resulted in major (100-year) flooding. For several days, flood water breached the Little Manistee River weir and many fish escaped upstream. While the lower Platte River weir never breached, high water levels in both the Platte River and Lake Michigan reduced the efficiency of the weir (Pecor 1987). Personal communication with WDNR personnel indicated that similar problems were encountered at the Strawberry Creek weir. With these two factors taken into consideration, the total Lake Michigan weir harvest appears to have slowly dropped since 1983 (Figure 15). The same general downward trend was also apparent in the harvest at the Little Manistee River weir (Table 26).

In the same 5-year period since 1983, coho harvest also varied extensively. Without regard to the number of coho salmon stocked, the total pounds of fish harvested ranged from a high of 1,268,553 pounds in 1983 to a low of 374,389 pounds in 1986 (Table 27). As was the case with chinook salmon, high water conditions in the fall of 1986 reduced harvest efficiency and tended to depress the total harvest. The same downward trend observed for chinook was also apparent in the weir harvest of coho salmon (Figure 16).

Lake Michigan's salmon fishery is primarily supported by stocking spring fingerlings. Since the number of fish planted has varied from year to year, total returns at age need to be adjusted for stocking rates. For the period of 1981 to 1986, stocking rates of chinook salmon in the Little Manistee River increased to a high of 805,773 in 1984 and then gradually decreased to the target stocking rate of 450,000 (Table 28). During this period of increasing stocking levels, year class performance for the complete 1981 to 1983 cohorts decreased from 5.9% to 5.0%. In fact, the 1984 year class was stocked in the greatest numbers and, to date, has produced returns of only 1.8%, which is significantly below average. Conversely, initial returns from the smaller 1985 and 1986 year classes were above average.

The general downward trend in total weight of the chinook salmon harvest was mirrored in return rates. Age-0.3 and age-0.4 fish are important in the weir harvest, both because of their large percent contribution (numbers) and their large individual size (weight). During this period, the percent return rate for age-0.3 fish consistently dropped from a high of 3.6% for the 1980 year class to a low of 1.5% for the 1984 year class. The drop in return rates of age-0.4 fish was not as significant but, nonetheless, they also contributed to a decrease in total harvest. However, it should be remembered that flooding conditions during the 1986 harvest reduced return rates for age-0.2 fish in the 1984 year class, age-0.3 fish in the 1983 year class, and age-0.4 fish in the 1982 year class.

The number of returning chinook salmon at Strawberry Creek in Wisconsin was substantially less than the average number of chinook encountered at the Little Manistee River weir (Table 29). However, the fact that these Wisconsin fish were of known age (coded wire tagged) makes information about them very valuable. In general, chinook salmon return rates were lower at Strawberry Creek than at the Little Manistee River weir and the year to year variability was less. The single exception was age-0.3 fish from the 1983 year class although harvest of these fish in 1986 was made difficult by flooding and high lake levels. This aside, the same downward trend in the return rate of age-0.3 fish was similar to Michigan's Little Manistee River.

Poor return rates for coho salmon have been reported for the last several years. In fact, poor returns have prompted the MDNR to re-evaluate its coho stocking strategy. Return rates for age-1.1 coho salmon at the lower Platte River weir consistently dropped from 15.6% for the 1981 year class to 6.5% for the 1984 year class (Table 30). Again, the age-1.1 fish of the 1984 year class were the fish affected by flooding in 1986. Therefore, the actual return rate was probably slightly higher and would likely approach the 8% level. If this is the case, the percent return rate for coho salmon has stabilized near 8% for the last three year classes and is close to the total return rate for chinook salmon.

When compared to West Coast returns, 8% should be acceptable. However, coho salmon are stocked as older, yearling fish. This, coupled with a shorter life cycle, should expose them to fewer sources of mortality. Therefore, coho salmon return rates should be significantly greater than chinook salmon return rates. One possible explanation for this discrepancy is natural reproduction. Because chinook salmon spend only a few months in their natal stream before smolting, many northern Michigan streams are very suitable for natural reproduction. For example, the Little Manistee River is one of Michigan's best trout streams. Although the harvest weir is designed to remove salmon from the river, very early run and late run fish gain access to the upper river before and after the weir is put in place. Such natural reproduction will artificially increase return rates.

The difference between chinook salmon return rates for the Little Manistee River and Strawberry Creek is also interesting. There is no reason to assume that open-water survival is better for chinook salmon smolts stocked in Michigan's versus Wisconsin's waters of Lake Michigan. The fisheries should be similar and both streams have intense fall fisheries near their mouths that are directed at, and attempt to intercept, returning fish. All other things being equal, there is one important factor which may explain the significant difference between return rates. Strawberry Creek is a small, sometimes intermittent stream that is not suitable for chinook salmon reproduction. However, either differential mortality due to tagging and/or clipping or poor tag retention could also affect the return rates of chinook to the Strawberry Creek Pond. Toneys and Royseck (WDNR, unpublished data) did not address these possibilities and thus the effects of such factors are unknown.

Of the four MDNR weirs currently operating on tributaries to Lake Michigan, species other than salmon were only observed at the Little Manistee and lower Platte River weirs. The Little Manistee weir is operated in the spring of each year for purposes of taking rainbow (steelhead) eggs. The number of rainbow (steelhead) observed at this facility ranged from a low of 347 fish in 1982 to a high of 6,356 fish in 1985 (Table 31). Anadromous brown trout have also been collected but only in very low numbers, never exceeding 200 fish in a season.

Rainbow (steelhead) trout, brown trout, and lake trout have all been intercepted at the lower Platte weir. Estimated numbers of rainbow (steelhead) at this weir have never exceeded 3,000 fish in a season during 1980-87 (Table 31). Brown trout numbers were much lower than at the Little Manistee weir and lake trout abundance was essentially negligible during this period, with the highest number of fish (69) observed in 1984.

Size at age of fish harvested.--Although biological data are now being taken at other Michigan weirs, age data for the 1983 to 1987 period were only available for the Little Manistee and Platte River weirs. Chinook jacks (age-0.1) were relatively small contributors to the total harvest at the Little Manistee weir (Table 32). With the exception of 1986, they ranged from 6% to 10% by number. After 2 summers in Lake Michigan, age-0.2 chinook appeared in greater numbers, ranging from 5% to 19% of the harvest. Age-0.3 fish were clearly the major component of the harvest. In most years they averaged nearly 50% of the total harvest. Prior to the development of the aging techniques currently in use, age-0.4 fish were assumed to be a small component of the harvest. Instead, it has been found that these fish have a significant impact. In certain years, age-0.4 fish represented over one-third of all salmon harvested and, on the average, comprised almost 30% of the total numbers. Although age-0.5 fish were a small fraction of the total harvest, their very presence is interesting. Prior to 1985, these fish were unknown in the weir harvest. There are two possible explanations. Again, the aging techniques presently used are more sensitive than those previously used. Age-0.5 fish were probably always present but never detected. The second possibility is that the population structure is actually changing with older fish becoming more common.

The presence of age-0.5 chinook salmon in Lake Michigan has also been verified by Wisconsin. They initiated a coded-wire tag program in 1982. In 1987, they collected one age-0.5 fish at the harvest weir on Strawberry Creek. In addition, several other age-0.5 fish were collected through Wisconsin's Lake Michigan sport harvest monitoring program. Since this is the 1982 year class, the first opportunity to observe age-0.6 fish will come in 1988.

For chinook salmon taken at the Little Manistee River weir, year to year variation was quite significant. For example, harvest in 1986 was primarily composed of age-0.3 and age-0.4 fish (94%). Although flooding was a problem in this year, there is no reason to assume escapement was age specific. In contrast, age-0.3 and age-0.4 fish in 1987 represented only 73% of the total harvest by number.

Because of the chinook salmon aging problems prior to 1985, length and weight data by age for the Little Manistee River weir were only available for the 1985 to 1987 harvest years (Table 33). The average length and weight of chinook salmon at this weir was highly variable between years. However, some general trends can be seen. With the exception of large, age-0.5 fish, both the average weight and length dropped between 1985 and 1986. For age-0.1 and 0.2 fish, length and weight recovered somewhat between 1986 and 1987. However, age-0.3 and age-0.4 fish maintained their downward trend in 1987. With the single exception of length at age 0.1, the average length and weight of salmon was less in 1987 than in 1985. Due to the small sample of age-0.5 fish, average length and weight should be viewed with caution.

Strawberry Creek data from Wisconsin are based on coded-wire tagged fish and were, therefore, only available commencing with the first returns of the 1982 year class (Table 34). In general, Strawberry Creek fish were slightly larger than Little Manistee River fish for ages 0.1 to 0.3, but the reverse was true for 0.4 and 0.5 aged fish. However, trend characteristics at the two weirs were similar between years. Except for age-0.1 fish, average lengths and weights decreased between 1985 and 1986. In 1987 there was some recovery in the average values for age-0.1 to age-0.3 fish. However, as in Michigan, age-0.2 to age-0.4 fish were smaller in 1987 than in 1985.

The mechanism responsible for causing the observed differences in average length and weight are unknown, although a partial explanation is available through analysis of aging techniques. Because of coded-wire tags, the ages of Wisconsin fish are known. Michigan does not have such a tagging system. Instead, scale analysis was used to determine age. Unfortunately, once chinook salmon begin their spawning migration, their scales become virtually impossible to remove and erosion of the scale margin makes analysis impractical. Therefore, Michigan used a length-age key developed with scales taken from open-water fish sampled by the Great Lakes Creel Census program during September and October. This approach assumed that no length or weight growth occurs between the time the fish are sampled in the open water and the time they are harvested at the weir. If growth does occur, larger fish of a given age will erroneously be included in the next older age group. This has a tendency to decrease the average size of younger fish while, at the same time, increase the average size of older fish. Although this was the same difference observed between Michigan and Wisconsin chinook salmon, no data were available to evaluate the magnitude of the effect.

One final observation needs to be made regarding chinook salmon length and weight information. It appears that growth, particularly weight, has slowed for older fish, although the small sample sizes for older fish make such observations tenuous. Since 1985, the average weight of Michigan age-0.5 fish has decreased more dramatically than the concurrent decrease in length. Because of insufficient data, it is unknown whether this is just a sampling artifact or whether it represents an actual trend in the population.

The age composition of coho salmon taken at the lower Platte River weir is presented in Table 35. Data on coho salmon taken from the Little Manistee River weir are also available, but were not used because of the strong similarities. With coho salmon, the year to year variation in age contribution was much more stable. Jacks (age-1.0) ranged from 1% to 4% of the harvest, while mature age-1.1 fish averaged 98% of the total harvest.

The average length and weight for coho salmon is best represented by fish taken at the Platte River weir (Table 36). The growth of these fish has been quite variable between years. However, the magnitude of change has been small. Coho salmon harvested in 1987 were only slightly smaller than those taken in 1983.

Tribal Harvest

As fish populations began to recover in the Great Lakes, the Indian tribes in northern Michigan claimed fishing rights granted to them by treaties. The State of Michigan disagreed and a long series of legal battles developed. By 1978 the federal government had been drawn into the controversy on the side of the tribes. Finally, in 1979, the U. S. District Court ruled that the tribes had the right to fish unrestricted by the state. An appeal by Michigan to the U. S. Court of Appeals was lost, and the U. S. Supreme Court declined to hear the case. Tribal commercial fishing was thereby authorized and the State of Michigan was denied regulatory authority in those waters covered by the treaty.

For the period between 1979 and 1985, the tribal fishery grew and court battles developed each year between the state and the tribes for allocation of the resource. Then, in the spring of 1985 the two parties, along with the federal government, entered into a mutually acceptable agreement to partition the fishery. In exchange for exclusive commercial fishing rights in certain waters, the tribes agreed not to fish in other treaty waters which were important sportfishing areas. This negotiated settlement remains in effect until the year 2000.

Unlike the state-licensed commercial fishery, this tribal fishery is authorized to harvest lake trout and salmon. Fortunately, a large share of the tribal fishery occurs in eastern Lake Superior and along the north shore of Lake Michigan. These areas do not have large, developed sport fisheries. However, in certain areas of Lake Michigan north of Leland, the sport and tribal fisheries come into direct conflict with one another as they compete for their share of the resource. The center of this conflict involves lake trout. Because of high consumer demand and resultant high price, lake trout are the prime tribal focus. However, sport fishermen also prize lake trout. They are relatively easy to catch and are relied upon for those days when the more desirable salmon are unavailable.

Since commercial harvest is generally reported as total round weight, the number of fish harvested by tribal operations was calculated from average individual weights (Table 37). No tribal harvest occurred in the central zone after 1985 as a result of the mutual agreement entered into by the tribes and the state. In the northern zone, lake trout production peaked in 1985 at nearly one-half million pounds and has since declined to 216,605 pounds. Several factors have contributed to this decline. The 1985 negotiated agreement was partially responsible. After 1985 the tribes were prevented from fishing in some of the more productive grounds and were encouraged to fish in other areas. In addition, lake trout abundance has declined in the northern end of Lake Michigan.

However, the agreement was only partially responsible. The tribes have been under increasing pressure to reduce harvest of lake trout. For example, in 1986 the Lake Michigan Technical Fisheries Review Committee recommended a maximum lake trout total allowable catch (TAC) of 52,000 pounds for 1987 in the northern priority zone (Hatch 1986). In 1987, the tribes actually harvested 193,000 pounds (preliminary estimate) from this area. Such overharvest is not unique. For most areas, TAC's have consistently been exceeded. In the long run, excess harvest reduces the number of older, larger fish and, since tribal regulations specify the allowable gill-net mesh-size, smaller fish cannot be harvested as efficiently. This should result in decreased harvest. Finally, commercial fisheries are difficult to monitor and individual fishermen frequently under-report harvest. This is most likely to occur when there is an economic incentive to under-report. In this instance, continued high reported harvest may result in increased regulations to reduce individual catch and therefore profit.

Commercial Effects

Although state-licensed commercial fishermen may not harvest salmonids, certain fishermen take lake trout and salmon incidental to authorized chub and whitefish fisheries. Since whitefish fisheries employ trap nets, most trout and salmon that are accidentally caught can be returned to the water alive, although some fish do become entangled in the mesh and are inadvertently killed. The magnitude of this incidental mortality is unknown for many operations. However, the MDNR monitored two whitefish trap-net fisheries operating out of the port of Muskegon (southeastern Lake Michigan) during 1985 and 1986. This research consisted of determining not only levels of incidental gilling mortality for non-target species but also to assess the effects of specific modifications to the nets with hopes of reducing this mortality (Smith 1988).

Results indicated that the number of lake trout killed was very low in comparison to the number caught in the nets. Although the catch per net lift of trout ranged from as low as 50 to as high as 200 fish, mortalities only ranged from 3 to 6 fish per lift. On the average, 3% to 6% of all trout caught died from gilling during the 2-year study period. This amounted to approximately 1,500 fish per year for both operations combined.

Other species observed in Smith's study included rainbow (steelhead) trout, brown trout, salmon (chinook and coho combined), yellow perch, and walleye. Only 10% each of all brown trout and walleye caught in the nets died as a result of gilling. Mortality for each of the remaining three species averaged about 60% of their abundance in the nets. However, the actual number of these species caught was extremely low in comparison to lake trout abundance in the nets.

Along with the two Muskegon fisheries, there is one additional trap-net operation at Leland which induces an unknown level of salmonid mortality. The remaining state-licensed trap-net fisheries in Green Bay of Lake Michigan probably do not contribute significantly to mortality due to low salmonid abundance in this area.

In addition to whitefish, Michigan authorizes six chub operations. Small-mesh gill nets (stretched mesh between 2.5 and 3 inches) are used in these commercial fisheries. In order to reduce gilling of lake trout, these nets must be set on the bottom in depths greater than 40 fathoms. Research has shown that incidental harvest of lake trout at these depths is less than one trout per 1,000 lineal feet of gill net lifted (R. Rybicki, MDNR, unpublished data). Using this rate, an estimate of the total 1987 incidental harvest of lake trout from the six operations in Lake Michigan was approximately 1,095 and 4,922 fish from the southern and central zones, respectively.

Salmon Egg Sale

The salmon program is primarily dedicated to the Great Lakes open-water sport fishery, and it is through this use that the greatest value is realized. In recent years, the total value to the state has been placed at approximately 1 billion dollars annually. The conversion of these recreational dollars into economic channels is primarily through the boating and fishing tackle industry, and related recreational service and travel industries. The direct sale of salmon contributes only a very small percentage to the total value.

In Michigan, fish, or parts of fish, taken under the authority of a sportfishing license may not be sold. With one exception, this has not been a problem. Most salmon are consumed by the angler's family or friends. This has not been the case with salmon eggs contained in adult, mature females.

In the United States, caviar made from salmon roe is generally not accepted by consumers. In Japan (and to a lesser degree, Europe), however, salmon caviar is considered a delicacy. And, in anadromous stream fisheries throughout the United States, salmon eggs for bait are in great demand. As a result, the salmon eggs taken from Great Lakes fish are economically important.

Early in the salmon program, this demand was primarily met by the black market. Many individuals snagged salmon solely for their eggs and the carcass of the adult was thrown back into the river. Although this was clearly illegal, reported profits as high as $20 per pound attracted many participants.

In an attempt to both control this illegal black market and enumerate the volume of egg sales, the MDNR authorized the sale of these eggs through a system of designated salmon egg buying stations. However, in 1985 the Michigan Attorney General ruled that the MDNR did not have the authority to allow the sale of eggs taken from sport-caught fish. Accordingly, the Michigan Legislature passed enabling legislation which authorized sport anglers to exchange salmon eggs for fish cleaning services at designated fish cleaning stations. Station operators were then legally allowed to sell salmon eggs, so collected, to wholesale fish dealers.

Salmon eggs have been sold through authorized channels since 1983 (Table 38). Unfortunately, caution must be used in interpreting these reported sales. The existing reporting system does not contain a method for verifying accuracy and most persons associated with this program assume there has been significant under-reporting.

Although there appears to be a clear downward trend in the pounds of eggs sold, another factor other than fewer adult females may be operating. The economic value of salmon eggs has also dropped during the same 5-year period. Processed salmon eggs at the Tokyo Central Market are now valued at approximately $4 to $6 per pound, depending on egg quality and existing international monetary exchange rates. In earlier years, values sometimes approached $10 to $14 per pound.

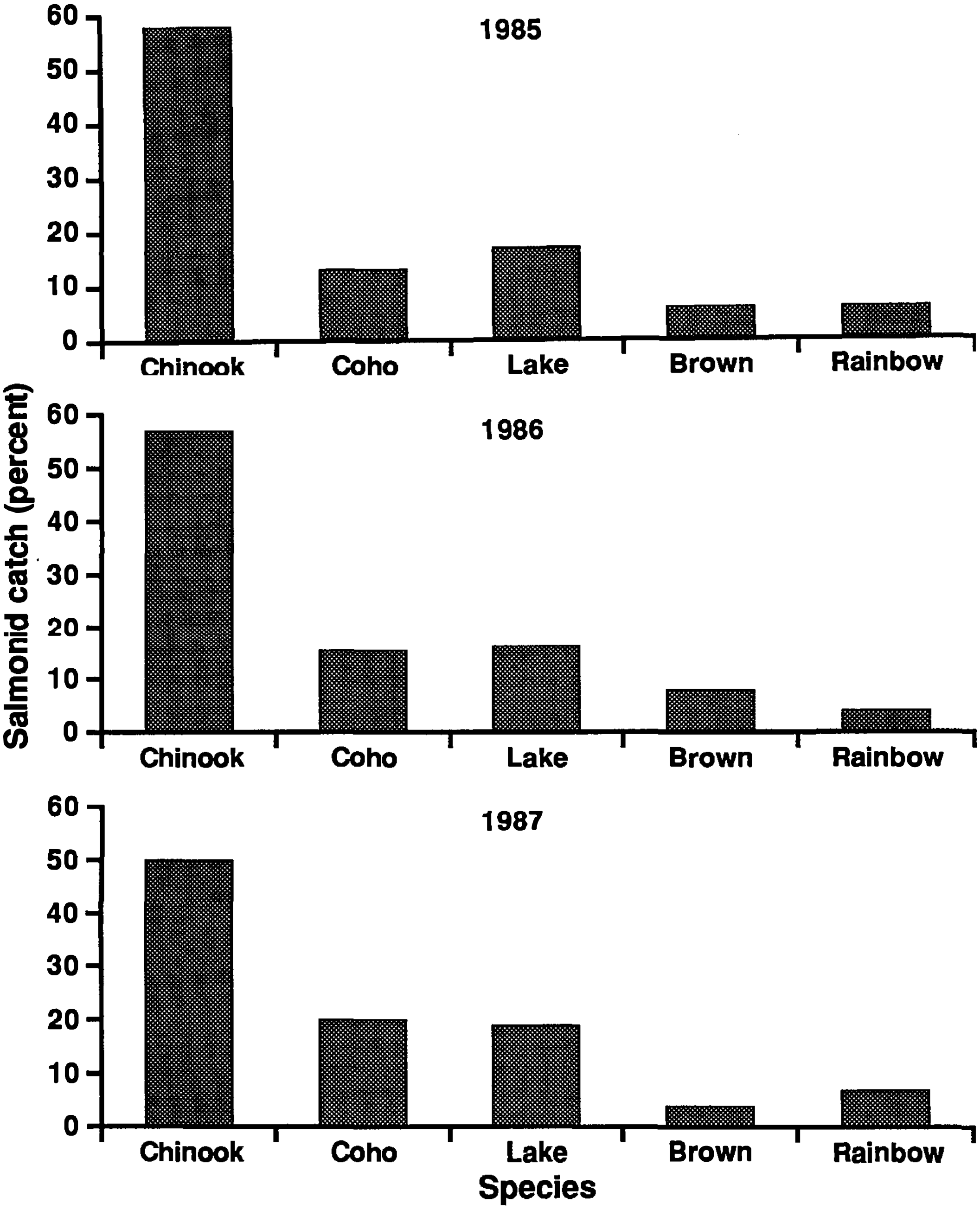

Figure 1. Species composition (percent) of salmonids harvested by anglers on Lake Michigan during the period 1985-87.

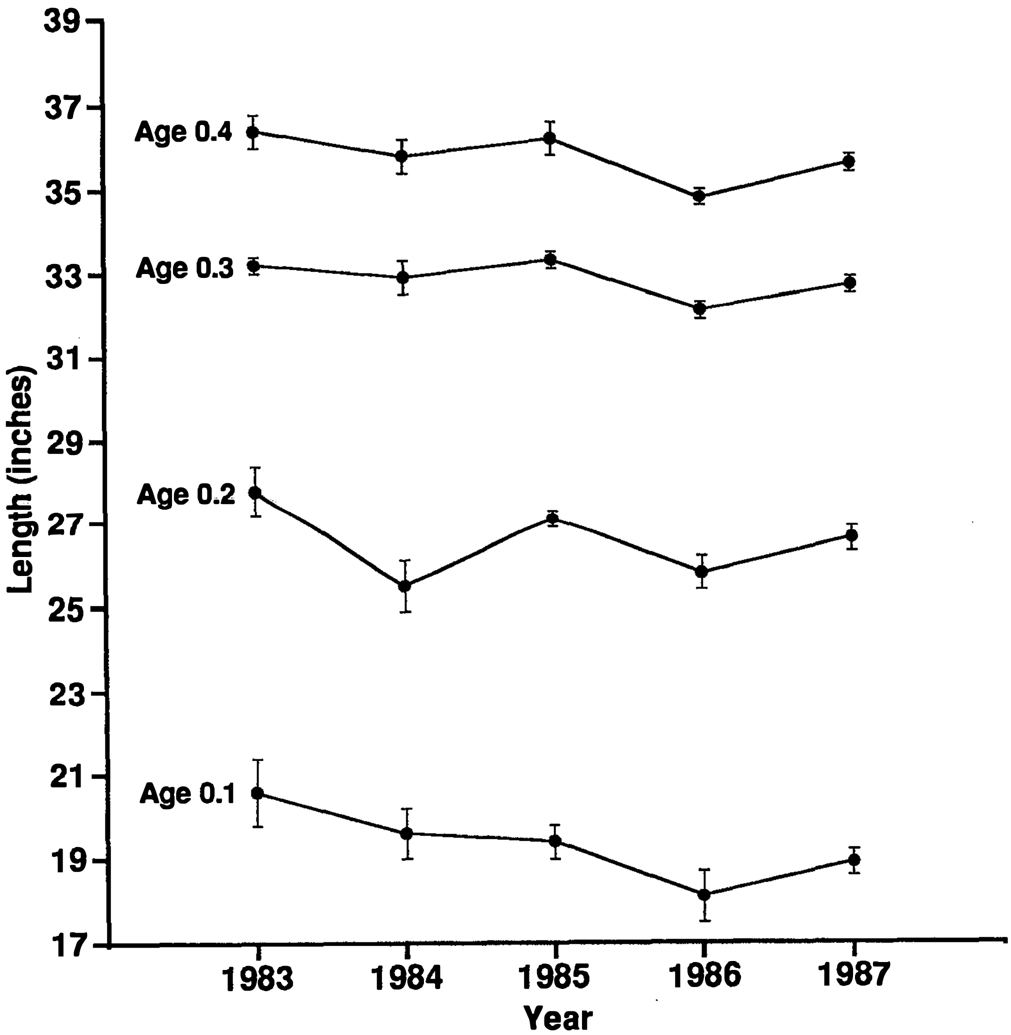

Figure 2. Mean total length (inches) at age of chinook salmon harvested by anglers on Lake Michigan during the period 1983-87.

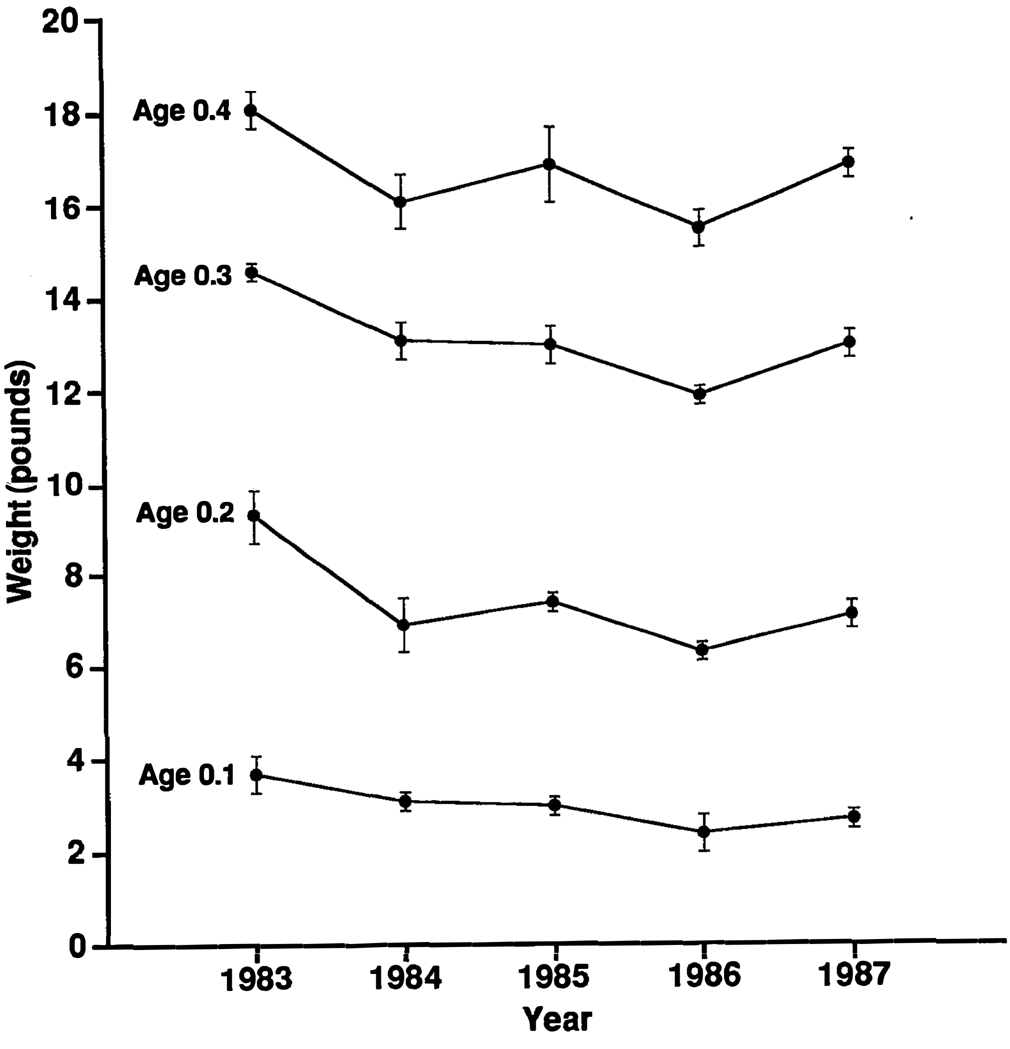

Figure 3. Mean round weight (pounds) at age of chinook salmon harvested by anglers on Lake Michigan during the period 1983-87.

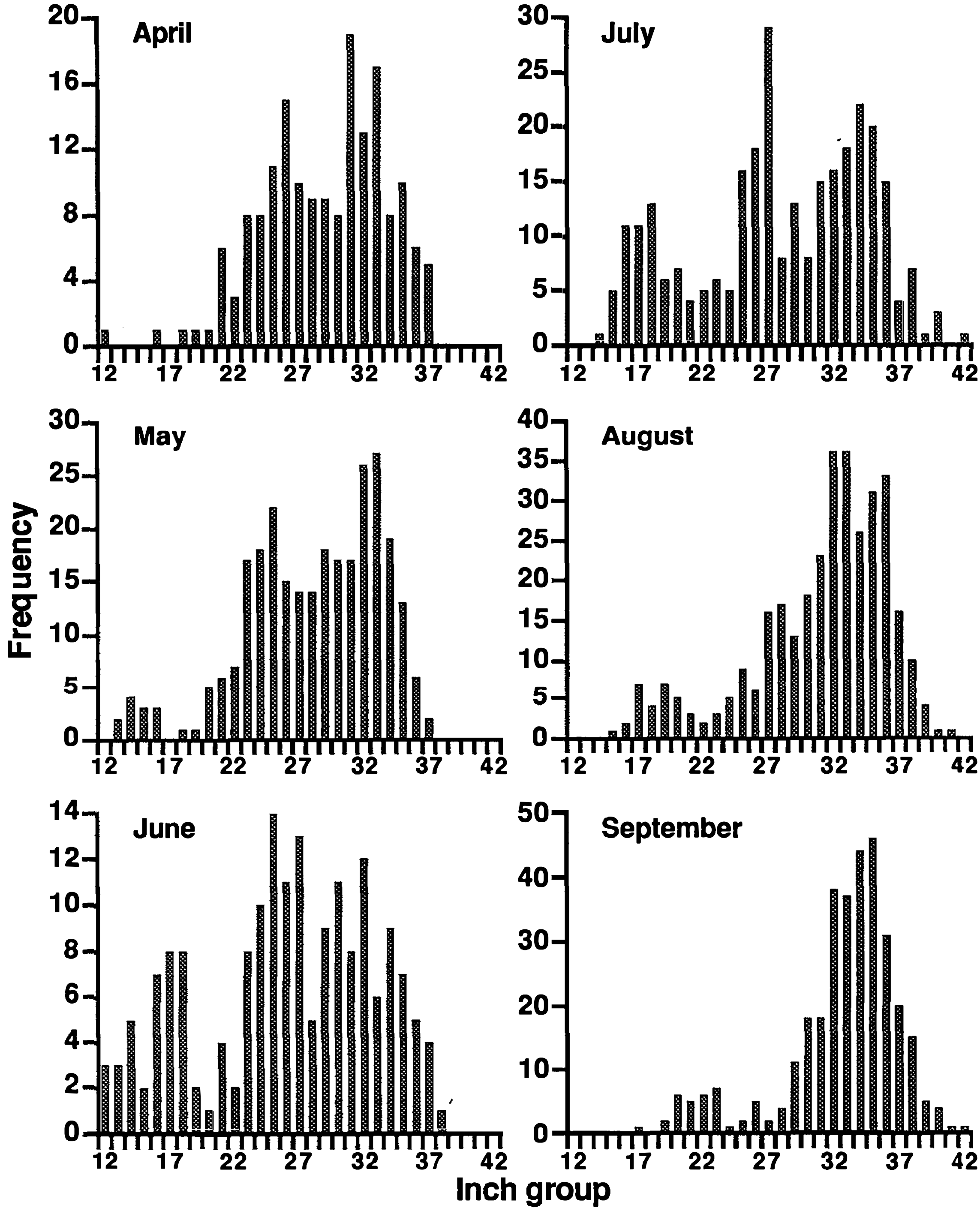

Figure 4. Length-frequency distributions of chinook salmon harvested by anglers on Lake Michigan during the period April to September 1985.

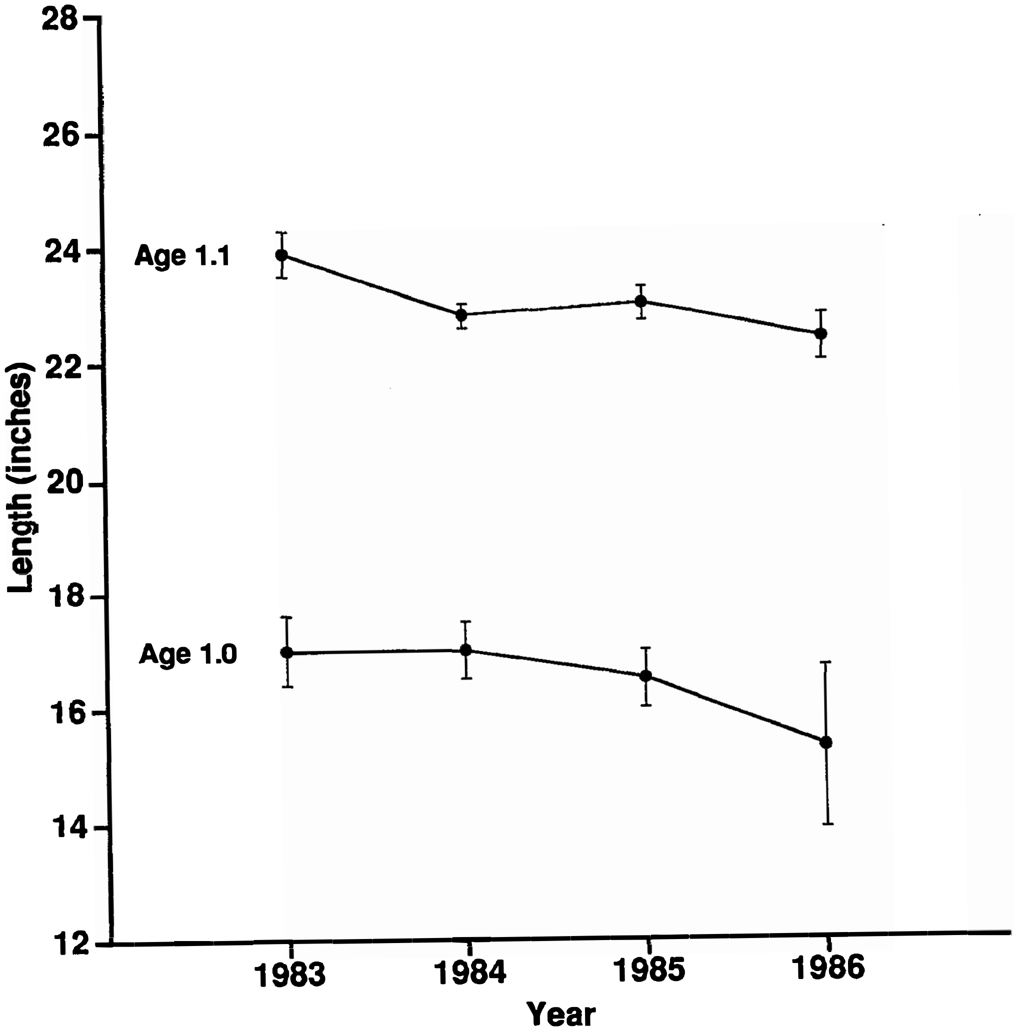

Figure 5. Mean total length (inches) at age of coho salmon harvested by anglers on Lake Michigan during the period 1983-86.

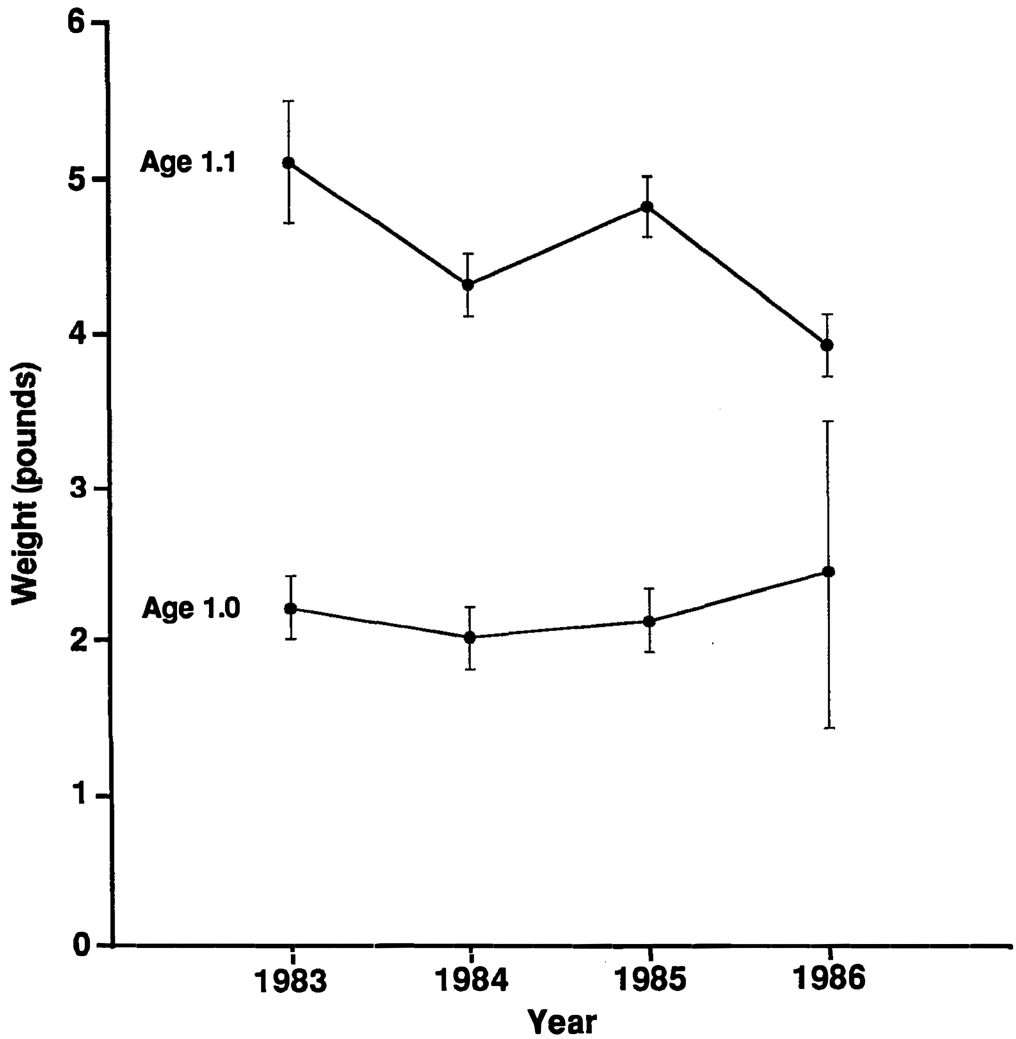

Figure 6. Mean round weight (pounds) at age of coho salmon harvested by anglers on Lake Michigan during the period 1983-86.

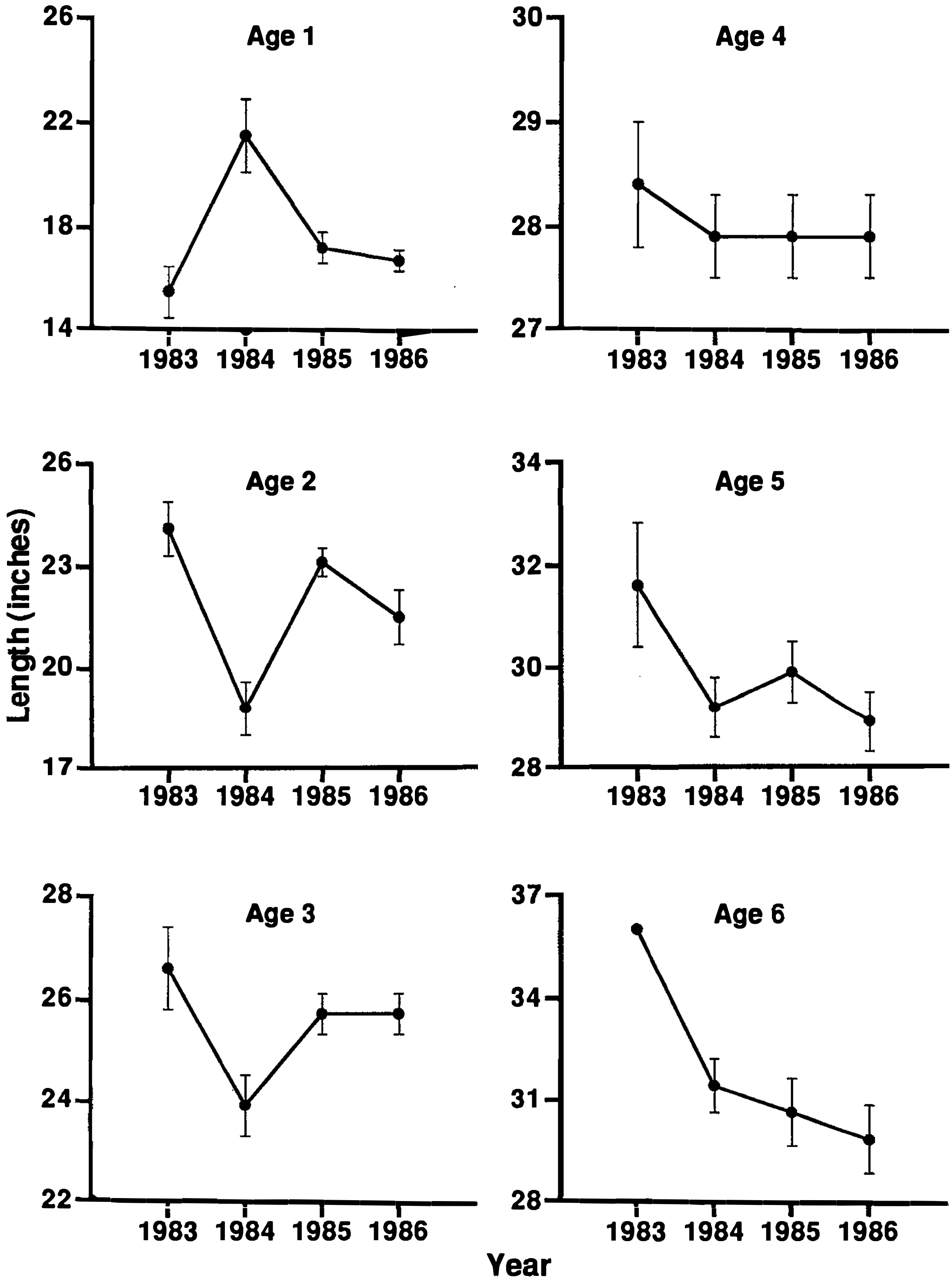

Figure 7. Mean total length (inches) at age of rainbow (steelhead) trout harvested by anglers on Lake Michigan during the period 1983-86.

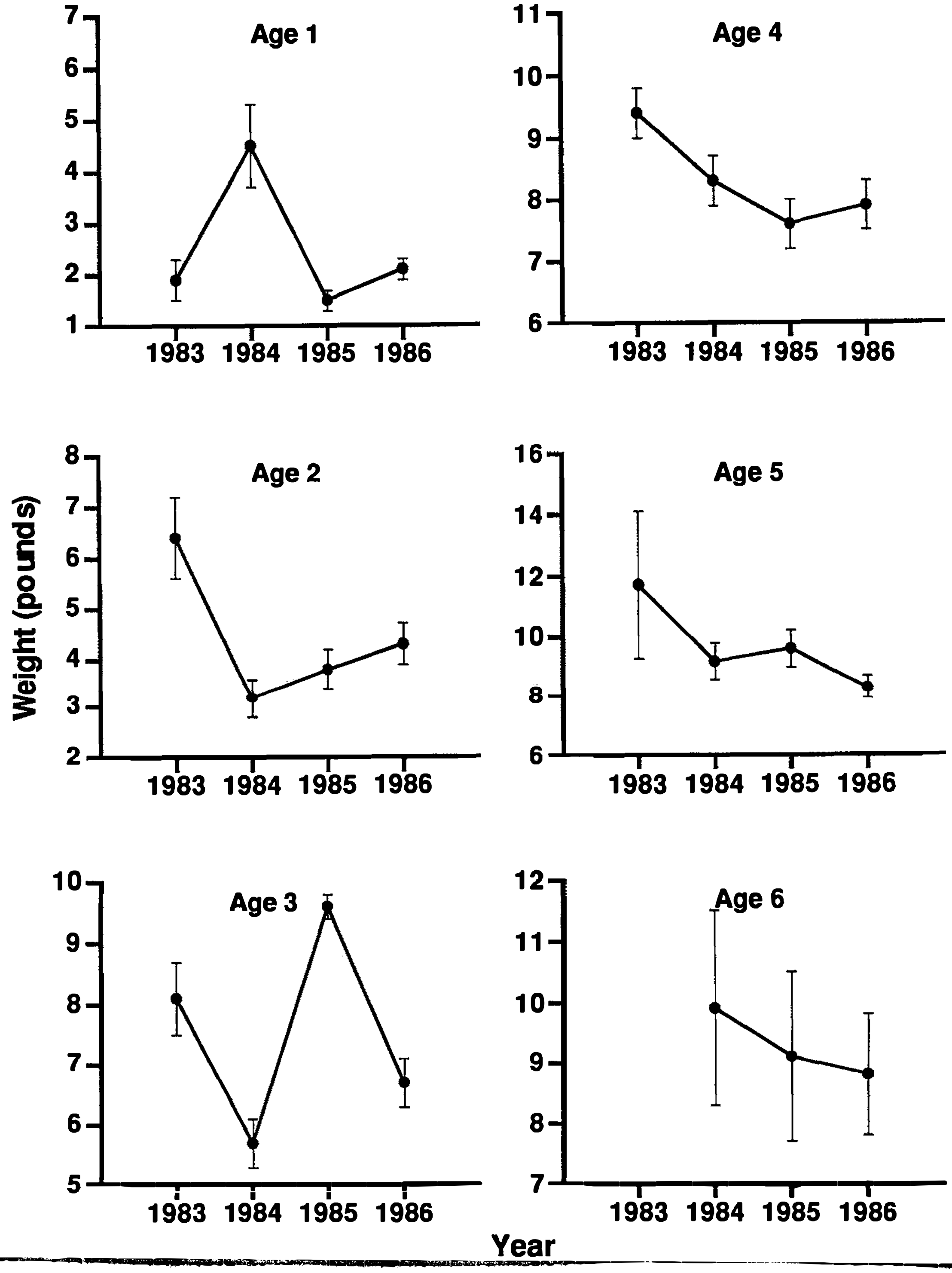

Figure 8. Mean round weight (pounds) at age of rainbow (steelhead) trout harvested by anglers on Lake Michigan during the period 1983-86.

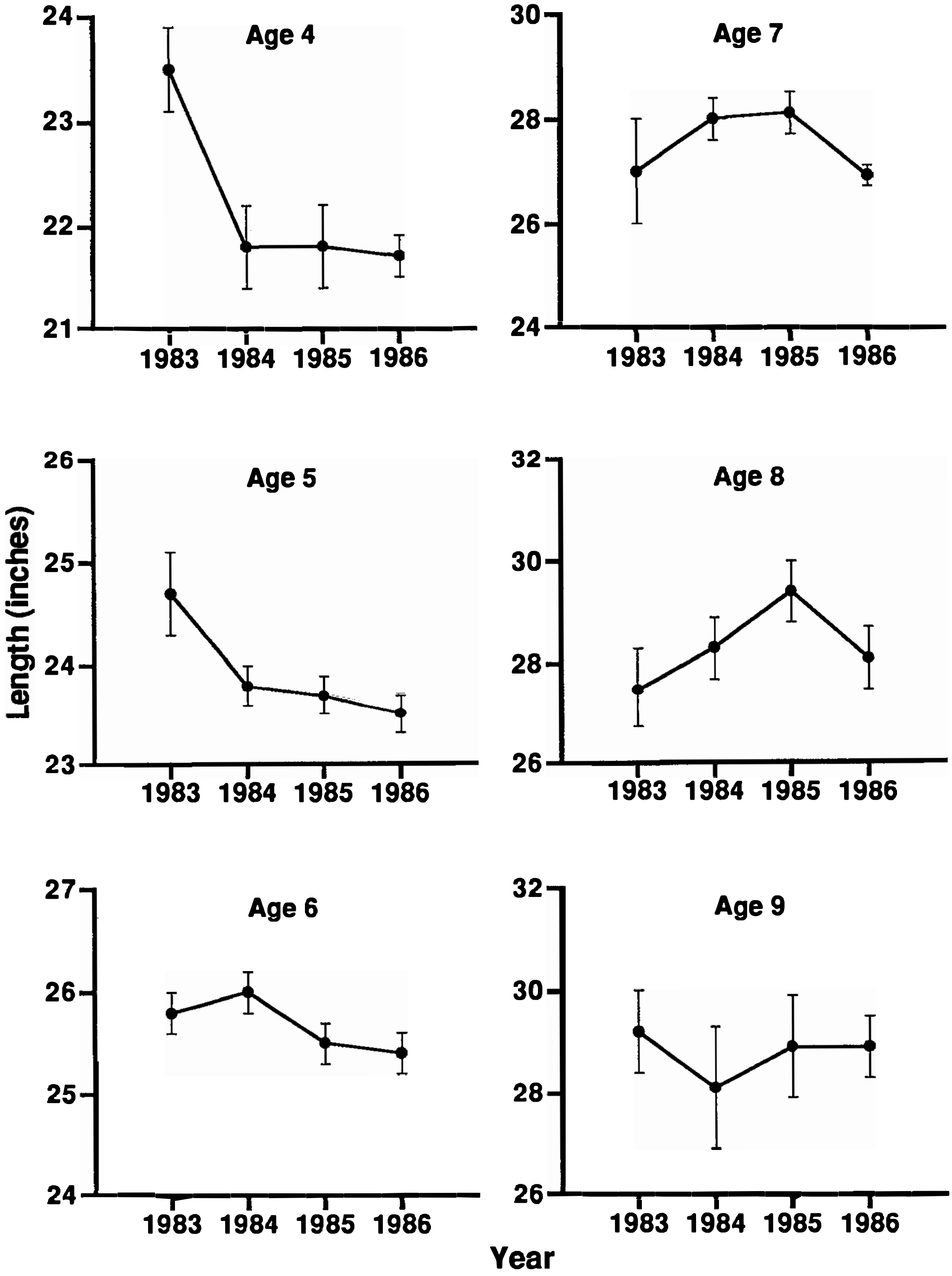

Figure 9. Mean total length (inches) at age of lake trout harvested by anglers on Lake Michigan during the period 1983-86.

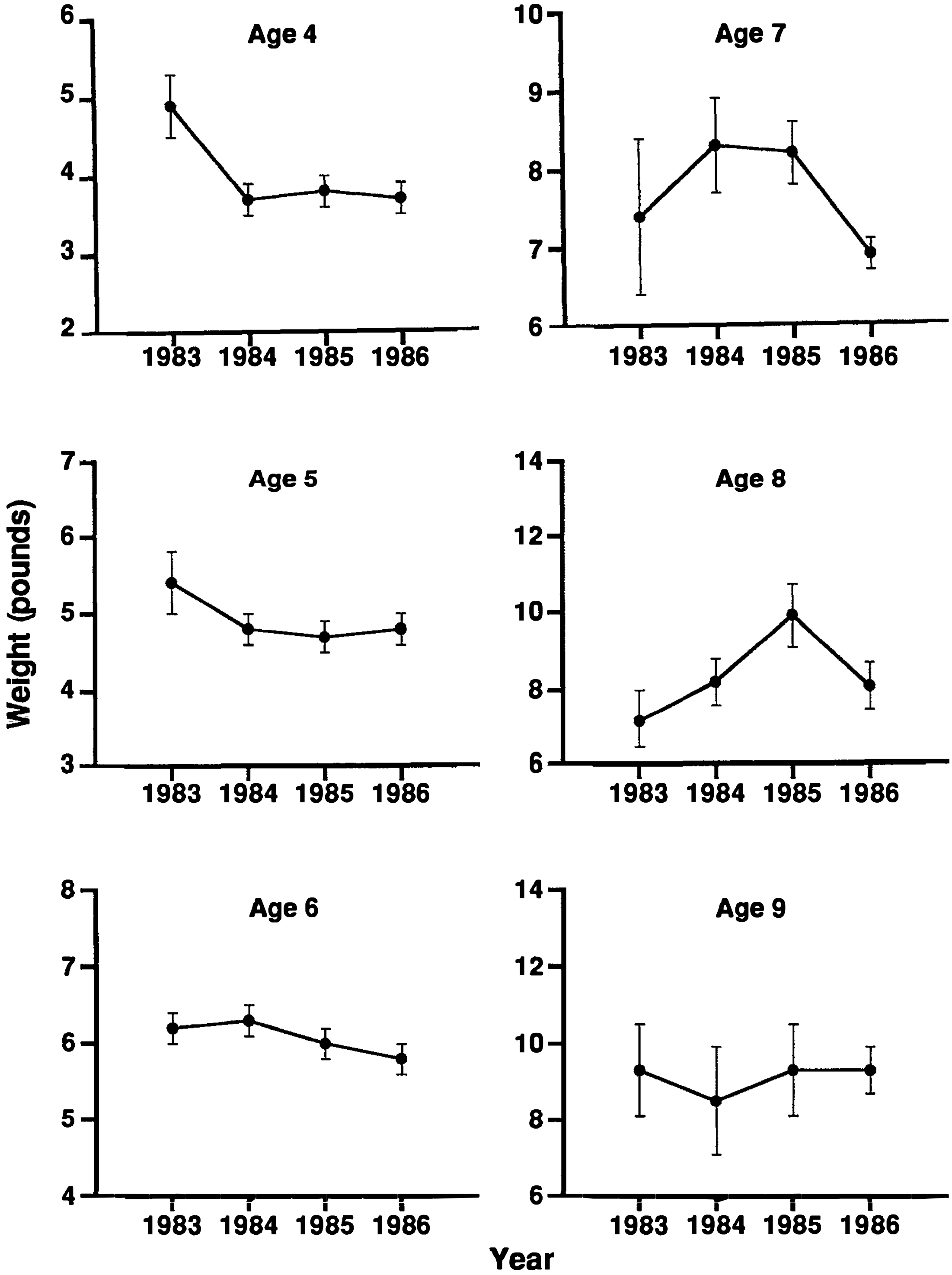

Figure 10. Mean round weight (pounds) at age of lake trout harvested by anglers on Lake Michigan during the period 1983-86.

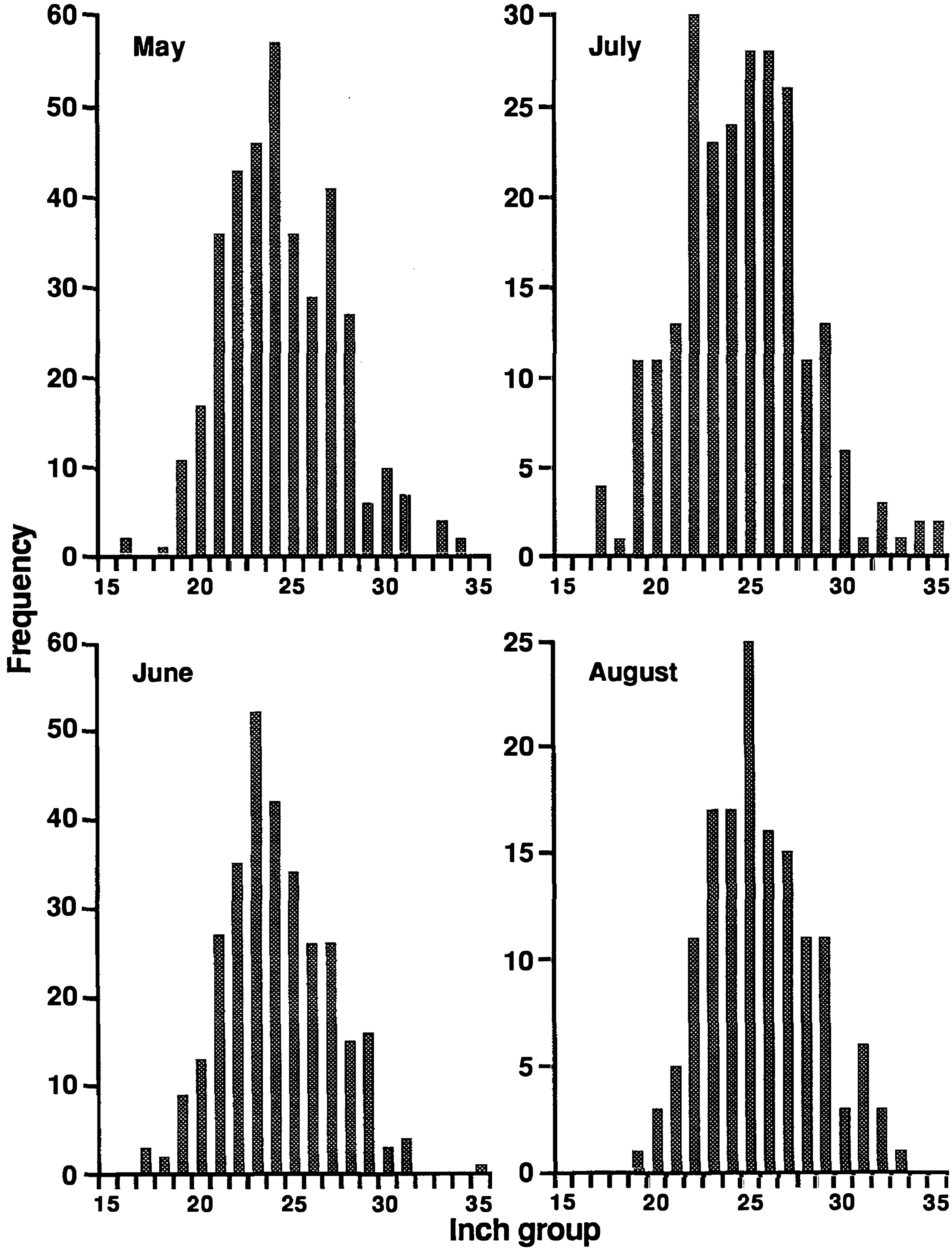

Figure 11. Length-frequency distributions of lake trout harvested by anglers on Lake Michigan during the period May to August 15, 1985.

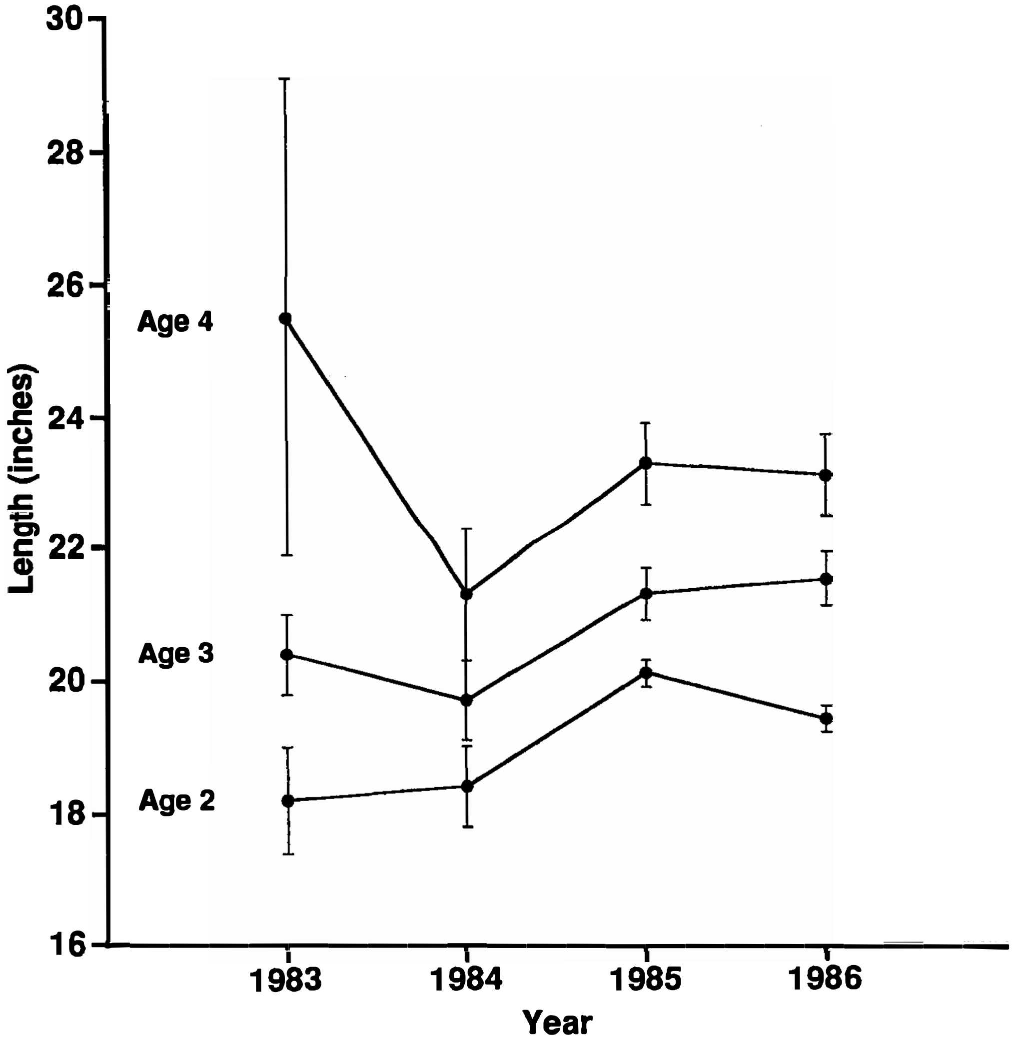

Figure 12. Mean total length (inches) at age of brown trout harvested by anglers on Lake Michigan during the period 1983-86.

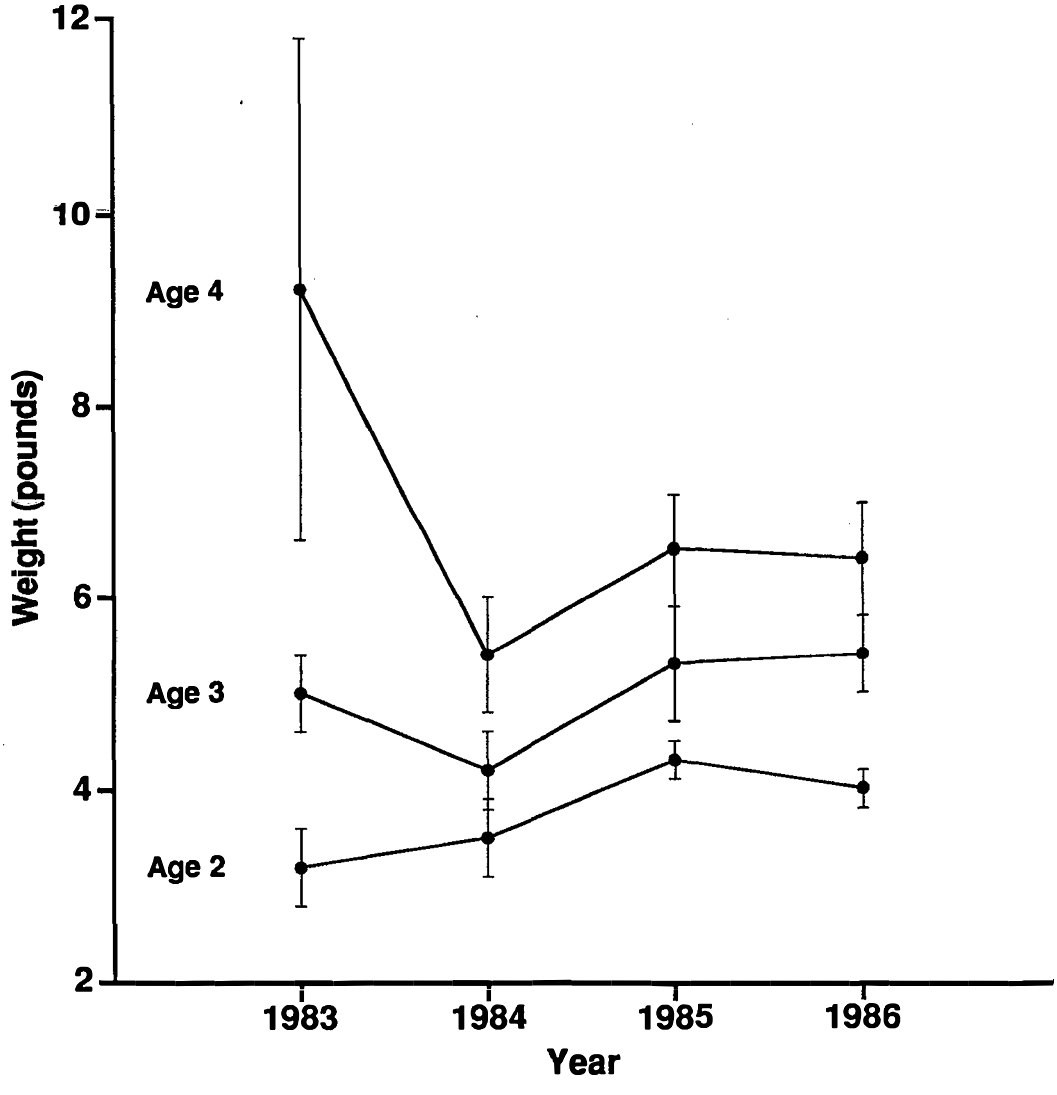

Figure 13. Mean round weight (pounds) at age of brown trout harvested by anglers on Lake Michigan during the period 1983-86.

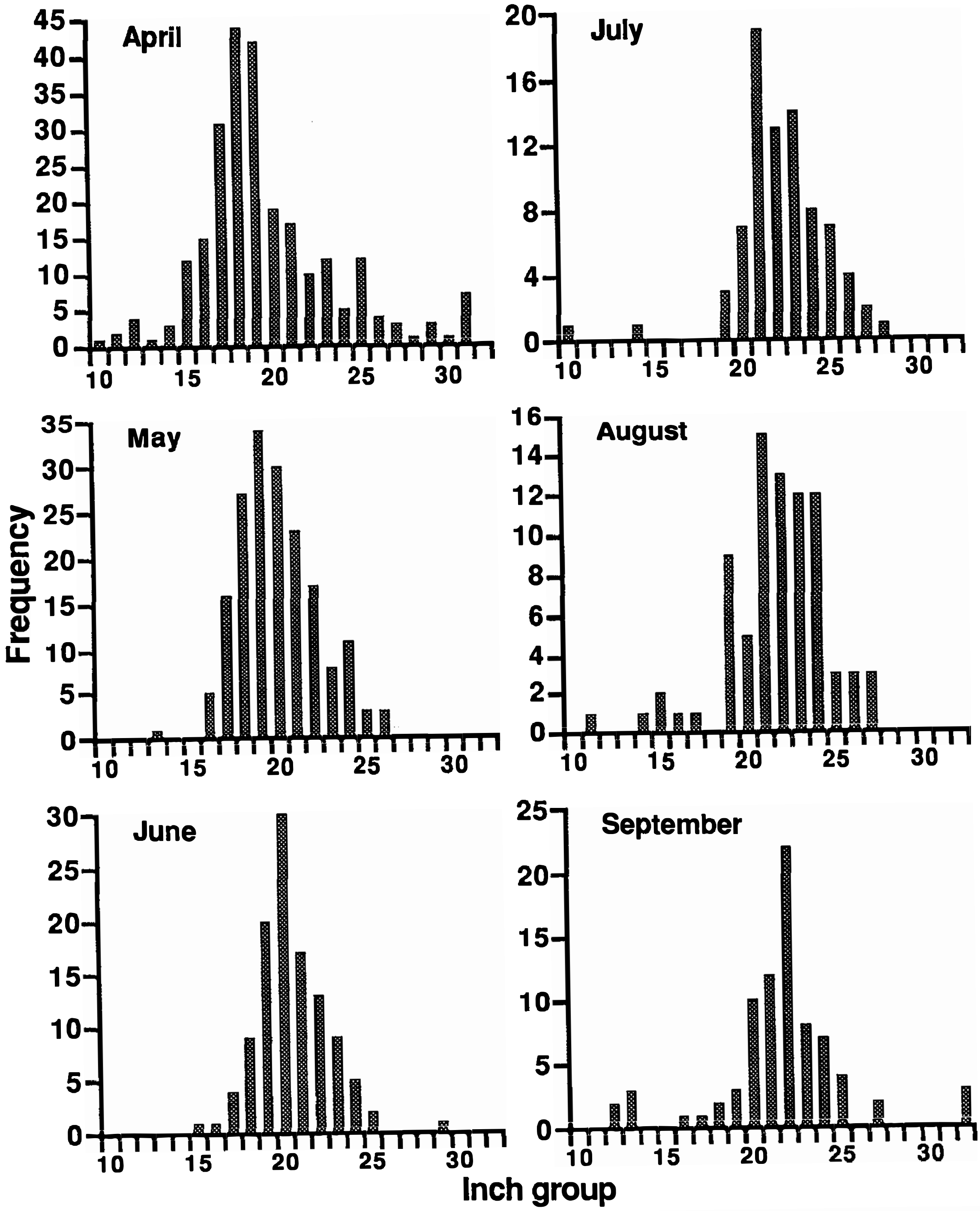

Figure 14. Length-frequency distributions of brown trout harvested by anglers on Lake Michigan during the period April to September 1985.

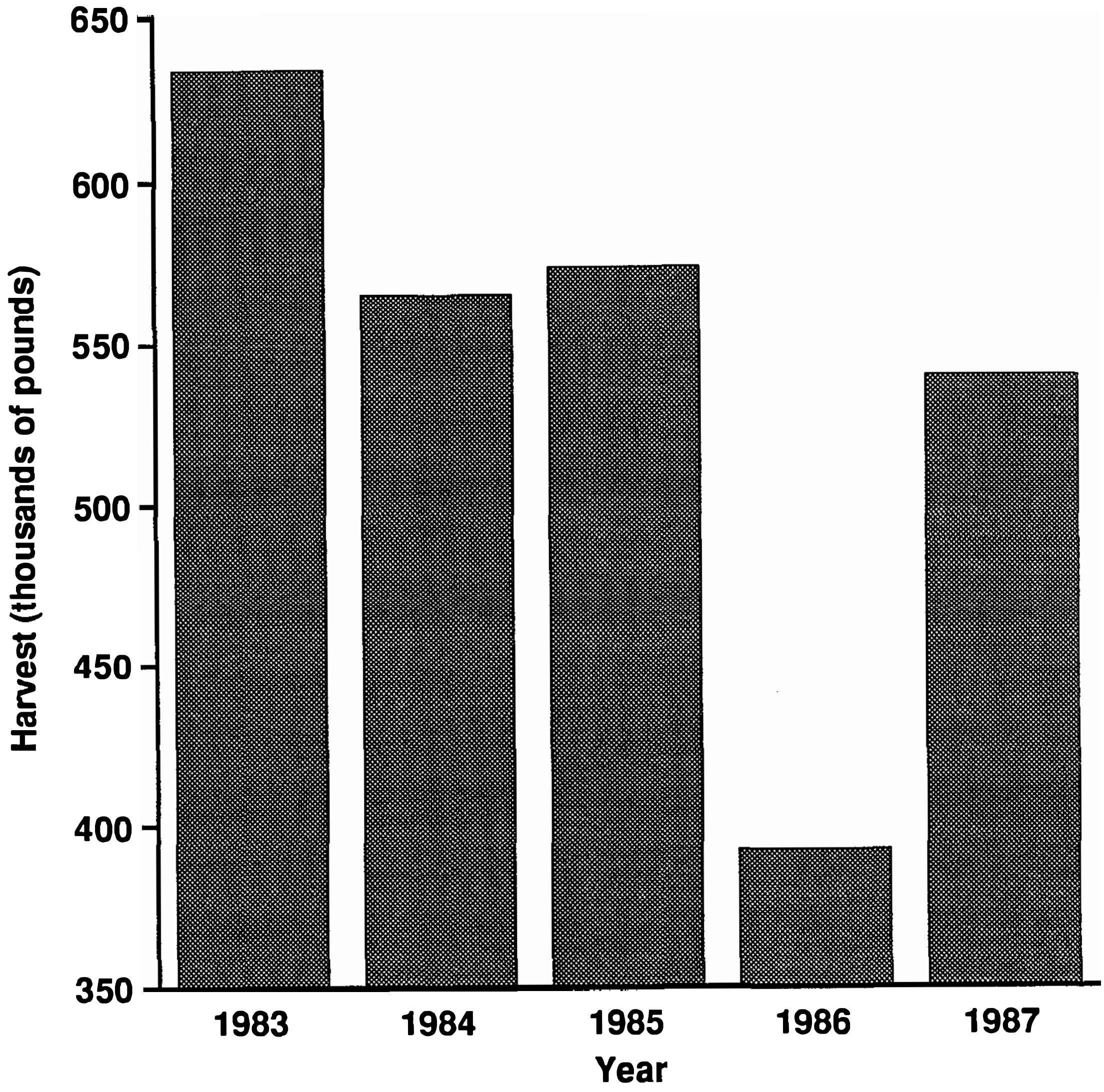

Figure 15. Total harvest (thousands of pounds) of chinook salmon at the Little Manistee and upper and lower Platte River weirs in Michigan, and the Strawberry Creek Pond in Wisconsin during the period 1983-87.

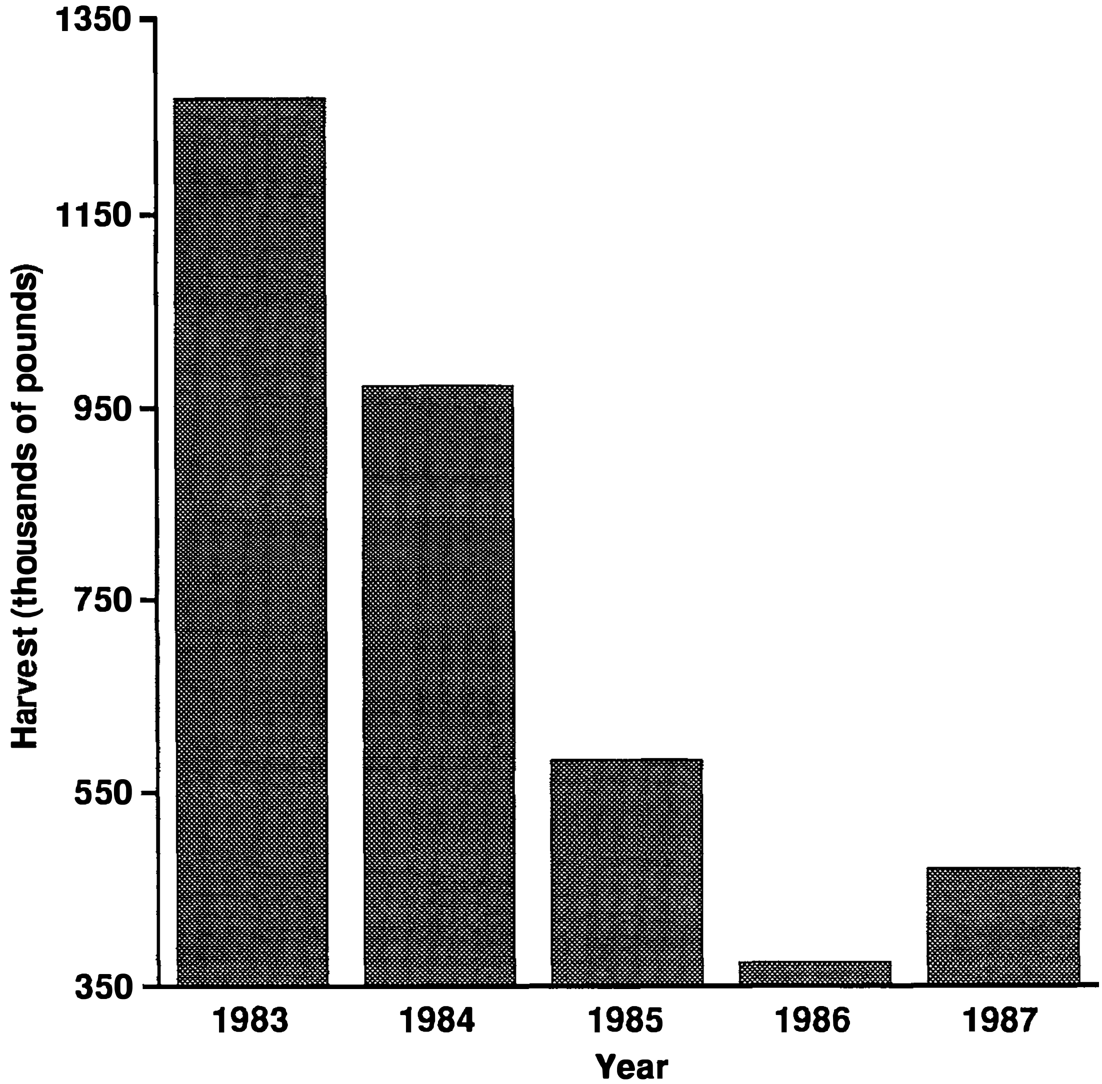

Figure 16. Total harvest (thousands of pounds) of coho salmon at the Little Manistee and lower Platte River weirs in Michigan during the period 1983-87.

Table 1. Estimated angler effort from areas sampled on Lake Michigan by month and zone during 1985-87. Two standard errors in parentheses.

Year	Month: Apr	May	Jun	Jul	Aug	Sep	Oct	Season
Southern								
1985	157,399	595,663	461,218	791,897	821,668	394,440	84,410	3,306,695
	(33,264)	(120,233)	(59,658)	(101,215)	(107,152)	(62,762)	(13,575)	(212,063)
1986	336,741	681,017	427,824	893,795	566,863	306,599	32,441	3,245,280
	(48,439)	(186,152)	(95,797)	(185,437)	(123,922)	(66,441)	(11,450)	(316,962)
1987	411,149	567,591	461,976	433,561	350,964	341,346	21,957	2,588,544
	(69,491)	(141,209)	(104,349)	(64,974)	(79,171)	(101,293)	(3,103)	(237,523)
Central								
1985	44,803	162,470	239,697	448,601	632,299	323,319	108,802	1,959,991
	(8,913)	(39,804)	(36,203)	(102,458)	(142,813)	(44,590)	(16,256)	(190,053)
1986	119,537	313,932	293,456	561,213	771,242	247,543	72,717	2,379,640
	(23,022)	(230,604)	(105,562)	(180,411)	(171,899)	(80,965)	(18,373)	(365,844)
1987	86,949	180,324	217,866	261,423	564,825	626,944	64,992	2,003,323
	(17,335)	(68,204)	(84,671)	(62,020)	(225,315)	(145,844)	(6,979)	(296,739)
Northern								
1985	43,506	91,365	168,014	277,605	231,819	141,811	76,735	1,030,855
	(5,874)	(17,062)	(17,221)	(42,604)	(37,379)	(12,763)	(11,195)	(64,208)
1986	85,149	143,197	125,832	267,722	222,024	82,781	43,297	970,002
	(12,494)	(15,804)	(34,084)	(45,051)	(23,667)	(13,862)	(7,447)	(66,370)
1987	100,735	59,391	119,274	275,076	200,466	114,803	47,411	917,156
	(13,319)	(7,822)	(15,361)	(21,606)	(30,368)	(11,880)	(6,395)	(45,228)
Lake wide								
1985	245,708	849,498	868,929	1,518,103	1,685,786	859,570	269,947	6,297,541
	(34,935)	(127,795)	(71,877)	(150,191)	(182,412)	(78,040)	(23,956)	(291,914)
1986	541,427	1,138,146	847,112	1,722,730	1,560,129	636,923	148,455	6,594,922
	(55,068)	(296,784)	(146,568)	(262,611)	(213,228)	(105,650)	(22,893)	(488,582)
1987	598,833	807,306	799,116	970,060	1,116,255	1,083,093	134,360	5,509,023
	(72,848)	(157,012)	(135,255)	(92,384)	(270,743)	(177,966)	(9,962)	(382,775)

Table 2. Estimated sport harvest of chinook salmon from areas sampled on Lake Michigan by month and zone during 1985-87. Two standard errors in parentheses.

Year	Month							
	Apr	May	Jun	Jul	Aug	Sep	Oct	Season
Southern								
1985	12,762 (4,061)	70,563 (22,984)	6,703 (2,332)	25,249 (9,363)	53,520 (21,000)	20,516 (5,663)	1,262 (666)	190,575 (33,338)
1986	17,492 (5,510)	87,881 (30,996)	7,431 (3,389)	31,316 (12,528)	35,754 (13,199)	14,816 (7,580)	70 (142)	194,760 (37,299)
1987	10,929 (5,184)	16,027 (7,561)	7,155 (4,773)	37,069 (29,542)	21,309 (11,879)	17,861 (10,340)	187 (222)	110,537 (35,038)
Central								
1985	2,063 (794)	17,581 (6,363)	20,186 (4,529)	49,284 (12,616)	92,947 (23,223)	21,378 (6,327)	2,592 (1,622)	206,031 (28,333)
1986	1,872 (1,294)	75,481 (72,945)	19,546 (15,874)	58,015 (31,001)	108,650 (33,143)	20,877 (9,603)	1,439 (993)	285,880 (87,905)
1987	773 (490)	8,679 (5,778)	9,174 (6,357)	24,650 (8,421)	100,530 (45,855)	47,025 (13,343)	1,075 (1,290)	191,906 (49,268)
Northern								
1985	3 (5)	0 (0)	540 (486)	8,407 (4,304)	19,396 (12,384)	5,785 (2,944)	4,418 (2,287)	38,549 (13,639)
1986	5 (11)	0 (0)	16 (23)	16,000 (12,250)	10,401 (3,383)	5,286 (1,756)	1,432 (673)	33,140 (13,105)
1987	0 (0)	0 (0)	2,073 (1,194)	19,508 (5,110)	13,603 (4,868)	6,447 (1,833)	2,938 (1,041)	44,569 (7,462)
Lake wide								
1985	14,828 (4,138)	88,144 (23,849)	27,429 (5,117)	82,940 (16,290)	165,863 (33,670)	47,679 (8,987)	8,272 (2,882)	435,155 (45,827)
1986	19,369 (5,660)	163,362 (79,258)	26,993 (16,232)	105,331 (35,704)	154,805 (35,835)	40,979 (12,360)	2,941 (1,208)	513,780 (96,387)
1987	11,702 (5,207)	24,706 (9,516)	18,402 (8,039)	81,227 (31,141)	135,442 (47,618)	71,333 (16,980)	4,200 (1,672)	347,012 (60,915)

Table 3. Salmonid harvest rates (fish per 100 angler hours) by year and zone for anglers fishing Lake Michigan during 1985-87. Two standard errors in parentheses.

Species	1985	1986	1987
Southern			
Chinook	5.8	6.0	4.3
	(1.1)	(1.3)	(1.4)
Coho salmon	1.5	2.4	2.8
	(0.4)	(0.6)	(0.9)
Lake trout	2.0	2.4	3.7
	(0.5)	(0.7)	(1.2)
Rainbow (steelhead) trout	0.4	0.5	0.3
	(0.1)	(0.4)	(0.1)
Brown trout	0.5	0.5	0.3
	(0.2)	(0.2)	(0.2)
Central			
Chinook salmon	10.5	12.0	9.6
	(1.8)	(4.1)	(2.8)
Coho salmon	2.3	2.3	3.3
	(0.4)	(0.8)	(1.0)
Lake trout	2.4	3.0	3.4
	(0.6)	(2.2)	(2.0)
Rainbow (steelhead) trout	1.1	0.6	1.8
	(0.2)	(0.2)	(0.6)
Brown trout	1.2	2.3	0.8
	(0.3)	(0.7)	(0.3)
Northern			
Chinook salmon	3.7	3.4	4.9
	(1.3)	(1.4)	(0.9)
Coho salmon	0.5	0.1	0.1
	(0.2)	(0.1)	(0.1)
Lake trout	4.9	2.8	3.2
	(1.4)	(0.8)	(0.6)
Rainbow (steelhead) trout	0.7	0.3	0.5
	(0.3)	(0.1)	(0.2)
Brown trout	0.6	0.3	0.6
	(0.2)	(0.1)	(0.2)
Lake wide			
Chinook salmon	6.9	7.8	6.3
	(0.8)	(1.6)	(1.2)
Coho salmon	1.6	2.0	2.5
	(0.2)	(0.4)	(0.5)
Lake trout	2.6	2.7	3.5
	(0.4)	(0.9)	(0.9)
Rainbow (steelhead) trout	0.7	0.5	0.8
	(0.1)	(0.2)	(0.2)
Brown trout	0.7	1.1	0.5
	(0.1)	(0.3)	(0.1)

Table 4. Estimated chinook salmon harvest and percent return by age from Lake Michigan during 1985-87.

Year	Estimated[1] harvest	Age	Percent distribution	Estimated harvest by age	Year class	Number stocked (millions)	Percent return
1983	---	0.1	9	---	---	---	---
	---	0.2	30	---	---	---	---
	---	0.3	44	---	---	---	---
	---	0.4	17	---	---	---	---
1984	---	0.1	12	---	---	---	---
	---	0.2	27	---	---	---	---
	---	0.3	40	---	---	---	---
	---	0.4	20	---	---	---	---
	---	0.5	1	---	---	---	---
1985	511,420	0.1	13	66,485	1984	3.35	2.0
		0.2	33	168,769	1983	2.98	5.7
		0.3	43	219,911	1982	2.58	8.5
		0.4	10	56,257	1981	2.25	2.5
1986	586,403	0.1	6	35,185	1985	2.26	1.6
		0.2	23	134,873	1984	3.35	4.0
		0.3	54	316,658	1983	2.98	10.6
		0.4	17	99,689	1982	2.58	3.9
1987	364,448	0.1	14[2]	51,023	1986	2.40	2.1
		0.2	27	98,401	1985	2.26	4.4
		0.3	35	127,557	1984	3.35	3.8
		0.4	23	83,823	1983	2.98	2.8
		0.5	1	3,644	1982	2.58	0.1

[1]Estimated harvest for all ports which were sampled.

[2]Preliminary data.

Table 5. Estimated total harvest, mean stocking rate, and estimated percent return of chinook salmon from Lake Michigan by state in 1985.

State	Estimated harvest (numbers)	Estimated harvest (percent)	Mean number stocked 1981-84 (millions)	Estimated return (percent)
Wisconsin	328,920[1]	36	2.38	13.8
Illinois	66,525[2]	7	0.55	11.7
Indiana	15,292[3]	2	0.44	3.5
Michigan	511,420	55	2.79	18.3
Total	922,157	---	6.16	15.0

[1]P. Schultz, WDNR, unpublished data.

[2]Assumes that the Illinois charter-boat harvest was the same in 1985 as in 1984 (Horns and Gorden 1986).

[3]D. Brazo, IDNR, unpublished data.

Table 6. Number of charter-boat operators on Lake Michigan by state during 1976-86.

Year	Illinois[1]	Wisconsin[2]	Michigan	Total
1976	50	188	177	415
1977	49	200	179	428
1978	99	159	224	482
1979	88	144	194	426
1980	113	154	212	479
1981	110	172	240	522
1982	138	264	309	711
1983	215	364	390	969
1984	222	477	498	1,197
1985	---	524	606	---
1986	---	---	639	---

[1]T. Trudeau, IDC, unpublished data.

[2]WDNR unpublished data.

Table 7. Harvest and harvest rates (fish per 100 angler hours) of chinook salmon in the Wisconsin and Illinois charter-boat fisheries during 1976-87.

	Wisconsin			Illinois		
Year	Harvest[1]	Percent of total charter harvest	Harvest rate	Harvest[2]	Percent of total charter harvest	Harvest rate
1976	3,066	16	4.5	146	4	1.0
1977	5,456	22	6.5	421	8	2.5
1978	8,978	31	8.5	609	15	4.7
1979	8,810	31	8.4	5,173	16	4.5
1980	12,631	37	10.3	5,088	15	4.0
1981	20,752	42	11.3	8,801	16	5.4
1982	26,193	41	11.0	7,679	12	4.9
1983	36,147	39	11.3	9,070	20	5.7
1984	49,612	42	12.7	9,109	17	6.2
1985	56,919	50	15.5	---	---	---
1986	67,520	54	16.3	---	---	---
1987	76,522	51	16.6	---	---	---

[1]WDNR, unpublished data.

[2]T. Trudeau, IDC, unpublished data.

Table 8. Estimated sport harvest of coho salmon from areas sampled on Lake Michigan by month and zone during 1985-87. Two standard errors in parentheses.

Year	Month							Season
	Apr	May	Jun	Jul	Aug	Sep	Oct	
Southern								
1985	8,839	19,875	4,503	2,855	7,865	3,251	2,455	49,643
	(3,309)	(10,820)	(2,033)	(1,418)	(2,969)	(2,174)	(1,001)	(12,195)
1986	53,436	18,860	1,275	932	1,714	1,829	28	78,074
	(15,693)	(9,781)	(884)	(792)	(851)	(2,109)	(63)	(18,669)
1987	38,357	25,293	4,475	909	1,498	1,176	0	71,708
	(17,907)	(10,507)	(5,055)	(1,757)	(2,392)	(1,271)	(0)	(21,611)
Central								
1985	78	903	1,962	4,654	16,303	19,539	1,714	45,153
	(65)	(704)	(1,202)	(1,759)	(4,969)	(4,151)	(1,129)	(6,945)
1986	1,860	2,552	796	10,392	29,954	9,069	704	55,327
	(1,791)	(2,307)	(911)	(7,641)	(13,769)	(5,270)	(506)	(16,893)
1987	1,587	2,688	1,406	1,921	19,785	37,375	836	65,598
	(1,227)	(1,775)	(1,132)	(1,832)	(13,277)	(11,101)	(539)	(17,581)
Northern								
1985	0	0	131	0	53	3,412	1,450	5,046
	(0)	(0)	(170)	(0)	(94)	(1,822)	(1,680)	(2,486)
1986	0	0	0	417	92	222	0	731
	(0)	(0)	(0)	(877)	(192)	(198)	(0)	(919)
1987	12	0	156	113	392	331	310	1,314
	(25)	(0)	(211)	(123)	(313)	(233)	(249)	(524)
Lake wide								
1985	8,917	20,778	6,596	7,509	24,221	26,202	5,619	99,842
	(3,309)	(10,843)	(2,368)	(2,259)	(5,789)	(5,028)	(2,258)	(14,252)
1986	55,296	21,412	2,071	11,741	31,760	11,120	732	134,132
	(15,794)	(10,050)	(1,270)	(7,731)	(13,797)	(5,680)	(510)	(25,194)
1987	39,956	27,981	6,037	2,943	21,675	38,882	1,146	138,627
	(17,949)	(10,656)	(5,185)	(2,541)	(13,495)	(11,176)	(594)	(27,864)

Table 9. Estimated coho salmon harvest and percent return by age from Lake Michigan during 1985-87.

Year	Estimated[1] harvest	Age	Percent distribution	Estimated harvest by age	Year class	Number stocked (millions)	Percent return
1983	---	1.0	8	---	---	---	---
		1.1	92	---	---	---	---
1984	---	1.0	8	---	---	---	---
		1.1	92	---	---	---	---
1985	111,981	1.0	8	8,959	1984	1.69	0.5
		1.1	92	103,022	1983	2.04	5.0
1986	146,033	1.0	7	10,222	1985	1.58	0.6
		1.1	93	135,811	1984	1.69	8.0
1987	139,409	1.0	8[2]	11,153	1986	1.33	0.8
		1.1	92	128,256	1985	1.58	8.1

[1]Estimated harvest for all ports which were sampled.

[2]Preliminary data.

Table 10. Estimated total harvest, mean stocking rate, and estimated percent return of coho salmon from Lake Michigan by state in 1985.

State	Estimated harvest (numbers)	Estimated harvest (percent)	Mean number stocked 1984 (millions)	Estimated return (percent)
Wisconsin	164,267[1]	37	0.27	60.8
Illinois	156,531[2]	35	0.00	---
Indiana	15,509[3]	3	0.13	11.9
Michigan	111,981	25	2.04	5.5
Total	448,288	---	2.44	18.4

[1]P. Schultz, WDNR, unpublished data.

[2]Assumes that the Illinois charter-boat harvest was the same in 1985 as in 1984 (Horns and Gorden 1986).

[3]D. Brazo, IDNR, unpublished data.

Table 11. Harvest and harvest rates (fish per 100 angler hours) of coho salmon in the Wisconsin and Illinois charter-boat fisheries during 1976-87.

	Wisconsin			Illinois		
Year	Harvest[1]	Percent of total charter harvest	Harvest rate	Harvest[2]	Percent of total charter harvest	Harvest rate
1976	2,982	15	4.4	3,183	90	21.7
1977	7,564	30	9.0	4,003	80	24.2
1978	4,921	16	4.7	3,013	76	23.5
1979	3,171	12	3.0	22,589	68	19.7
1980	9,251	26	7.6	24,726	73	19.7
1981	7,695	16	4.2	42,049	74	26.0
1982	13,263	21	5.6	46,238	75	29.3
1983	5,135	6	1.6	19,272	43	12.1
1984	25,217	22	6.5	35,814	66	24.3
1985	21,058	19	5.7	---	---	---
1986	20,442	16	4.9	---	---	---
1987	19,078	13	4.1	---	---	---

[1]WDNR, unpublished data.

[2]T. Trudeau, IDC, unpublished data.

Table 12. Estimated sport harvest of rainbow (steelhead) trout from areas sampled on Lake Michigan by month and zone during 1985-87. Two standard errors in parentheses.

Year	Month							Season
	Apr	May	Jun	Jul	Aug	Sep	Oct	
Southern								
1985	639	2,679	948	2,295	1,876	1,352	3,845	13,634
	(337)	(1,225)	(512)	(1,224)	(846)	(817)	(1,329)	(2,554)
1986	1,272	3,091	1,361	7,606	862	3,047	400	17,639
	(810)	(2,061)	(1,150)	(11,464)	(622)	(4,080)	(403)	(12,444)
1987	297	643	1,059	1,135	440	1,647	1,862	7,083
	(371)	(577)	(852)	(827)	(586)	(1,637)	(1,010)	(2,434)
Central								
1985	366	387	616	1,680	2,808	1,258	13,653	20,768
	(237)	(241)	(360)	(755)	(1,183)	(779)	(3,390)	(3,783)
1986	856	980	419	2,411	4,249	3,156	2,748	14,819
	(561)	(800)	(545)	(2,734)	(2,996)	(276)	(1,216)	(5,178)
1987	161	377	3,708	746	2,775	16,699	10,569	35,035
	(188)	(381)	(2,503)	(798)	(2,481)	(8,457)	(3,306)	(9,782)
Northern								
1985	1,701	118	159	175	720	2,112	1,987	6,972
	(1,878)	(117)	(120)	(167)	(1,212)	(1,980)	(1,242)	(3,243)
1986	1,033	277	11	185	311	179	617	2,613
	(966)	(236)	(21)	(160)	(423)	(227)	(439)	(1,199)
1987	1,400	188	28	1,631	188	304	425	4,164
	(892)	(169)	(40)	(1,091)	(186)	(241)	(309)	(1,485)
Lake wide								
1985	2,706	3,184	1,723	4,150	5,404	4,722	19,485	41,374
	(1,923)	(1,254)	(637)	(1,448)	(1,893)	(2,279)	(3,847)	(5,599)
1986	3,161	4,348	1,791	10,202	5,422	6,382	3,765	35,071
	(1,380)	(2,223)	(1,272)	(11,787)	(3,089)	(4,931)	(1,355)	(13,531)
1987	1,858	1,208	4,795	3,512	3,403	18,650	12,856	46,282
	(985)	(712)	(2,645)	(1,585)	(2,556)	(8,617)	(3,471)	(10,188)

Table 13. Estimated rainbow (steelhead) trout harvest and percent return by age from Lake Michigan during 1985-87.

Year	Estimated[1] harvest	Age	Percent distribution	Estimated harvest by age	Year class	Number[2] stocked (millions)	Percent return
1983	---	1	14	---	---	---	---
		2	37	---	---	---	---
		3	27	---	---	---	---
		4	18	---	---	---	---
		5	3	---	---	---	---
		6	1	---	---	---	---
1984	---	1	12	---	---	---	---
		2	23	---	---	---	---
		3	24	---	---	---	---
		4	24	---	---	---	---
		5	12	---	---	---	---
		6	4	---	---	---	---
		7	1	---	---	---	---
1985	46,822	1	11	5,150	1984	0.92	0.6
		2	20	9,364	1983	0.39	2.4
		3	33	15,451	1982	0.88	1.8
		4	24	11,237	1981	0.49	2.3
		5	9	4,214	1980	1.37	0.3
		6	3	1,406	1979	1.24	0.1
1986	40,005	1	8	3,200	1985	0.49	0.7
		2	16	6,401	1984	0.92	0.7
		3	36	14,402	1983	0.39	3.7
		4	24	9,602	1982	0.88	1.1
		5	12	4,801	1981	0.49	1.0
		6	3	1,200	1980	1.37	0.1
		7	1	400	1979	1.24	<0.1
1987	42,270	1	11[3]	4,650	1986	0.54	0.9
		2	24	10,145	1985	0.49	2.1
		3	30	12,681	1984	0.92	1.4
		4	23	9,722	1983	0.39	2.6
		5	9	3,804	1982	0.88	0.4
		6	2	845	1981	0.49	0.2
		7	1	423	1980	1.37	<0.1

[1]Estimated harvest for all ports which were sampled.

[2]Combination of fall fingerling and yearling plants.

[3]Preliminary data.

Table 14. Estimated total harvest, mean stocking rate, and estimated percent return of rainbow (steelhead) trout from Lake Michigan by state in 1985.

State	Estimated harvest (numbers)	Estimated harvest (percent)	Mean number[1] stocked 1981-84 (millions)	Estimated return (percent)
Wisconsin	24,264[2]	24	1.20	2.0
Illinois	9,489[3]	9	0.20	4.7
Indiana	19,786[4]	20	0.29	6.8
Michigan	46,822	47	0.67	7.0
Total	100,361	---	2.36	4.3

[1]Includes both fall fingerlings and yearlings.

[2]P. Schultz, WDNR, unpublished data.

[3]Assumes that the Illinois charter-boat harvest was the same in 1985 as in 1984 (Horns and Gorden 1986).

[4]D. Brazo, IDNR, unpublished data.

Table 15. Harvest and harvest rates (fish per 100 angler hours) of rainbow (steelhead) trout in the Wisconsin and Illinois charter-boat fisheries during 1976-87.

	Wisconsin			Illinois		
Year	Harvest[1]	Percent of total charter harvest	Harvest rate	Harvest[2]	Percent of total charter harvest	Harvest rate
1976	1,261	7	1.9	115	3	0.8
1977	1,986	8	2.4	275	6	1.7
1978	2,508	9	2.4	175	4	1.4
1979	1,460	5	1.4	1,900	6	1.7
1980	1,149	3	0.9	1,030	3	0.8
1981	1,525	3	0.8	1,567	3	1.0
1982	873	1	0.4	1,312	2	0.8
1983	1,967	2	0.6	2,609	6	1.6
1984	3,247	3	0.8	2,634	5	1.8
1985	2,790	2	0.8	---	---	---
1986	4,010	3	1.0	---	---	---
1987	15,635	10	3.4	---	---	---

[1]WDNR, unpublished data.

[2]T. Trudeau, IDC, unpublished data.

Table 16. Estimated sport harvest of lake trout from areas sampled on Lake Michigan by month and zone during 1985-87. Two standard errors in parentheses.

Year	Month: May	Jun	Jul	Aug	Season
Southern					
1985	21,250	11,864	14,416	6,938	54,468
	(8,649)	(4,524)	(5,228)	(4,036)	(11,785)
1986	27,542	13,866	16,728	2,802	60,938
	(12,346)	(5,995)	(8,223)	(1,641)	(16,083)
1987	33,539	14,494	13,870	5,256	67,159
	(13,924)	(9,338)	(8,918)	(4,350)	(19,482)
Central					
1985	2,631	10,179	19,143	3,403	35,356
	(1,235)	(2,922)	(6,599)	(1,170)	(7,415)
1986	3,053	34,820	17,841	1,851	57,565
	(1,699)	(38,884)	(14,505)	(1,599)	(41,567)
1987	6,739	19,726	7,369	7,359	41,193
	(2,697)	(21,912)	(2,991)	(4,681)	(22,765)
Northern					
1985	5,889	10,601	14,527	6,665	37,682
	(2,747)	(3,085)	(8,570)	(3,211)	(10,041)
1986	1,803	7,989	5,702	5,891	21,385
	(1,830)	(3,302)	(2,950)	(2,560)	(5,432)
1987	2,265	5,936	9,693	3,005	20,889
	(1,545)	(1,875)	(2,667)	(1,521)	(3,915)
Lake wide					
1985	29,770	32,644	48,086	17,006	127,506
	(9,158)	(6,207)	(12,013)	(5,289)	(17,166)
1986	32,398	56,675	40,271	10,544	139,888
	(12,596)	(39,482)	(16,932)	(3,436)	(44,890)
1987	42,543	40,156	30,932	15,620	129,251
	(14,267)	(23,892)	(9,777)	(6,569)	(36,218)

Table 17. Estimated lake trout harvest and percent return by age from Lake Michigan during 1985-87.

Year	Estimated[1] harvest	Age	Percent distribution	Estimated harvest by age	Year class	Number stocked (millions)	Percent return
1983	---	3	1	---	---	---	---
		4	9	---	---	---	---
		5	31	---	---	---	---
		6	30	---	---	---	---
		7	9	---	---	---	---
		8	12	---	---	---	---
		9	4	---	---	---	---
		10	2	---	---	---	---
		11	2	---	---	---	---
1984	---	3	3	---	---	---	---
		4	21	---	---	---	---
		5	35	---	---	---	---
		6	23	---	---	---	---
		7	10	---	---	---	---
		8	3	---	---	---	---
		9	4	---	---	---	---
		10	<1	---	---	---	---
		11	<1	---	---	---	---
1985	142,176	4	14	19,904	1981	1.25	1.6
		5	39	55,448	1980	1.25	4.5
		6	27	38,388	1979	1.31	2.9
		7	11	15,639	1978	1.12	1.4
		8	4	5,687	1977	1.25	0.5
		9	2	2,844	1976	1.06	0.3
		10	2	2,844	1975	1.25	0.2
		11	1	1,422	1974	1.13	0.1
1986	152,650	3	4	6,106	1983	0.39	1.6
		4	20	30,530	1982	1.09	2.8
		5	23	35,110	1981	1.25	2.8
		6	25	38,163	1980	1.25	3.1
		7	15	22,898	1979	1.31	1.8
		8	6	9,159	1978	1.12	0.8
		9	4	6,106	1977	1.25	0.5
		10	1	1,526	1976	1.06	0.1
		11	1	1,526	1975	1.25	0.1
		12	1	1,526	1974	1.13	0.1
1987	132,101	3	2[2]	2,642	1984	1.44	0.2
		4	17	22,457	1983	0.39	5.7
		5	31	40,951	1982	1.09	3.8
		6	26	34,346	1981	1.25	2.7
		7	13	17,173	1980	1.25	1.4
		8	5	6,605	1979	1.31	0.5
		9	3	3,964	1978	1.12	0.4
		10	2	2,642	1977	1.25	0.2
		11	1	1,321	1976	1.06	0.1

[1]Estimated harvest for all ports which were sampled.

[2]Preliminary data.

Table 18. Estimated total harvest, mean stocking rate, and estimated percent return of lake trout from Lake Michigan by state in 1985.

State	Estimated harvest (numbers)	Estimated harvest (percent)	Mean number[1] stocked 1977-81 (millions)	Estimated return (percent)
Wisconsin	81,005[2]	34	1.04	7.8
Illinois	12,935[3]	5	0.13	10.0
Indiana	1,253[4]	1	0.18	0.7
Michigan	142,176	60	1.22	11.7
Total	237,369	---	2.57	9.2

[1]Includes both fall fingerlings and yearlings.

[2]P. Schultz, WDNR, unpublished data.

[3]Assumes that the Illinois charter-boat harvest was the same in 1985 as in 1984 (Horns and Gorden 1986).

[4]D. Brazo, IDNR, unpublished data.

Table 19. Harvest and harvest rates (fish per 100 angler hours) of lake trout in the Wisconsin and Illinois charter-boat fisheries during 1976-87.

	Wisconsin			Illinois		
Year	Harvest[1]	Percent of total charter harvest	Harvest rate	Harvest[2]	Percent of total charter harvest	Harvest rate
1976	11,449	60	17.0	71	2	0.5
1977	9,660	38	11.5	253	5	1.5
1978	11,873	41	11.2	115	3	0.9
1979	13,978	49	13.4	3,321	10	2.9
1980	9,900	29	8.1	2,715	8	2.2
1981	17,464	35	9.5	3,777	7	2.3
1982	20,997	33	8.8	5,486	9	3.5
1983	46,730	50	14.6	13,045	29	8.2
1984	34,503	30	8.9	6,031	11	4.1
1985	26,475	23	7.2	---	---	---
1986	27,984	22	6.7	---	---	---
1987	32,696	22	7.1	---	---	---

[1]WDNR, unpublished data.

[2]T. Trudeau, IDC, unpublished data.

Table 20. Estimated sport harvest of brown trout from areas sampled on Lake Michigan by month and zone during 1985-87. Two standard errors in parentheses.

Year	Apr	May	Jun	Jul	Aug	Sep	Oct	Season
	Month							
Southern								
1985	2,170	5,133	1,839	2,552	3,249	184	326	15,453
	(785)	(3,842)	(888)	(1,793)	(2,687)	(177)	(345)	(5,172)
1986	4,925	6,945	1,479	1,053	1,158	44	325	15,929
	(2,434)	(5,354)	(1,415)	(865)	(854)	(54)	(762)	(6,217)
1987	1,298	1,464	1,059	1,756	792	61	0	6,430
	(932)	(1,148)	(1,986)	(2,658)	(1,178)	(125)	(0)	(3,821)
Central								
1985	2,365	8,714	6,852	2,771	2,820	109	142	23,773
	(995)	(3,150)	(2,798)	(998)	(1,210)	(128)	(217)	(4,611)
1986	28,929	13,309	5,172	3,459	3,351	486	41	54,747
	(8,058)	(9,706)	(6,281)	(3,676)	(2,850)	(731)	(58)	(14,858)
1987	1,979	5,764	3,296	1,601	2,530	335	173	15,678
	(1,245)	(3,199)	(3,271)	(879)	(1,550)	(442)	(196)	(5,089)
Northern								
1985	1,951	274	651	1,571	835	135	489	5,906
	(1,078)	(261)	(363)	(900)	(512)	(149)	(459)	(1,633)
1986	1,440	36	133	692	522	162	107	3,092
	(723)	(52)	(244)	(411)	(411)	(194)	(154)	(992)
1987	1,633	905	612	1,882	354	200	28	5,614
	(775)	(760)	(465)	(690)	(235)	(185)	(56)	(1,401)
Lake-wide								
1985	6,486	14,121	9,342	6,894	6,904	428	957	45,132
	(1,664)	(4,975)	(2,958)	(2,241)	(2,991)	(264)	(614)	(7,119)
1986	35,294	20,290	6,784	5,204	5,031	692	473	73,768
	(8,448)	(11,085)	(6,443)	(3,798)	(3,003)	(758)	(780)	(16,136)
1987	4,910	8,133	4,967	5,239	3,676	596	201	27,722
	(1,738)	(3,482)	(3,855)	(2,883)	(1,961)	(495)	(204)	(6,515)

Table 21. Estimated brown trout harvest and percent return by age from Lake Michigan during 1985-87.

Year	Estimated[1] harvest	Age	Percent distribution	Estimated harvest by age	Year class	Number[2] stocked (millions)	Percent return
1983	---	1	7	---	---	---	---
		2	25	---	---	---	---
		3	59	---	---	---	---
		4	6	---	---	---	---
		5	2	---	---	---	---
		6	1	---	---	---	---
1984	---	1	4	---	---	---	---
		2	41	---	---	---	---
		3	41	---	---	---	---
		4	12	---	---	---	---
		5	1	---	---	---	---
		6	1	---	---	---	---
1985	48,861	1	7	3,420	1984	0.48	0.7
		2	49	23,942	1983	0.64	3.7
		3	32	15,636	1982	0.44	3.6
		4	11	5,375	1981	0.00	---
		5	1	488	1980	0.14	0.3
1986	77,342	1	7	5,414	1985	0.53	1.0
		2	55	42,538	1984	0.48	8.9
		3	24	18,562	1983	0.64	2.9
		4	11	8,508	1982	0.44	1.9
		5	2	1,547	1981	0.00	---
		6	1	773	1980	0.14	0.6
1987	30,063	1	7[3]	2,104	1986	0.51	0.4
		2	52	15,633	1985	0.53	2.9
		3	29	8,718	1984	0.48	1.8
		4	11	3,307	1983	0.64	0.5
		5	1	301	1982	0.44	0.1

[1]Estimated harvest for all ports which were sampled.

[2]Combination of fall fingerling and yearling plants.

[3]Preliminary data.

Table 22. Estimated total harvest, mean stocking rate, and estimated percent return of brown trout from Lake Michigan by state in 1985.

State	Estimated harvest (numbers)	Estimated harvest (percent)	Mean number[1] stocked 1980-84 (millions)	Estimated return (percent)
Wisconsin	70,880[2]	56	1.34	5.3
Illinois	4,188[3]	3	0.05	8.4
Indiana	1,789[4]	2	0.04	4.5
Michigan	48,861	39	0.34	14.4
Total	125,718	--	1.77	7.1

[1]Includes both fall fingerlings and yearlings.

[2]P. Schultz, WDNR, unpublished data.

[3]Assumes that the Illinois charter-boat harvest was the same in 1985 as in 1984 (Horns and Gorden 1986).

[4]D. Brazo, IDNR, unpublished data.

Table 23. Harvest and harvest rates (fish per 100 angler hours) of brown trout in the Wisconsin and Illinois charter-boat fisheries during 1976-87.

	Wisconsin			Illinois		
Year	Harvest[1]	Percent of total charter harvest	Harvest rate	Harvest[2]	Percent of total charter harvest	Harvest rate
1976	418	2	0.6	8	<1	<0.1
1977	399	2	0.5	13	<1	<0.1
1978	791	3	0.8	68	2	<0.1
1979	987	3	0.9	282	1	0.2
1980	1,559	5	1.3	369	1	0.3
1981	1,872	4	1.0	401	1	0.2
1982	1,748	3	0.7	755	1	0.5
1983	3,111	3	1.0	554	1	0.4
1984	4,822	4	1.2	914	2	0.6
1985	5,801	5	1.6	---	---	---
1986	4,305	3	1.0	---	---	---
1987	5,705	4	1.2	---	---	---

[1]WDNR, unpublished data.

[2]T. Trudeau, IDC, unpublished data.

Table 24. Estimated sport harvest of Atlantic and pink salmon from areas sampled on Lake Michigan by year and zone during 1985-87. Two standard errors in parentheses.

Species	1985	1986	1987
Southern			
Atlantic salmon	3 (7)	529 (1,071)	0 (0)
Pink salmon	125 (173)	29 (62)	13 (26)
Central			
Atlantic salmon	1,253 (1,442)	25 (52)	92 (141)
Pink salmon	52 (81)	0 (0)	236 (245)
Northern			
Atlantic salmon	0 (0)	0 (0)	0 (0)
Pink salmon	156 (425)	9 (19)	3,076 (2,069)
Lake wide			
Atlantic salmon	1,256 (1,442)	554 (1,072)	92 (141)
Pink salmon	333 (446)	38 (65)	3,325 (2,084)

Table 25. Target stocking rates (in millions of fish) for State of Michigan rivers which are tributary to Lake Michigan and have salmon harvest weirs. Percent of the total Lake Michigan stocking level by all agencies combined is shown in parentheses.

Stocking and weir location	Chinook salmon	Coho salmon
Medusa Creek	0.300 (12.4)	0 (0)
Boardman River	0.250 (10.3)	0 (0)
Platte River	0 (0)	0.700 (47.5)
Little Manistee River	0.450 (18.6)	0.325 (22.0)
State of Michigan total	1.000 (41.2)	1.025 (69.5)
Lake Michigan total (all agencies)	2.425	1.475

Table 26. Total number of chinook salmon harvested at Lake Michigan weirs, 1983-87. Weight (pounds) is in parentheses.

Weir location	Year 1983	1984	1985	1986	1987
Michigan					
Little Manistee	39,359 (493,628)	32,632 (421,947)	34,006 (441,096)	22,131 (297,544)	31,736 (367,690)
Lower Platte	4,839 (71,250)	4,358 (64,326)	2,880 (38,829)	2,973 (33,879)	5,341 (70,382)
Upper Platte	296 (3,247)	215 (2,515)	306 (3,030)	687 (7,238)	256 (2,584)
Jordan River	0 (0)	313 (4,510)	1,916 (25,254)	0 (0)	0 (0)
Medusa Creek	0 (0)	0 (0)	118 (720)	1,506 (14,677)	11,231 (134,289)
Boardman River	0 (0)	0 (0)	0 (0)	0 (0)	4,899 50,004)
White River	695 (10,977)	0 (0)	0 (0)	0 (0)	0 (0)
Total	45,189 (579,102)	37,518 (493,298)	39,226 (508,929)	27,297 (353,338)	53,463 (624,949)
Wisconsin[1]					
Strawberry Creek	3,852 (66,090)	5,208 (76,905)	5,601 (90,860)	4,392 (53,700)	7,624 (99,100)
Total	49,041 (645,192)	42,726 (570,203)	44,827 (599,789)	31,689 (407,038)	61,087 (724,049)

[1]Toneys and Royseck, WDNR, unpublished data.

Table 27. Total number of coho salmon harvested at Lake Michigan weirs, 1983-87. Weight (pounds) is in parentheses.

Weir location	Year 1983	1984	1985	1986	1987
Michigan					
Little Manistee	26,968 (185,502)	33,721 (190,566)	15,286 (94,693)	16,886 (94,385)	15,100 (96,792)
Lower Platte[1]	162,911 (1,083,035)	143,765 (782,447)	81,746 (489,543)	54,297 (280,004)	61,149 (374,054)
Jordan River	0 (0)	16 (117)	47 (307)	0 (0)	0 (0)
Medusa Creek	0 (0)	0 (0)	1 (6)	0 (0)	0 (0)
Boardman River	0 (0)	0 (0)	0 (0)	0 (0)	306 (1,730)
White River	4 (16)	0 (0)	0 (0)	0 (0)	0 (0)
Total	189,883 (1,268,553)	177,502 (973,130)	97,080 (584,549)	71,183 (374,389)	76,555 (472,576)

[1]Values for the lower Platte River weir include the total coho harvest plus coho passed upstream and coho jacks harvested at the Platte River Hatchery.

Table 28. Number of chinook salmon returning to the Little Manistee River weir by year class, 1982-87. Percent return is in parentheses.

Year class	Number stocked	Age 0.1	0.2	0.3	0.4	0.5	Total
1978	400,028	--- (---)	--- (---)	--- (---)	--- (---)	236[1] (0.1)	--- (---)
1979	603,098	--- (---)	--- (---)	--- (---)	11,532[1] (1.9)	196[1] (<0.1)	--- (---)
1980	550,272	--- (---)	--- (---)	19,601[1] (3.6)	9,561[1] (1.7)	248 (<0.1)	--- (---)
1981	500,204	2,077 (0.4)	5,235[1] (1.0)	16,251[1] (3.2)	5,990 (1.2)	10 (<0.1)	29,563 (5.9)
1982	600,294	2,755 (0.5)	4,340[1] (0.7)	19,437 (3.2)	6,849 (1.1)	862 (0.1)	34,243 (5.7)
1983	677,250	2,284 (0.3)	6,326 (0.9)	13,850 (2.0)	11,068 (1.6)	--- (---)	33,528 (5.0)
1984	805,773	2,005 (0.2)	1,025 (0.1)	11,895 (1.5)	--- (---)	--- (---)	--- (---)
1985	500,012	397 (0.1)	4,768 (1.0)	--- (---)	--- (---)	--- (---)	--- (---)
1986	450,273	3,143 (0.7)	--- (---)	--- (---)	--- (---)	--- (---)	--- (---)
Mean	565,245	2,110 (0.4)	4,339 (0.8)	16,207 (2.9)	9,000 (1.6)	310 (0.1)	31,966 (5.7)

[1]Due to difficulties in aging spawning chinook salmon, reported returns for age-0.2 and older fish for the harvest years before 1985 are unknown. These values were calculated from the average percent age contribution (standardized by number stocked) for the harvest years 1985 to 1987.

Table 29. Number of known aged, coded wire tagged, chinook salmon returning to the Strawberry Creek Pond weir in Wisconsin, 1983-87. Percent return is in parentheses.[1]

Year class	Number stocked	Age 0.1	0.2	0.3	0.4	0.5	Total
1982	20,000	48 (0.2)	43 (0.2)	441 (2.2)	79 (0.4)	1 (<0.1)	612 (3.1)
1983	20,000	21 (0.1)	37 (0.2)	116 (0.6)	69 (0.3)	--- (---)	--- (---)
1984	20,000	47 (0.2)	47 (0.2)	302 (1.5)	--- (---)	--- (---)	--- (---)
1985	50,000	24 (<0.1)	106 (0.2)	--- (---)	--- (---)	--- (---)	--- (---)
1986	25,000	91 (0.4)	--- (---)	--- (---)	--- (---)	--- (---)	--- (---)
Mean	27,000	46 (0.2)	58 (0.2)	286 (1.1)	74 (0.3)	1 (<0.1)	465 (1.7)

[1]Toneys and Royseck, WDNR, unpublished data.

Table 30. Number of coho salmon returning to the lower Platte River weir by year class, 1982-87. Percent return is in parentheses.

Year class	Number stocked	Age 1.0	Age 1.1	Total
1981	1,000,010	--- (---)	156,358 (15.6)	--- (---)
1982	953,499	6,553 (0.7)	142,102 (14.9)	148,655 (15.6)
1983	989,192	1,663 (0.2)	80,354 (8.1)	82,017 (8.3)
1984	817,483	1,392 (0.2)	52,770 (6.5)	54,162 (6.6)
1985	751,183	1,527 (0.2)	59,848 (8.0)	61,375 (8.2)
1986	622,079	1,301 (0.2)	--- (---)	--- (---)
Mean	855,574	2,487 (0.3)	98,286 (11.5)	100,773 (11.8)

Table 31. Total number of rainbow (steelhead) trout, brown trout, and lake trout encountered at the Little Manistee River and lower Platte River weirs during 1980-87.

	Little Manistee weir		Lower Platte weir		
Year	Steelhead	Brown trout	Steelhead	Brown trout	Lake trout
1980	1,111	28	124	7	0
1981	849	101	682	78	0
1982	347	62	1,276	38	38
1983	3,100	43	1,545	58	7
1984	1,909	141	1,292	74	69
1985	6,356	177	1,189	79	20
1986	4,720	99	364	31	14
1987	1,401	47	2,962	31	4

Table 32. Number of chinook salmon harvested at the Little Manistee River weir by age during 1983-87. Percent contribution by age in parentheses.

Harvest year	Age 0.1	0.2	0.3	0.4	0.5	Total
1983[1]	2,755 (7.0)	5,235 (13.3)	19,601 (49.8)	11,532 (29.3)	236 (0.6)	39,359
1984[1]	2,284 (7.0)	4,340 (13.3)	16,251 (49.8)	9,561 (29.3)	196 (0.6)	32,632
1985	2,005 (5.9)	6,326 (18.6)	19,437 (57.2)	5,990 (17.6)	248 (0.7)	34,006
1986	397 (1.8)	1,025 (4.6)	13,850 (62.6)	6,849 (30.9)	10 (<0.1)	22,131
1987	3,143 (9.9)	4,768 (15.0)	11,895 (37.5)	11,068 (34.9)	862 (2.7)	31,736
Mean	2,117 (6.6)	4,339 (13.6)	16,207 (50.7)	9,000 (28.1)	310 (1.0)	31,973

[1]Due to difficulties in aging spawning chinook salmon, reported returns for age-0.2 and older fish for the harvest years before 1985 are unknown. These values were calculated from the average percent age contribution (standardized by number stocked) for the harvest years 1985 to 1987.

Table 33. Mean total length (inches) and weight (pounds) by age of chinook salmon harvested at the Little Manistee River weir during 1985-87. Two standard errors in parentheses.

Harvest year	Measure-ment	Age				
		0.1	0.2	0.3	0.4	0.5
1985	Length	22.7 (0.824)	30.8 (1.158)	34.4 (0.620)	37.3 (1.024)	41.1 (0.752)
	Weight	4.5 (0.406)	9.5 (0.936)	13.4 (0.708)	17.7 (1.708)	22.0 (0.094)
1986	Length	21.0 (0.683)	28.3 (0.507)	33.6 (0.165)	36.9 (0.203)	42.0 (---)
	Weight	4.2 (0.273)	7.6 (0.386)	12.7 (0.197)	17.1 (0.318)	25.5 (---)
1987	Length	22.8 (0.278)	28.4 (0.659)	33.2 (0.266)	35.9 (0.221)	39.1 (1.077)
	Weight	4.4 (0.172)	7.9 (0.508)	11.9 (0.314)	14.7 (0.360)	18.9 (1.529)

Table 34. Mean total length (inches) and weight (pounds) by age of coded wire tagged chinook salmon harvested at the Strawberry Creek Pond weir in Wisconsin during 1983-87. Two standard errors in parentheses.[1]

Harvest year	Measure-ment	Age				
		0.1	0.2	0.3	0.4	0.5
1983	Length	24.1 (0.400)	--- (---)	--- (---)	--- (---)	--- (---)
	Weight	6.0 (0.318)	--- (---)	--- (---)	--- (---)	--- (---)
1984	Length	22.7 (0.509)	32.9 (0.506)	--- (---)	--- (---)	--- (---)
	Weight	4.4 (0.296)	12.3 (0.740)	--- (---)	--- (---)	--- (---)
1985	Length	23.5 (0.378)	32.7 (0.523)	36.3 (0.216)	--- (---)	--- (---)
	Weight	4.6 (0.325)	11.8 (0.780)	16.1 (0.367)	--- (---)	--- (---)
1986	Length	23.6 (0.513)	30.9 (0.601)	34.8 (0.347)	36.1 (0.394)	--- (---)
	Weight	4.7 (0.288)	10.6 (0.613)	14.3 (0.450)	15.7 (0.683)	--- (---)
1987	Length	24.1 (0.291)	32.2 (0.350)	35.0 (0.235)	35.5 (0.632)	39.0 (0)
	Weight	5.2 (0.181)	11.8 (0.411)	14.7 (0.305)	14.8 (0.826)	11.1 (0)

[1]Toneys and Royseck, WDNR, unpublished data.

Table 35. Number of coho salmon harvested at the lower Platte River weir by age during 1983-87. Percent contribution by age in parentheses.[1]

Harvest year	Age 1.0	Age 1.1	Total
1983	6,553 (4.0)	156,358 (96.0)	162,911
1984	1,663 (1.2)	142,102 (98.8)	143,765
1985	1,392 (1.7)	80,354 (98.3)	81,746
1986	1,527 (2.8)	52,770 (97.2)	54,297
1987	1,301 (2.1)	59,848 (97.9)	61,149
Mean	2,487 (2.5)	98,286 (97.5)	100,773

[1]Harvest includes the number of coho salmon intentionally passed upstream to create a river fishery.

Table 36. Mean total length (inches) and weight (pounds) by age of coho salmon harvested at the lower Platte River weir during 1983-87.

Harvest year	Measurement	Age	
		1.0	1.1
1983	Length	16.4	26.6
	Weight	1.6	6.9
1984	Length	15.8	24.8
	Weight	1.5	5.5
1985	Length	15.9	25.7
	Weight	1.6	6.1
1986	Length	15.7	24.4
	Weight	1.8	5.3
1987	Length	15.9	26.2
	Weight	1.8	6.3

Table 37. Tribal salmonid harvest by number and, in parentheses, weight (pounds) from Lake Michigan during 1983-87 (1987 data are preliminary).[1,2]

Year	Lake trout	Chinook salmon	Coho salmon
<u>Central</u>			
1983	13,331 (66,656)	0 (0)	0 (0)
1984	17,579 (87,897)	2 (23)	0 (0)
1985	9,012 (45,061)	0 (0)	0 (0)
<u>Northern</u>			
1983	53,889 (269,447)	365 (4,089)	0 (0)
1984	55,431 (277,156)	417 (4,674)	89 (393)
1985	99,442 (497,211)	538 (6,026)	53 (235)
1986	49,744 (248,721)	640 (7,171)	67 (295)
1987	43,321 (216,605)	872 (9,762)	0 (0)

[1]Chippewa/Ottawa Treaty Fishery Management Authority, personal communication.

[2]Numbers were derived from mean weights using an average of 5.0 pounds for lake trout, 11.2 pounds for chinook salmon, and 4.4 pounds for coho salmon.

Table 38. Pounds of salmon eggs taken from sport caught fish and sold to wholesale fish dealers through designated salmon egg buying stations and authorized fish cleaning stations.

Year	Pounds
1983	271,066
1984	143,096
1985	152,190
1986	193,176
1987	123,938

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BIOLOGY OF SALMONIDS

Ronald Rybicki, Paul Seelbach, and Wilbert Wagner

Coho Salmon

The deplorable condition of fish populations in Lake Michigan in the early to mid-1960s demanded bold and imaginative management action. Hordes of alewives were estimated to have accounted for as much as 80% of the fish biomass in Lake Michigan at that time (Smith 1968), when they fouled Lake Michigan beaches and plugged city water supply intakes. Tody and Tanner (1966) perceived that the solution to the alewife problem was the building of a large, predatory salmonid population. Not only would biological pressure be exerted on the alewife population, but a high value fishery could be established on the predators as well. They gambled that the coho salmon, a Pacific Ocean native, could be successfully introduced into the Great Lakes and brought to a high level of abundance. Thus, the coho salmon was introduced into Lake Michigan in 1966 when 395,000 yearlings were stocked in Bear Creek, a tributary to the Manistee River, and 264,000 were planted in the Platte River (Borgeson 1970).

The coho salmon have a 3-year life cycle. They spawn in streams during the fall of the year, hatch the following spring, and live as juveniles in the stream for one additional year. They migrate to Lake Michigan in the spring of the second year of life (18 months) when smolting occurs, which is a physiological change that enables the fish to survive in their native saltwater habitat. Hatchery-reared coho are planted in streams, prior to smolting, at about 18 months of age. After spending about 18 months or two growing seasons in Lake Michigan, the adult coho return to their natal streams (although there is considerable straying to other streams) to spawn and die, as do all Pacific salmon. A few also return to spawn after only one summer in the lake (precocious males called jacks) and a few may spend three growing seasons in the lake.

Food habits.--Coho salmon lived up to expectations and did indeed consume alewives in huge quantities. But the ecosystem is dynamic and therefore nothing remains without change. The species composition of prey fishes consumed by coho salmon while in Lake Michigan changed with a shifting forage base. In the summer of 1967, 86% of the stomachs from 430 Lake Michigan coho examined contained alewives, and 14% had either smelt, sculpins or unidentifiable fish fragments (Patriarche 1981). More recently, Kogge (1985) reported that of the coho salmon stomachs examined in 1983, 21% contained alewives, 35% had consumed smelt, and 22% had eaten bloater chubs. The percentage frequencies in 1984 were similar with estimates of 24% alewives, 38% smelt, and 16% bloaters. Expressed as the percentage occurrence of prey items in coho stomachs in 1983 and 1984, respectively, alewives were 16.9% and 17.2%, smelt were 24.5% and 33.5%, and bloater chubs were 8.2% and 11.4% (Table 1). In recent times, smelt have been of greater importance to coho salmon than to either chinook salmon or lake trout. It is evident that coho salmon will also prey on bloater chubs, something not seen in the mid to late 1970s when bloater chubs were relatively scarce.

While in stream residence, aquatic insects are the preferred food items of yearling coho. Peck (1974) observed that juvenile coho salmon fed primarily on aquatic insects and crustaceans while in the Whitefish River and upon entry into Little Bay de Noc. However, while in the Bay, 11% of the juvenile coho also fed upon smelt, spottail shiners, and rock bass. Wagner (1975) also noted that young coho in the Platte River fed largely on aquatic insects such as caddis flies, black flies, and mayflies.

Natural reproduction.--Spawning by coho salmon was encouraged as early as the fall of 1967 when 17,000 adults were transferred to seven Lake Michigan streams and three Lake Huron tributaries (Borgeson 1970). Electrofishing in the summer of 1968 disclosed that young coho salmon were present in several of those streams, especially in the Boardman and Boyne rivers. Production of native coho has since been quantified by several investigators. Taube (1975) estimated natural recruitment of coho in the Platte River during 1967-72 averaged 3,000 fingerlings and 2,200 yearlings per km of stream. Carl (1983) calculated that subyearling coho salmon densities ranged from 10 to 60 fish per 100 square m in Baldwin, Bigelow, and Pine creeks during 1977-79, which he considered low when compared to small, west coast streams that produced over 70 coho smolts per 100 square m. Seelbach (1985) estimated that the production of yearling coho salmon in the Little Manistee River during 1982-83 averaged 253 smolts per ha, but the recruitment of naturally spawned coho dropped to 76 smolts per ha in 1984. Coho reproduction in 1984 may have been artificially low because spawner escapement was kept to a minimum. Nevertheless, that amount of natural recruitment is minor when compared to that from west coast rivers. Crone (1980) reported yields for coho between 970-4,200 smolts per ha for streams in Oregon, British Columbia, and Alaska.

Naturally recruited coho salmon have contributed modestly to the sport catch. Patriarche (1980) estimated that the 1978-79 coho catches in the Lake Michigan watershed consisted of about 9% native fish.

Movement and lake distribution.--In the 3 to 4 years following the introduction of Pacific salmon, bits and pieces of information from Indiana, Illinois, and Wisconsin clearly indicated, to no one's astonishment, that coho salmon were great wanderers. However, not until Patriarche's (1980) definitive study on Lake Michigan coho salmon migration in 1978-79 was the magnitude of the distribution clear. The following commentary relies extensively on Patriarche's (1980) account of his findings.

Returns in the fall, 1978 suggested that a few coho salmon roamed widely. Three Michigan juvenile coho from the St. Joseph and Black River plantings were caught by Wisconsin anglers, eight Indiana coho were captured at Michigan power plants by anglers in the Saugatuck area, and at the Little Manistee River weir, one Illinois coho appeared at Saugatuck, and four Wisconsin fish were recovered at the Consumers Power Company pump storage plant at Ludington and one at Saugatuck. An estimated 2% of the catch by Michigan anglers in 1978 had been planted in Lake Erie either by Ohio or New York the previous year. There was no evidence that a reverse movement by Lake Michigan stocks into Lake Erie had occurred in 1979.

In March through May, 1979 there was a pronounced concentration of adult coho (1977 year class) in the southern end of the lake, particularly in the southeastern corner. Over the course of the 1979 fishing season, an estimated 2,400 coho (2%) were furnished by plantings in other states to the Michigan catch. In contrast, Michigan's contribution to the 1979 fishery in the other three Lake Michigan jurisdictions ranged between 13,000 and 45,000 coho or 50% to 75% of their catches. A report published by the WDNR (Kernen 1986) stated that up to 60% of the coho salmon taken in Wisconsin's waters of Lake Michigan were stocked by other states.

By fall, 1979 adult coho were seeking their home streams. In the Indiana catch, 95% of the fish were from Indiana plants but a few were captured in both Wisconsin and Michigan waters as late as November, 1979. Seventy-four percent of the Illinois fall catch of marked coho salmon was comprised of Illinois plants, but a number of Illinois coho were taken also by Wisconsin and Michigan anglers and at Michigan weirs.

Homing frequency of adult coho salmon to natal streams in the autumn of 1979 varied widely. The percentage frequency of homing ranged from a low of 47% for the plants in the Grand and Muskegon rivers to a high of nearly 100% for those stocked in the St. Joseph and Black River complex and the Platte River (Table 2). Three of the five coho plants strayed to rivers that were considerable distances from the natal stream. Coho planted as yearlings in the Grand and Manistee rivers strayed as far south as the St. Joseph River and as far north as the Platte River. Some of the coho planted in the Upper Peninsula's Thompson Creek were observed in the Lower Peninsula's Platte and Manistee rivers. In 1986, about 1.6% of the coho salmon examined at the Platte River weir originated from Illinois (Pecor 1987).

Competition.--Most of the available evidence indicates that coho salmon have had little impact on native trout species in streams. Taube (1975) concluded that coho salmon had little effect on brown and rainbow trout in the Platte River except when the salmon spawners were highly concentrated. In that instance, there were fewer brown trout than there were before intense salmon spawning activity, but the decline was not reflected in the abundance of older age groups in subsequent years. Taube explained that the loss of young brown trout was compensated by a better rate of survival to the older ages. Carl (1983) reached the same conclusion, although based on growth rather than numbers, for coho salmon and rainbow trout in Pine Creek. Carl observed that the apparent absence of competition between coho salmon and the native stream trout may have been due partly to spatial segregation between the species; coho salmon were found more often in pools or along stream edges while rainbow trout frequently were observed in the areas of faster current. Wagner (1975) noted that the overall food habits of various groups of salmonids in the Platte River were similar. However, he judged that a significant degree of competition for food between trout and salmon did not occur because the growth of trout was not affected, and because of evidence that coho salmon and rainbow trout were spatially segregated in streams. Stauffer (1977a) observed that newly established populations of juvenile coho salmon had no detectable impact on numbers and growth of rainbow trout in several Lake Superior tributaries. However, Stauffer did note that his data suggested a depressant effect by coho salmon on brook trout in three of the streams and on brown trout in one creek. Laarman (1969) compared growth rates of coho salmon and rainbow (steelhead) trout held in a laboratory raceway. He found that when trout and salmon less than 84 mm in length were held together in the same raceway, the steelhead grew at a significantly faster rate. Thus, steelhead were dominant over coho salmon in utilizing food from a limited supply.

Salmon may negatively effect native stream trout in a manner more subtle than head-to-head competition for food and space. Hildebrand (1971) reported that coho spawning activity in the Platte River in 1967 so disrupted the streambed that the total number and weight of benthic organisms (per square foot of bottom) had decreased significantly. As compared to the control section, the number and weight of benthic organisms had decreased by 66% in total number and 78% in total weight. Hildebrand (1971) also mentioned that the benthos had not yet fully recovered 5 months later. Hildebrand concluded his report with the statement, "In the Platte River, if there is extensive recruitment of young coho salmon, [then the] added predation pressure on the benthos, [when] coupled with a reduction in the benthos density due to coho spawning activity, might reduce the benthic populations to the extent where growth of native trout and salmon may be limited."

Mortality.--Mortality rates of coho salmon while in stream residence as juveniles have received some attention, whereas death rates of coho salmon while in lake residence have not been determined. Seelbach (1985) reported that hatchery-reared coho stocked in the Little Manistee River in 1982 and 1984 had mortality rates of 22-30% from the time of release to smolting and he considered survival rates of 70% or better to be excellent. At best, mortality of coho salmon while in the lake can only be expressed as a proportion of the number planted that were subsequently caught by anglers. Patriarche (1980) calculated that, of the 1977 year class stocked in all of Lake Michigan, about 7.4% were subsequently harvested by the sport fishery. For each state's planting of the 1977 year class, the proportion caught was 2.3% by Illinois, 3.2% by Wisconsin, 7.5% by Indiana, and 9.3% by Michigan.

Chinook Salmon

Chinook salmon, introduced into Lake Michigan in 1967, are well integrated with and a permanent part of the lake's fish community. Chinook are the largest of the three species of Pacific salmon that occur in Lake Michigan. Fall chinook, the strain chosen for introduction in Michigan's Great Lakes, migrate to and spawn in streams in the autumn. They usually return as 3- and 4-year-old adults to the stream in which they were either stocked or spawned, although a few return as precocious males (jacks) at age 2 and a few at age 5. The young chinook smolts leave the rivers the following spring as soon as flows increase and water temperatures rise. While in the lake, chinook feed voraciously on alewives, smelt, and bloater chubs, and contribute heavily to Michigan's fishery and undoubtedly to the fisheries in other states bordering Lake Michigan.

Food habits.--A changing species composition of the fish-forage base has been reflected to some degree in the diet of eastern Lake Michigan chinook salmon. During 1969-72, alewife, smelt, and a few sculpins accounted for nearly 100% of the fish-food items consumed by chinook salmon. In 1983-84, Kogge (1985) reported that the predominant prey item was still alewives (38-57%) but significant numbers of smelt and young bloater chubs (less than 150 mm total length) were also found in the chinook salmon diet.

The feeding habits of chinook were not consistent from year to year and also differed regionally within a year. A notable shift in diet occurred from 1983 to 1984 when consumption of alewives decreased and that of young bloater chubs rose. In 1983, the species composition of ingested fishes was 57% alewives, 19% smelt, and 5% chubs while, in 1984, the fish items eaten consisted of 38% alewives, 15% smelt, and 25% bloater chubs (Table 3). However, this short-term shift may have been a normal, year-to-year variation in feeding habits. Regionally, northern zone chinook fed most heavily on alewives in both years, smelt consumption varied by relatively small amounts, and chubs were an important staple in diets of chinook in the southern and central areas in 1984. Thus, from Kogge's (1985) data, it is clear that feeding habits of chinook salmon are highly variable between years and geographic localities.

In 1986, R. Elliot (MSU, personal communication) found that the species composition of fish eaten changed with age, hence size, of chinook salmon. The diet (by weight) of 0.1 aged chinook in southern Lake Michigan consisted of 70% young chubs, 5% alewives, and 5% smelt. Age-0.2 chinook salmon consumed alewives and young chubs in approximately equal proportions (37%) with smelt consisting of 10% of the diet. Age-0.3 and older chinook fed heavily on alewives, which accounted for 65% of the ingested food.

Recent food studies of eastern Lake Michigan salmonines have relied on the sport fishery for samples. The nature of the fishery is to exploit the more pelagic and relatively shallow water, inshore segment of the stocks (G. Rakoczy, MDNR, personal communication). Consequently, observations on food habits may not be applicable to the whole population.

Natural reproduction.--Naturally recruited chinook salmon fingerlings have been observed in at least 14 Lake Michigan tributaries (Carl 1982), although most of the chinook reproduction was found in the larger trout streams. Carl (1982) estimated that 630 thousand chinook salmon smolts were produced in seven of Michigan's Lower Peninsula streams tributary to Lake Michigan in 1979, which accounted for about 23% of the total number of smolts produced (wild plus hatchery output of 2.1 million) in that year. The top producers of wild chinook smolts, according to Carl's estimates, were the Muskegon River (349,700 smolts), Pere Marquette River (146,700 smolts), and the Manistee River (98,700 smolts; Table 4). Because no recent surveys have been made of streams that produced wild chinook salmon in the past, the extent of the present-day yield of naturally produced chinook and the annual variation of that yield are unknown.

Seelbach (1985) reported that the yield of age-0.0 chinook salmon averaged 232 smolts per ha in the Little Manistee River during 1982-83 and rose to 992 smolts per ha in 1984. Seelbach speculated that the fourfold increase in smolt production was due to the larger number of spawners that were passed upstream in 1983 than in previous years. He also calculated that Michigan's best streams could have produced 1,000-2,000 chinook smolts per ha, comparable to the 2,000 smolts per ha that he calculated for one British Columbia stream.

Movement and lake distribution.--Although it has long been suspected that Michigan-reared chinook salmon contribute heavily to the fisheries of Wisconsin, Indiana, and Illinois, migratory patterns of chinook salmon in Lake Michigan have not been determined by the MDNR. Wisconsin began an ambitious chinook tagging program in 1982. Results from that study indicated widespread migration in western Lake Michigan (Lychwick 1985). However, only six marked fish from those plants were observed in the creel from Michigan's side of the lake during 1983-86, which indicated that Wisconsin-raised chinook salmon were not abundantly available to Michigan anglers.

As young fish in Lake Michigan tributaries, most chinook salmon smolts move downstream in May and June (Bryant 1968; Carl 1984; Seelbach 1985). Apparently the rate of smolting by chinook salmon varies rather widely. Carl (1984) reported that no age-0.0 chinook were found to have remained in Baldwin or Pine creeks by late summer or early fall. Seelbach (1985) stated that most wild age-0.0 chinook smolted in June with the proportions migrating as yearlings varying from 3% to 17%. Data presented by Healey (1986) showed that a 1-year stream residency by west coast juvenile chinook salmon is a common occurrence, with holdovers ranging from 1-77%.

Competition.--When it became apparent that the introduction of Pacific salmon was successful in the upper Great Lakes, there was concern about the potentially negative impact of salmon on native stream trout. Carl (1980) found no competitive interactions between juvenile chinook and coho or rainbow trout in Bigelow, Baldwin, or Pine creeks, although the brown trout population was considerably smaller in 1978 than in 1954-56 when no chinook were present. However, counts of drifting brown trout fry suggested adequate reproduction, and he concluded that any interference from chinook salmon in 1978-79 was minor. It is probable that competition from juvenile chinook salmon would be less than from juvenile coho salmon because most young chinook smolt and migrate from the stream by June following hatching, whereas young coho spend nearly 18 months in the stream before migrating to Lake Michigan.

Mortality.--Mortality rates of chinook salmon while in the Lake Michigan environment have not been determined. An unusual source of mortality of numerous species of Lake Michigan fish is the Ludington pump storage facility. Liston et al. (1981) estimated that the operation of the Ludington pump storage facility resulted in the loss of 410,000 small (less than 200 mm) and 15,700 large (greater than 200 mm) chinook salmon in 1979-80.

An instantaneous natural mortality rate of wild, juvenile chinook salmon in Baldwin and Pine creeks was estimated by Carl (1984) to have been on the order of 0.025 (2%) per day while in stream residence (emergent fry stage through late June). Seelbach (1985) reported that mortality of hatchery-reared chinook salmon from planting to smolting ranged from 0-32% in the Little Manistee River.

Lake Trout

Populations of lake trout were extinct in Lake Michigan by the mid-1950s because of decimation by the parasitic sea lamprey and overfishing. Sea lamprey control permitted the reintroduction of lake trout into Michigan waters of Lake Michigan in 1965 when 1.07 million yearlings were planted. Annual plants of lake trout through 1986 have ranged from 837,000 to

2.3 million in Michigan waters alone. Despite the massive plantings, lake trout have failed to reproduce themselves in significant quantities anywhere in Lake Michigan and are still dependent upon the hatchery product to maintain the stocks. Nevertheless, lake trout have thrived in Lake Michigan and have provided a highly successful sport fishery and, since about 1978, an Indian commercial fishery.

Age and growth.--The length-at-age and weight-at-length of Lake Michigan lake trout in 1985-87 were geographically oriented. When compared between zones, lengths (predicted from von Bertalanffy growth coefficients given in Table 5) of lake trout were the largest in the northern zone, intermediate in the central region, and smallest in the southern area (Figure 1). The predicted length-at-age of trout in the southern zone was consistently the lowest of all. As compared to growth curves in 1975, the average length-at-age of lake trout during 1985-87 in the northern zone was slightly larger up to age 4 but smaller at ages 8-10, in the central region was almost identical through age 5 although the trout in 1975 were somewhat larger at ages 8-10, and was consistently smaller at all ages in the southern area (Figure 2).

During the period 1985-87, analysis of covariance showed that weight-at-length regressions of lake trout differed significantly ($P<0.05$) between statistical zones. Weight-at-length of lake trout in the northern zone was significantly larger ($P<0.05$) than those in the central region at 200-500 mm, and also weighed significantly more than southern zone trout in the 200-700 mm length classes (Table 6). Central region lake trout were significantly heavier than those in the southern zone in the 400-800 mm length groups. As compared to 1975, the weight-at-length curves of lake trout in 1985-87 in the northern zone were virtually identical (Figure 3). However, in the central and southern regions, weight began to decrease at about 650 mm so that at a total length of 850 mm the weight loss per fish amounted to 0.6 kg in the central zone and 1.0 kg in the southern area. Hansen (1986) reported that no significant change occurred in standard weight (weight predicted at 635 mm from a weight-at-length regression) of lake trout in Wisconsin's waters of Lake Michigan during 1969-84. Neither did we detect much difference in weight at a total length of 635 mm from 1975 to 1985-87 because the weight-at-length did not begin to diverge until about 650 mm in the central and southern zones.

The mean length of 5-year-old lake trout, which usually is the modal age in the index catch, varied without trend ($P>0.05$) from 1975-87 in the central and northern zones (Figure 4). The length trend of trout in the central zone does show a slight loss of 22 mm from 1975 to 1987, but it cannot be declared statistically significant. Lake trout in the northern zone, on the other hand, exhibited a slight gain of 27 mm from 1975 to 1987, which also was statistically insignificant. Lake trout in the southern zone have not been indexed consistently so that a similar comparison could not be made. However, Eck and Wells (1983) demonstrated a decreasing trend in the mean length of 3- to 5-year-old lake trout in the Saugatuck area of southern Lake Michigan from 1971-79 (fall-collected data). As compared to mean lengths of 5-year-old lake trout in July 1975 (Rybicki and Keller 1978), the average total length of southern Lake Michigan lake trout in April 1985-87 was 522 mm versus 612, an apparent loss of 90 mm. It appears that lake trout in southern Lake Michigan have experienced a loss in growth over a long period of time. Aside from the variation in sampling month (July in 1974-75 versus April in 1985-87), the cause of the difference in growth is unknown but may be related to interspecific competition and more recently to a shift in the species composition of the forage base. Only from future assessment of the southern Lake Michigan lake trout stock will we know whether or not the decline of growth has stabilized.

Food habits.--The diet of lake trout in Lake Michigan has changed dramatically over the decades in response to an equally dramatic change in the fish-forage base. In 1931-32, sculpins were found in over 50% of the stomachs of immature lake trout in Lake Michigan, followed by coregonids (19.4%) and miscellaneous species (11.5%), which were primarily ninespine sticklebacks (Table 7). At that time, alewives had not yet entered Lake Michigan and smelt apparently were a minor item in the diet of Green Bay lake trout only. The first alewife was discovered in Lake Michigan near South Manitou Island in May 1949 (Smith 1968). By the mid-1960s, the alewife population had attained astronomical proportions and was estimated to be 80% of the fish biomass in Lake Michigan (Smith 1968). With a burgeoning alewife population, the chub stocks went into a lake wide decline, the severity of which eventually forced the closure of the commercial chub fishery in 1973. The changes in species composition of the fish-forage base were reflected with mirror clarity in the lake trout diet of the mid-1960s. Wright (1968) ascertained that 43% of the lake trout examined in 1966-67 contained alewives, 16% were feeding on smelt, chubs were practically nonexistent, and sculpin consumption had dropped from 52% in 1931-32 to 25%. The relatively low frequency of trout stomachs containing alewives may have been due to the generally small size of the lake trout in 1966-67. The first significant lake trout plants were made in Lake Michigan in 1965, and Wright's (1968) analysis showed that frequencies of trout stomachs holding alewives increased with trout length. By 1983-84, alewives were overwhelmingly the most important food item (65%) to lake trout, followed by smelt, which ranked a distant second at 17% while sculpins were found in less than 5% of the trout stomachs. The pronounced shift in diet to 65% alewives in 1983-84 is due partly to the sampling of larger, sport-caught lake trout than were examined in the earlier time periods. Van Oosten's and Deason's (1937) samples were immature lake trout caught in small-mesh gill nets. These investigators stressed that lake trout over 380 mm in total length fed heavily on coregonids (ciscoes, chubs, and whitefish), and that sculpins were more important to trout smaller than 380 mm. Of significance is that chubs were found in 10% of the trout stomachs in 1983-84, as compared to only 0.1% in 1966-67, which is reflective of the recovery of Lake Michigan's bloater chub population.

The consumption of smelt, chubs, and perch by lake trout differed sharply between broad geographical areas of the lake and also between 1983 and 1984 (Table 8). However, alewives were ingested with the greatest frequency (48-64% of the diet) regardless of geographical area or year. The ranking between smelt and chubs depended on the zone and year with smelt being preyed upon more frequently by lake trout in the southern zone than elsewhere. The large variation in diet between areas and years clearly indicates that feeding habits of lake trout are largely unpredictable over the short term.

Eck and Brown (1985) believed that the bulk of the Lake Michigan forage base now consists of species less pelagic than alewives (i.e., bloater chubs and sculpins), a belief that is supported by recent findings. Preliminary results from a multi-agency hydroacoustic survey of the Lake Michigan forage base in 1987 indicate that chubs may now be as much as 75% of the prey biomass (R. Argyle, USFWS, personal communication). As a consequence, Eck and Brown (1985) reasoned that lake trout, the most bottom oriented of the salmonines, should adapt to the changing species composition of the forage base more readily than the more pelagic chinook and coho salmon. However, lake trout do not appear to be taking particular advantage of those benthic-oriented food sources. Sculpins and chubs comprised only 3% and 9%, respectively, of the lake trout diet in 1984 (Table 8). In contrast, the diet of chinook salmon contained 26% chubs (Table 3) in 1984, although it all but ignored the abundant sculpin.

From an energetics point of view, a switch in forage base from alewives to bloater chubs may yet prove to be beneficial. The energy content in chubs is about 20% greater than in sculpins or alewives. Rottiers and Tucker (1982) determined that the caloric content (dry weight) was 5.775 kcal/g for deepwater sculpins, 5.982 kcal/g for alewives, and 6.884 kcal/g for bloater chubs.

Natural reproduction.--The lack of natural reproduction by lake trout continues to thwart the rehabilitation of the species in Lake Michigan. A brief surge of unclipped lake trout in the index catch from Grand Traverse Bay occurred during 1980-83, when the percentage of unmarked trout progressively increased from less than 1% to 5.7% (Rybicki 1983). However, the proportion of unclipped lake trout in the index catch from Grand Traverse Bay subsequently decreased to 5.2% in 1984, 0.7% in 1985, 4.3% in 1986, and 1.3% in 1987.

Ideally, the proportion of unmarked lake trout in a sample should be an indicator of natural recruitment because all stocked lake trout are fin clipped. However, some percentage of unmarked fish is due to clips missed in the hatchery or subsequent regeneration of excised fins. The percentage of unclipped trout as the result of not having been marked in the hatchery appears to be minor. Of 4,581 yearling lake trout examined shortly after planting in Grand Traverse Bay during 1984-87, only three (0.1%) were unmarked. Regeneration of excised fins with increased age of the fish has also been offered as an explanation for the sometimes greater frequency of unmarked, older fish. Although regeneration of clipped fins certainly has occurred, it is often detectable because of the fin's irregular growth pattern. Moreover, there was no statistically significant correlation ($r^2 = 0.01$; $P = 0.54$) between age and the proportion of unmarked lake trout in the index catch from Grand Traverse Bay during 1983-87. From 1975 to 1980, the mean frequency of unclipped lake trout was 0.5% (±1.5%) in the catch at five index stations from Little Traverse Bay to Pentwater (Rybicki 1983). The clip data obtained during those years is believed to represent the missed clip and regenerated fin error rates in the absence of lake trout reproduction. If the upper confidence limit of the mean percentage (0.5% + 1.5% = 2.0%) of unclipped lake trout during 1975-80 is taken as the baseline and compared to observed percentage of unmarked fish, then an estimate of the magnitude of natural recruitment can be made. Of course, such a comparison assumes that neither the clipping error rate nor the fin regeneration rate has changed from that during the baseline period. When the proportion of unclipped fish within a cohort is compared to the expected proportion of 2%, the 1976 and 1981 year classes in Grand Traverse Bay and the 1983 cohort at Point Betsie (Frankfort) contained significantly larger proportions ($P<0.05$) of unmarked fish than would be expected because of fin clip and regeneration error alone (Table 9). Thus, when the clip error rate of 2% is subtracted from the observed clip rate, about 14% of the 1976 year class and 11% of the 1981 year class are attributed to natural reproduction in Grand Traverse Bay, and 5% of the 1983 year class at Point Betsie is considered wild recruitment. Although encouraging, the estimated natural recruitment was only a modest proportion of a cohort, occurred infrequently, and was not geographically widespread. On the average, the data in Table 9 indicate that a detectable level of natural recruitment occurred in only one of every five year classes of lake trout in Grand Traverse Bay.

The reproductive failure of Lake Michigan lake trout often is attributed to inadequate numbers of spawners and/or contaminant laden eggs and fry. When compared with egg densities on spawning grounds in self-sustaining lake trout populations in other lakes, Dorr et al. (1981) suggested that the number of lake trout eggs deposited on spawning grounds in southeastern Lake Michigan appeared to be critically low. Large mortality rates of sub-adult and mature lake trout in Lake Michigan may well be a key factor limiting the numbers of spawners, which in turn may result in insufficient egg deposition in optimal habitat. Healey (1978) concluded that self-sustaining trout populations with natural mortality rates in the 20-30% range could withstand fishing that would push the annual total mortality to 50%. However, when total mortality was in excess of 50%, the lake trout populations were in serious difficulty. Pycha (1980) also suggested that a total mortality in excess of 50% may preclude restoration of spawning stocks in Lake Superior. It is now suspected that a hatchery-sustained lake trout stock may have a lower spawning efficiency than does a self-sustaining population. Thus, even a 50% total mortality rate may not allow adequate escapement of hatchery-maintained stocks. The Lake Michigan Lake Trout Technical Committee (Brown 1983) accordingly set a target rehabilitation mortality of 40% annually on the exploitable segment of the population. Since natural mortality (25% annually) of the fishable ages (4 years and older) was within Healey's range of 20-30%, and yearly total mortality rates usually were well above the recommended level of 40% (Figure 5; Table 10), it is believed that natural recruitment has been virtually nonexistent because of low spawner density. A long-term, multi-agency research project designed to quantify the relationship between spawner density and recruitment began in 1986, when yearling lake trout were stocked in two refuges established in central and northern Lake Michigan where fishing for lake trout is prohibited. In view of the large exploitation rates and their potentially devastating impact on natural reproduction, management of Lake Michigan's lake trout stock can be characterized fairly as put, grow, and catch.

Studies evaluating the effects of contaminants on the survival of lake trout eggs and fry have produced conflicting results. Willford et al. (1981) concluded that the levels of PCB and DDE present in the water and biota of Lake Michigan during the early to mid-1970s were sufficient to reduce significantly the survival of lake trout fry. Stauffer's (1977b) findings were quite the opposite of Willford's. Stauffer believed that DDT and PCB were not the cause of reproductive failure by lake trout in Lake Michigan. He was unable to demonstrate a greater mortality in Lake Michigan eggs and fry when compared to low contaminant-bearing eggs and fry from the Marquette Hatchery broodstock.

Age and length-at-maturity of female lake trout varies by geographical zone. At age 6, percentages of the female lake trout mature in the northern and central zones were similar at 78% and 75%, respectively, but in the southern zone only 56% were mature (Table 11). Maturity schedules by length group exhibited rather large variability between length classes within a zone (Table 12). To smooth the irregularities of the frequencies of length-at-maturity, cumulative percent frequencies were used for female lake trout. The upper series of curves in Figure 6 show that at an arbitrarily selected length of 63 cm (25 inches) the distribution of the mature segment of the female trout stock also differs between geographical zones. If the minimum size limit were set at 63 cm, then 37% of the mature female stock in the northern zone would be protected from the sport fishery, 46% would theoretically be uncatchable in the central area, and 54% would be protected in the southern region. For the lake as a whole, a 63 cm minimum size limit would shield about 44% of the mature females from exploitation by the sport fishery (lower curve in Figure 6). A modeling exercise by Clark and Huang (1985) showed that only complete closure of the lake trout fisheries would allow the stocks to attain a rehabilitation goal of 25,000 wild fish at age 4 in the Frankfort to Good Harbor Bay area of Lake Michigan. Their work also indicated that rehabilitation of lake trout stocks could be achieved in less than 25 years if first year survival were as large as 0.01, current stocking rates were maintained, and a size limit of 711 mm (28 inches) were imposed on the sport and Indian commercial fisheries. A 711 mm minimum size limit would protect about 81% of the mature, female lake trout population (lower curve in Figure 6).

Movement and lake distribution.--Migratory patterns of Lake Michigan lake trout appear to be related to various life stages of the animal. Hesse (1969) followed nine groups of marked juvenile lake trout planted in Lake Michigan during 1965-67. He found that the majority of hatchery-reared juveniles remained within the general area of release up to 3 years at large, although substantial migration did occur. Yearling trout planted at sites along the eastern half of the north shore of Lake Michigan traveled as far west as Little Bay De Noc in northern Green Bay, and as far south as Benton Harbor on the east side and Milwaukee on the west side of the lake. Conversely, a few lake trout released on the Milwaukee Reef in southern Lake Michigan were captured in the northeastern quadrant of the lake. Adult lake trout appear to be relatively sedentary. Rybicki and Keller (1978) reported that 85% of the recaptures of marked, mature lake trout, which were tagged during the spawning season at Charlevoix in 1973-74, came from a 20 mile radius of the release site over a 2-year period. They also demonstrated that the adult lake trout exhibited a strong tendency to home to the general tagging area during the spawning season.

Although autumn migrations of lake trout into Lake Michigan tributaries is not a new development in Michigan, the sightings have increased in the last decade. MDNR biologists in the Grand Rapids and Plainwell districts reported lake trout in the Grand, Kalamazoo, Black (Van Buren County), St. Joseph, and Galien rivers in the fall of 1980. In the St. Joseph River, lake trout were observed below the Berrien Springs dam, about 25 miles upstream from Lake Michigan (D. Johnson, MDNR, personal communication). Lake trout were also found in the Grand River below the Sixth Street dam in Grand Rapids, some 50 miles upstream from Lake Michigan (J. Trimberger, MDNR, personal communication). MDNR district personnel estimated that the sport fishery caught about 5,000 lake trout in the Grand River in 1980. Pecor (1985, 1986, and 1987) reported that lake trout were captured for the first time in the lower weir near the mouth of the Platte River in 1982, when 38 fish were passed upstream. Since then, lake trout have been caught in the Platte River's lower weir each year through 1986 in numbers ranging from 7 to 69. Whether or not lake trout were spawning in these rivers is unknown, although many of the trout creeled from the Grand River in 1980 were either ripe or spent.

Mortality.--The annual total mortality rates of lake trout usually were very large during 1975-86, when the estimates ranged from 45% to 76% (Table 10). However, the mortality rates also were highly variable from year to year, which indicated that the mortality estimates were subject to rather large sampling error. Consequently, a more useful approach to examining mortality rates is from a calculated trend line, which provides predicted total mortality rates. The observed and predicted rates are given in Table 10, and the trend lines are shown in Figure 5 (a third order polynomial equation was used to fit the trend lines). Death rates of southern Lake Michigan lake trout showed a trend of increasing slightly each year from 51% in 1978 to 59% in 1986. In the central zone, lake trout mortality dipped modestly from 51% in 1975 to 46% in 1977, rose steadily to 61% in 1984, and again began dropping in 1985-86, suggesting that mortality rates may again be entering a period of decline. The trend in the northern zone has been one of steadily increasing mortality from 45% in 1975 to 69% in 1983, with a stable rate from 1983-86.

Given a constant instantaneous natural mortality rate of 0.284 (Rybicki and Keller 1978), the annual exploitation rates were estimated to range from a low of 25% (central zone, 1976) to a phenomenal 53% (northern zone, 1983-84; Table 10). In most years in the central and southern zones, fishing mortality was induced by the sport fishery. In the northern region, an Indian gill-net fishery has harvested lake trout since at least 1978 in addition to an ongoing sport fishery. In the northern zone in 1986, the sport fishery harvested 20,900 lake trout (34% of the total catch in number) and the Indian fishery caught 40,600 lake trout (66% of the total in number). The proportion of total deaths of northern zone lake trout was 49% by the Indian fishery and 26% by anglers.

Lake trout is the only salmonid for which hooking mortality has been assessed in the Great Lakes. Loftus (1986) found that overall hooking mortality in the sport fishery averaged about 15% during a 2-year study period. However, trout that were not found immediately after being hooked or that had been hooked in internal regions showed a much higher incidence of mortality. For example, trout hooked in the jaw and subsequently released had a total mortality of 7% while those hooked in internal regions died at a rate of 71.4%. Loftus also found that the hooking mortality rate was related to the size of fish caught, with smaller fish having a significantly higher chance of death. However, no relationship between the rate of hooking deaths and the depth from which the fish was caught, temperature differential between this depth and the surface, gear type, or handling times was observed during the 2-year study.

Rainbow (Steelhead) Trout

The steelhead, the anadromous form of the rainbow trout, was introduced from its native Pacific Coast range into the Great Lakes in the late 1800s (Biette et al. 1981). Present Lake Michigan steelhead populations are maintained by a combination of natural reproduction and supplemental plantings of hatchery-raised fish (Seelbach 1986 and 1987). Adult steelhead spawn in tributary streams. Juveniles, or parr, spend from 1 to 3 years in the stream before emigrating to the lake. Emigrants include both smolts and presmolts. Smolts are juveniles, ages 1-3, which have undergone a physiological transformation (in preparation for ocean life in their native range) and are actively migrating downstream to the lake. Presmolts are age-1 juveniles which have not yet undergone the smolting transformation but are actively migrating downstream, presumably due to habitat limitations. Adult steelhead return to the river to spawn after 1-5 years of lake life.

Steelhead runs occur in nearly all the tributaries of Lake Michigan. These streams fall into three main categories: 1) the predominantly warmwater rivers of southern lower Michigan, Indiana, and Wisconsin, 2) the exceptional trout streams of northern lower Michigan which have stable flows dominated by groundwater inputs, and 3) the trout streams of upper Michigan which have unstable flows dominated by surface runoff.

Several hatchery strains of steelhead are currently stocked in Lake Michigan. Wisconsin stocks the Ganaraska, Chamber's Creek, and Skamania strains. Indiana and Michigan are stocking the Michigan and Skamania strains. Fish of the Ganaraska and Michigan strains are first-generation offspring of wild steelhead captured in the Ganaraska River, Ontario, and the Little Manistee River, Michigan, respectively. The Chamber's Creek is a hatchery strain from Washington. The Skamania is a hatchery strain of summer-run steelhead, also from Washington.

Age and growth.--Wild steelhead populations are mostly found in the trout streams of upper and northern lower Michigan. Stream parr populations have been reported to consist of 68-86% age-0+, 14-29% age-1+, and 0-3% age-2+ fish (Stauffer 1972; Taube 1975; Carl 1983; Seelbach 1986). Stream growth is among the fastest reported (Seelbach 1986). Fall parr total lengths are quite large relative to northern Great Lakes and Pacific Coast populations, with lengths of 71-80 mm, 153-169 mm, and 236-244 mm reported for the above age groups, respectively (Greeley 1933; Stauffer 1972; Avery 1974; Taube 1975; Carl 1983; Seelbach 1986).

Seelbach (1986) found that the majority (83-91%) of smolts in the Little Manistee River (northern lower Michigan) were age 2, the remainder being age 1 (7-15%) and age 3 (1-2%). Less than 2% of the total number of emigrants were presmolts. In contrast, Stauffer's (1972) studies of an upper Michigan trout stream suggested that a large proportion (approximately 68%)

of the steelhead emigrants were presmolts (Seelbach 1986). Presmolts are believed to be a population's surplus juveniles, moving downstream due to habitat limitations. The lack of presmolts observed in the Little Manistee River study indicated that, in this type of stream, rearing habitat for age-1+ parr was ample relative to the number of age-0+ parr produced.

Smolts from the Little Manistee River were the largest reported anywhere, with total lengths of age-1, age-2, and age-3 smolts averaging 165-183 mm, 201-220 mm, and 253-269 mm, respectively (Seelbach 1986). Smolts from an upper Michigan stream were smaller, with total lengths of age-2 and age-3 fish averaging 150-170 mm and 203-213 mm, respectively (Stauffer 1972). Presmolts ranged in length from 70 to 100 mm.

Scales from adults returning to the Little Manistee showed that 73% of these had spent 2 years rearing in a stream (Seelbach 1986). In most Great Lakes steelhead populations, greater than 80% of the returning adults have spent 2 years rearing in a stream (Biette et al. 1981). Adult runs in two southern lower Michigan rivers showed different proportions of stream years, with one having 74% and the other 29% age-2 fish (Seelbach 1988). These southern rivers contain significant numbers of hatchery fish which smolt at age 1 and whose presence would be expected to lower the proportion of age-2 fish.

Most adults returning to both the Little Manistee and to the two southern lower Michigan rivers had spent 3 years in the lake (Seelbach 1986 and 1988) (Table 13). However, the southern rivers were somewhat different in having a relatively high proportion of spawners which had spent 4 or 5 years in the lake. In the remainder of the Great Lakes, only one other steelhead population has been reported where age-.3 fish were predominant (Karges 1987). Typically, age-.2 fish are the most common (Biette et al. 1981; Scholl et al. 1984; Swanson 1985).

The percentages of returning adults which were repeat spawners were similar for southern and northern lower Michigan populations (Seelbach 1988). Repeat spawners made up 6-12% of the age-.2 fish, 17-18% of the age-.3 fish, 48-65% of the age-.4 fish, and 100% of the age-.5 fish. Due to the rapid growth experienced by steelhead during lake life, adult length is primarily a function of lake age, although stream age, season, and sex have some influence (Seelbach 1986). Interestingly, repeat spawning has not been found to affect length. Growth is quite similar for southern and northern lower Michigan populations (Seelbach 1988) (Tables 14 and 15), indicating that fish from both regions had experienced strikingly similar growth regimes in Lake Michigan. Steelhead size in these two regions and in Wisconsin waters has remained quite constant during recent years (1980-1985, 1979-1985, and 1969-1984 for the respective regions), suggesting that steelhead numbers have been at some stable equilibrium point as indexed by growth (Hansen 1986; Seelbach 1988).

Returning adult age structure differs some among the different hatchery strains. For example, age structure of the Michigan strain is essentially identical to that of its parent Little Manistee population (P. Seelbach, MDNR, unpublished data), while the Skamania strain returns at older ages (.3, .4, and .5) (Fielder 1987; MDNR, unpublished data). The Skamania strain is present to some degree in the southern lower Michigan populations discussed above and this likely explains the relatively high frequency of older fish in these populations. Growth of the various hatchery strains parallels that of wild fish (Fielder 1987; MDNR, unpublished data).

Food habits.--Juvenile steelhead in Great Lakes tributaries feed primarily on drifting aquatic insects and, to a lesser extent, on terrestrial invertebrates (Hannuksela 1973; Wagner 1975; Johnson 1981a and 1981b). The diet of first-summer postsmolts in Lake Michigan has not been well studied. Tesar and Jude (1985) found postsmolts in nearshore waters of southeastern Lake Michigan to have been feeding mostly on invertebrates, many of which were terrestrial insects.

Older steelhead in the lake feed during spring and summer predominantly on terrestrial insects in the surface film and on alewives (R. Elliott, Michigan State University, personal communication). Alewives typically dominate the diet by weight, but at times anglers have observed the diet to almost exclusively consist of terrestrial insects. Steelhead in southern Lake Michigan also incorporate yellow perch and bloater chubs into their diets. In the fall, steelhead feed primarily on young-of-the-year rainbow smelt, bloater chubs, and alewives, and, in recent years, on the newly introduced cladoceran (European waterflea) *Bythotrephes cederstroemi*.

Of the pelagic Great Lakes salmonids, the steelhead's diet is most similar to that of the coho salmon, and least similar to those of the chinook salmon and lake trout which feed more heavily on alewives. Brandt (1986) also observed that steelhead in Lake Ontario fed primarily on alewives and terrestrial insects. Steelhead in the Pacific Ocean are reported to live near the surface and feed on threespined sticklebacks, lanternfish, squid, polychaetes, and crustaceans (J. Light, University of Washington, personal communication). Laboratory studies have shown the steelhead to be a relatively slow-swimming predator (Savitz et al. 1986) which may explain its tendency to prey on relatively slow-swimming, awkward species.

Anglers have observed that steelhead which enter the river in summer, fall, and winter feed on aquatic invertebrates and salmon eggs. However, feeding ceases as the spring spawning season approaches.

Natural reproduction.--Naturally reproducing, or wild, steelhead populations exist in many tributary streams, in particular those in both northern lower and upper Michigan. Michigan and Wisconsin have long had substantial stocking programs although these have been relatively ineffective due to either the stocking of small-sized fish (parr) rather than the necessary smolts (Seelbach 1987) or the stocking of non-steelhead rainbow strains (B. Belonger, WDNR, personal communication). Thus, the good-to-excellent steelhead fisheries of northern lower and upper Michigan have been historically supported by natural reproduction. This conclusion has been supported by the documentation of substantial natural parr populations (Stauffer 1972; Taube 1975; Carl 1983; Seelbach 1986), the observations that most (66-84%) of the adults returning to two Michigan rivers had been produced in those rivers (Biette et al. 1981; Seelbach 1986), and by Seelbach and Whelan's (1988) analysis of scale growth patterns which showed populations in northern lower Michigan to be made up of greater than 90% wild fish. The contribution of natural reproduction is believed to be negligible-to-minor in most other areas of the lake (Avery 1974; B. Belonger, WDNR, personal communication), although uncertainty exists as to the magnitude in some of the large rivers of southern lower Michigan (Seelbach 1988).

Wisconsin, Indiana, and Michigan have all greatly improved their stocking programs in recent years. All are now stocking large smolts and strains of steelhead which have proven to be successful. The contribution of these plants are expected to be significant wherever they are stocked.

Movement and lake distribution.--Seelbach (1986) found steelhead smolt migrations out of the Little Manistee River in northern lower Michigan to begin in mid-April, peak in mid-May, and taper off by mid-June. Age-3 smolts migrated earliest, followed in turn by age-2 and age-1 smolts. This migration pattern was very similar to that reported for populations in other areas of the Great Lakes and on the Pacific Coast. Stauffer (1972) found, in an upper Michigan tributary, that age-2 smolts migrated in May and presmolts moved primarily in June. The consistent migration dates which have been observed support the idea that both the increase in day length during the spring and the rate of that increase are the primary factors triggering migrations (Ruggles 1980; Wedemeyer et al. 1980). The spring increase in water temperature is believed either to set limits on the migration period or to merely have a coincidental relationship with migration. Hatchery smolts stocked in the Little Manistee migrated in synchrony with the wild fish (Seelbach 1987). It is possible, however, that hatchery smolts would migrate earlier if stocked in an earlier warming, more southern river.

Little is known about the movements or distribution of steelhead during their life in Lake Michigan. However, some inferences can be made based on angler observations and studies from other areas of the Great Lakes and from the Pacific Ocean. Nothing is known about the movements of postsmolts upon lake entry. In the Pacific, steelhead smolts move immediately out to sea while remaining near the surface (J. Light, University of Washington, personal communication). In Lake Michigan, anglers find adult steelhead near the shore during the spring and fall and far offshore during the summer, generally inhabiting the near-surface waters. Haynes et al. (1986) reported, similarly, that radio-tagged steelhead in Lake Ontario were found close to shore in the spring and then dispersed to the open lake as water temperatures rose in the summer. Steelhead were generally found near the surface in waters ranging from 9° to 10°C in temperature, often near thermal fronts which were associated with concentrations of terrestrial insects. The same association with insect concentrations was noted in Lake Superior (Winter 1976 cited by Haynes et al. 1986).

A variety of information suggests that, during the summer, steelhead in Lake Michigan disperse widely and that fish from different wild and hatchery stocks intermix to a large degree. Both anglers and biologists have reported catching groups of steelhead in a given location in Lake Michigan which were marked with a great variety of fin-clip patterns, implying extensive mixing of stocks. The similarities in growth of southern and northern stocks described above supports this notion of mixing. Similarly, Haynes et al. (1986) reported that, during summer, steelhead in Lake Ontario were widely dispersed throughout the entire lake. In the Pacific Ocean, steelhead also are found near the surface, dispersed widely throughout the north Pacific (Sutherland 1973).

Although steelhead spawn during the early spring, adults migrate into Great Lakes tributaries during the fall, winter, and spring months (Biette et al. 1981; Seelbach 1986). Fall upstream migrations began in September, increased in mid-October, and were still underway when observations ceased in early November. Few fish were migrating when observations resumed in early March, however, large numbers migrated during late March and April with movements tapering off sharply by May. It is not known whether the fall-winter and spring periods of peak movement actually represent movements of distinct stocks, although these groups bear striking similarities to the summer and winter stocks of the Pacific Coast (Biette et al. 1981; Seelbach 1986). Michigan strain hatchery fish migrate upstream similar to wild fish (P. Seelbach, MDNR, unpublished data). Skamania strain summer steelhead migrate into the river beginning in late June and on through the summer and fall. These fish spawn the following spring (Fielder 1987; MDNR, unpublished data).

Competition.--Juvenile steelhead dominate the stream environment but share it with several other salmonids including resident brown and brook trout, and juvenile coho and chinook salmon. Stream salmonids are believed to compete primarily for space but, in natural communities, behavioral differences have generally evolved which minimize this (Chapman 1966). Steelhead coevolved with coho and chinook salmon on the Pacific Coast and have well documented differences in habitat preference and length of stream residency which minimize competition for resources. As steelhead, brown, and brook trout each evolved separately, however, these might be expected to use similar resources and to compete heavily for them. Indeed, both brown and rainbow trout have been shown to compete with brook trout (Fausch and White 1981; Larson and Moore 1985; Rose 1986). Brown trout are the most abundant potential competitor of steelhead, and both anglers and biologists have voiced concerns that the abundant juvenile steelhead are out competing young brown trout for stream space (Kruger 1985). Preliminary studies of the habitat preferences of juvenile steelhead and brown trout indicate a great deal of overlap suggesting that competition for this resource may occur (R. Ziegler, MDNR, personal communication).

Through studies of mortality patterns, Pacific Coast researchers have identified the first summer of a salmonid's ocean life as a critical period during which intra-, and possibly, interspecific competition for food occurs (Walters et al. 1978; Peterman 1980). In addition, Peterman (1984) documented density-dependent growth during the early ocean life of sockeye salmon, indicating competition for limited food resources. Seelbach (1986) has argued that the first summer of lake life, similarly, is a critical period for Great Lakes salmonids, including steelhead. Tesar and Jude (1985) found that juvenile steelhead, brown trout, chinook salmon, and coho salmon, as well as other small non-salmonid fishes, all fed primarily on terrestrial insects while in near-shore waters of Lake Michigan. The heavy concentrations of postsmolts, which undoubtedly occur in early summer, and the apparent similarities in distributions and diets among species suggest that intra- and interspecific competition may be intense during this period.

Interspecific competition among adult (defined hereafter as the period following the first lake summer) steelhead and other salmonids has not been studied. However, angler and biologist reports on the lake distributions and food habits of salmonids suggest that steelhead have a relatively unique niche throughout much of the year, living offshore near the surface and feeding to a large extent on terrestrial insects in the surface film. This suggests a minimum of interspecific competition. Intraspecific competition has not been studied either. However, the constant growth rates described above imply that adult numbers have been fairly stable and that food is not a limiting factor.

Mortality.--Mortality during early stream life is generally believed to be variable and quite high. Karges (1987) estimated an egg-to-emergence mortality rate of 95% for steelhead in a Lake Ontario tributary. The mortality of trout in streams is probably density-dependent, with densities being limited by the carrying capacity of the stream for parr of a given age (Elliott 1985). Taube (1975), Stauffer (1979), and Seelbach (1986) all found age-1+ parr densities to remain fairly constant from year to year, supportive of the above conclusion. Similar data have been collected for Pacific Coast populations (Everest et al. 1984; Chilcote et al. 1985). The exceptions to this scenario occur when recruitment in some years is below the carrying capacity of the stream due to either limited spawner numbers or catastrophic early mortalities (i.e., floods during the hatching period). Stauffer (1972) documented such a situation in an upper Michigan stream. Seelbach (1986) felt that the former scenario was descriptive of most northern lower Michigan streams where stable flow conditions would contribute to consistent fall age-1+ parr production. Streams in upper Michigan, on the other hand, which have highly variable flow patterns and lower drought flows would exhibit more variable fall age-1+ parr production.

As nearly all smolts are age-2, the dynamics of this group are critical. Overwinter survival of age-1+ parr to age-2 smolt in a northern lower Michigan river was found to be quite variable, ranging from 13-90%, and negatively related to the severity of cold-winter temperatures (Seelbach 1986). Supportive of this idea, Hassinger et al. (1974) found overwinter survival for this group to be 6% in a Lake Superior tributary where cold temperatures were quite severe. In many cases, the severity of winter temperatures may determine smolt yield.

Mortality rates for steelhead cohorts while in Lake Michigan are not known. The cohort is generally measured as it leaves and returns to the river and, in most years, only a portion of the cohort returns to the river. Based on theory developed for salmonids in the ocean (Walters et al. 1978), lake mortality is hypothesized to be highest during the first few months when smolts are concentrated at high densities and conceivably competing for food and when they are small enough to be vulnerable to predatory fishes (Seelbach 1986). After a few months' growth, steelhead may be large enough to escape all predation by Great Lakes fishes and mortality after this point may be very low. Survival from smolt to returning adult has been studied for a few cohorts, with minimum estimates of 8%, 17%, 31%, and 48% (Seelbach 1986; MDNR unpublished data). These figures imply that total lake survival is extremely high. Total ocean survival typically ranges from 1-19% (Larson and Ward 1954; Hallock et al. 1961; Wagner et al. 1963; Wagner 1968; B. Ward, British Columbia Ministry of Environment, personal communication).

Returns of adult salmonids from the ocean have been found to be positively related to both smolt size and smolt numbers (Foerster 1954; Ricker 1976; Holtby and Hartman 1982; B. Ward, British Columbia Ministry of Environment, personal communication). Similarly, Seelbach (MDNR, unpublished data) found adult steelhead returns to be related to indices of both smolt size and numbers (Figure 7).

Steelhead can spawn more than once, however, considerable mortality does occur between spawnings. Survival to second spawning has been reported to be 18-63% for a Lake Michigan population and 18-49% for a Lake Ontario population, with survival varying according to lake age (Seelbach 1986; Karges 1987).

Little is known about the survival of stocked hatchery smolts. Seelbach (1987) found that 48% of one group of smolts migrated from the river, however, these fish were stocked much too early and mortality was probably unnecessarily high. Lake survival of these fish was 31% for a total survival of 15% (P. Seelbach, MDNR, unpublished data). Mortalities and stress have been observed in adult Skamania strain steelhead which returned in summer to rivers with summer temperatures which were marginal for trout survival.

Brown Trout

Brown trout were introduced from their native European range into Great Lakes tributaries approximately 100 years ago (Scott and Crossman 1979). Brown trout populations presently in Lake Michigan and its tributaries can be classified into 1) wild (naturally reproducing) stream-resident fish, 2) wild anadromous fish, and 3) hatchery fish (a domestic strain) which are stocked directly into the lake. It is not clear whether the wild resident and anadromous fish are distinct stocks or different forms of one stock (Jonsson 1985). The remainder of this discussion will focus on the wild anadromous and hatchery populations which contribute to the lake and anadromous fisheries.

Brown trout spawn in October and November in tributary streams (Hay 1986b). Young fish go through parr and smolt life stages similar to those described elsewhere for steelhead (Jonsson 1985). The fishery for brown trout is almost exclusively in the near-shore waters of Lake Michigan and in connected river mouth lakes, with very few anadromous browns caught in the tributaries (P. Seelbach, MDNR, personal observation).

Age and growth.--Little is known about the stream life of anadromous brown trout. Smolts leaving a Lake Superior tributary were predominantly age 2 (86%), the rest being age 1. The age-2 smolts averaged 180-200 mm in length. Seelbach (MDNR, unpublished data) captured smolts emigrating from the Little Manistee River in northern lower Michigan which averaged approximately 200 mm in length. Nearly all of the adults returning in the fall to two northern lower Michigan rivers were ages .1 and .2, with a few being age .3 (Hay 1986a and 1986b; Pecor 1987). The relative proportions of age-.1 and age-.2 fish in the runs varied between years in relation to year-class strength.

Age-.2 fish averaged 560 mm in length and age-.3 fish approximately 635 mm in length. Growth of these fish in Lake Michigan has remained quite constant for the past 10-15 years in both Michigan and Wisconsin waters (Hansen 1986; Hay 1986b). Growth is somewhat faster than that reported from a Lake Superior tributary, where age-.2 fish averaged 510 mm in length (Scholl et al. 1984). Brazo and Liston (1977), Tesar et al. (1985), and Brandt (1986) found similar size distributions for adults in the near-shore waters of southeastern and central-eastern Lake Michigan and in the southern Lake Ontario sport catch (most being 400-700 mm in length).

Tesar et al. (1985), Tesar and Jude (1985), and Brazo and Liston (1977) found that near shore Lake Michigan populations were made up of 12-60% age-.0 fish which were generally less than 270 mm in length.

Food habits.--During stream life, juvenile brown trout feed on drifting aquatic insects and terrestrial invertebrates (Hannuksela 1973; Wagner 1975; Johnson 1981a and 1981b). Tesar and Jude (1985) found that immature brown trout in the near-shore waters of southeastern Lake Michigan fed chiefly on terrestrial insects and small fish. Adults in both lakes Michigan and Ontario have similar diets, feeding almost entirely on alewives and rainbow smelt (Brandt 1986; R. Elliott, Michigan State University, personal communication). Brown trout diets are very similar to those of coho salmon, chinook salmon, and lake trout. No information is available on the feeding habits of adults during their upstream spawning migrations. However, as migrations occur just prior to spawning, feeding may be minimal.

Natural reproduction.--The relative contributions of wild and hatchery populations to overall adult populations has not been examined, but it is generally believed that the contribution of wild fish is minimal in most areas. Seelbach (MDNR, unpublished data) captured small numbers of brown trout smolts emigrating from one northern lower Michigan river and has observed first-year growth patterns on some adult scales which are similar to those of known-origin wild steelhead (Seelbach and Whelan 1988). Estimates of annual smolt production from the above river were very low, usually less than 100 fish per year. In addition, the numbers of adults which typically return each fall to this river and a neighboring one, of which only a small portion are probably wild fish, are very low, averaging between 50 and 200 fish per year. Tesar and Jude (1985) found that the abundance of immature (<254 mm) brown trout near shore in southeastern Lake Michigan was significantly correlated over a 10-year period with stocking rates at nearby sites. Brown trout populations in Lake Ontario are also primarily hatchery supported (Nettles et al. 1987), while one Lake Superior tributary supports a substantial wild run (Scholl et al. 1984).

Movement and lake distribution.--Brown trout smolts emigrate during late April and early May (P. Seelbach, MDNR, unpublished data). Immature fish have been found during spring and summer in shallow near-shore waters of southeastern Lake Michigan (Tesar et al. 1985). Adults in Lake Michigan are found close to shore during spring and early summer, and during fall when water temperatures are between 7° and 17°C (Brazo and Liston 1977; Tesar et al. 1985).

The movement and distribution of adults in Lake Ontario have been studied using radio telemetry and appear quite similar to those in Lake Michigan (Haynes and Nettles 1983; Nettles et al. 1987). During spring, brown trout are typically found in nearshore, fairly shallow waters close to original stocking sites, streams, and power plant outflows in waters ranging from 8° to

18°C. In summer, as nearshore waters become too warm, fish move further off shore and associate with the thermocline, presumably attracted to the prey fishes which are also associated with the thermocline.

Brown trout also exhibit diurnal movements, moving in very close to shore at night. They generally do not move as extensively around the lake as do Pacific salmonids. Adults in Lake Michigan make upstream spawning migrations during September and October (Hay 1986b; Pecor 1987), however, it is not clear what proportion of the hatchery fish migrate upstream.

Competition.--The notion of competition during stream life is difficult to address, as the relationship between wild anadromous and resident brown trout is not understood. However, juvenile anadromous brown trout likely compete for stream space with the juvenile resident brown trout and steelhead which are abundant in most streams. This competition probably explains the poor smolt output mentioned above. The distribution patterns and food habits of brown trout and other salmonids which have been observed during early lake life suggest that intra- and interspecific competition for food may occur during this period and may be significant. The food habits of adult brown trout overlap with those of other salmonids. However, the strong association of brown trout with nearshore and thermocline regions and their tolerance of a fairly wide range of temperatures suggests that they may be spatially isolated to a fair degree from the other salmonids (Nettles et al. 1987).

Mortality.--Nothing is known about mortality during stream life in the Great Lakes region. In general, stream mortality of anadromous brown trout is regulated by density-dependent mechanisms related to the carrying capacity of the stream (Elliott 1985). No data are available on lake mortality although the general absence of fish older than age 2 implies that mortality is quite high. It is possible that both pre-spawning (predation and fishing) and post-spawning mortalities are high and contribute to the lack of older fish. Scholl et al. (1984) estimated that survival to repeat spawning was 4-11% in a Lake Superior stream. Fishing mortality on adults migrating upstream to spawn is believed to be fairly low as these are difficult to catch (Scholl et al. 1984).

Pink Salmon

Pink salmon of an odd-year spawning stock were unintentionally introduced into the Great Lakes in 1956 when 20,000 fingerlings were released into a north-shore tributary of Lake Superior (Nunan 1967). They have since extended their range into the other Great Lakes.

During September, pink salmon in the Great Lakes enter tributary streams to spawn. The first mature adults in tributary streams were reported for Lake Superior in 1959, Lake Huron in 1969, Lake Michigan in 1973, and lakes Erie and Ontario in 1979 (Kwain and Lawrie 1981). The pink salmon in the Great Lakes are unique in that they are the only known self-perpetuating population of the species in fresh water.

In Michigan waters of Lake Michigan, pink salmon have been observed in 19 Upper Peninsula tributaries and 13 Lower Peninsula tributaries. Generally, the estimated abundance of pink salmon in the spawning runs ranged from a few to 1,000 individuals, but in the Black River, Manistique River, and Thompson Creek in the Upper Peninsula and the Manistee River in the Lower Peninsula, runs during some recent years were judged to be in the 1,000 to 10,000 fish range.

Pink salmon have been collected during the spawning runs since 1973 to obtain biological information (Wagner 1985). Fish from Lake Michigan averaged considerably larger than those from lakes Huron and Superior and males were larger than females (Table 16). Weight is a poor parameter for comparing size of fish collected during the spawning runs. This was demonstrated at the St. Marys River in 1987 when, although mean length varied little during the spawning season, there was a significant reduction in mean weight as the season progressed and a greater proportion of the fish had completed spawning (W. Wagner, MDNR, unpublished data).

Ovaries were taken from females whose eggs were still encased in the ovarian sac. Counts ranged from 1,333 eggs for Lake Michigan fish with an average length of 471 mm to 727 eggs for Lake Huron fish averaging 389 mm (Table 17).

Pink salmon have a 2-year life cycle, however a single 3-year-old was collected from a Lake Superior tributary in 1976 and a few were collected from several Lake Superior tributaries in 1978. Three-year-old pink salmon have become common in Lake Superior but have not been reported from lakes Michigan and Huron. The few pink salmon seen during even years in Lake Michigan most likely originated from 3-year-old Lake Superior fish.

Only one major study of the food habits of pink salmon in the Great Lakes has been reported. Stomach samples from Lake Huron fish caught by anglers during June-August 1985 were examined (Kocik and Taylor 1987). The diet of pink salmon, by volume, was found to be 45% rainbow smelt, 39% alewives, and 7% other fish and unidentified fish remains. Various insects and crustaceans made up the remainder of the diet. Food habits of pink salmon in Lake Michigan may be similar since the ecosystems of lakes Michigan and Huron are similar. The authors state that other salmonids also feed extensively on rainbow smelt and alewives, thus the potential for food competition exists.

Brook Trout

Although highly prized by anglers, the native coaster brook trout population in Lake Michigan is very small indeed and, except in a few instances, has all but been ignored by fishery managers. The coaster, an anadromous strain of brook trout, also was considered by Tody and Tanner (1966) as a potential predator to bring alewives under control. They concluded that it would be difficult, perhaps even impossible, to propagate the species to the extent necessary to consume the available quantities of alewives. Factors against the coaster were the lack of widespread availability of the quality of streams that brook trout require for spawning, a shortage of suitable hatchery facilities, and little knowledge of the coaster's Great Lakes habits, which amounted to only a few generalizations that brook trout tended to inhabit relatively shallow water, were short-lived, and were highly vulnerable to fishing. Our knowledge of coaster brook trout has increased very little in the intervening years.

Most hatchery-reared brook trout planted in the Great Lakes have been stocked in Grand Traverse Bay of Lake Michigan and at a few locations in Lake Superior. Plants of brook trout in Grand Traverse Bay were made annually during 1965-72 (except 1969), but only two small releases were made during 1973-86. These plants occasionally provided a good, albeit brief, fishery.

Miller (1973) reported that yearling brook trout planted in Copper Harbor (Lake Superior) in 1967-68 averaged 114 mm and 140 mm in new growth in 1 year, tended to migrate out of the Harbor (although he did not say how far), were distributed in relatively shallow water (2 to 9 m), and apparently did not survive more than 18 months after planting. Miller's observations were consistent with those noted for brook trout planted in Grand Traverse Bay during the mid-1960s through the early 1970s (M. Keller, MDNR, personal communication).

Prospects of establishing even a modest coaster brook trout population in Lake Michigan appear dim. The Assinica strain of brook trout may provide better results than did the old domestic strain (J. Driver, MDNR, personal communication). However, a small plant of 8,000 Assinica strain brook trout in the west arm of Grand Traverse Bay in 1984 apparently was unsuccessful as few were seen in the 1985-86 creel census in that area (R. Hay, MDNR, personal communication).

Splake

Before the days of lamprey control, the splake, a cross between male brook trout and female lake trout, was considered as having potential for filling the ecological niche vacated by the extinct lake trout in lakes Michigan and Huron. Accordingly, Ontario researchers painstakingly developed a variety of splake that possessed the early maturing characteristics of the brook trout and the deep water habits of the lake trout. In 1958, representatives of the Special Committee on Lake Trout Rehabilitation (sponsored by the Great Lakes Fishery Commission) recommended that Lake Huron and Georgian Bay be reserved for the planting of the splake (Saalfeld 1958). However, in 1968 or 1969, Michigan's fishery administrators decided to abort the splake plan in favor of reintroducing the lake trout to Lake Huron, although Ontario has continued the splake program in its waters of Lake Huron. Thus, much of the documentation of the biology of Great Lakes splake has been by fishery workers in Ontario.

Spangler and Berst (1976) evaluated the performance of F_1 splake (brook trout x lake trout), backcrosses (F_2 male splake x female lake trout), and lake trout in Lake Huron. They found that the F_1 splake and backcrosses grew at about the same rate, attaining an average length of about 40 cm by the end of their second year in the lake. By age 4, both hybrids were almost 5 cm greater in length than were hatchery lake trout of the same age. Based on weight-length regressions presented by Spangler and Berst (1976), at a fork length of 40 cm the F_1 hybrids were heaviest at 824 g, the backcrosses were intermediate in weight at 783 g, and planted lake trout weighed the least at 577 g.

The first age at sexual maturity, as reported by Spangler and Berst (1976), of the three groups occurred in the same order as growth. The F_1 splake matured earliest at age 2, when 34% of the males and 4% of the females were mature. None of the age-2 backcrosses were sexually mature, but 91% of the males and 5% of the females were mature at age 3. Male lake trout in Lake Huron begin to mature at age 5 (37%) and females at age 6 (13%) (J. Weber, MDNR, personal communication).

F_1 splake and backcrosses planted in Lake Huron were relatively short-lived. Spangler and Berst (1976) calculated that annual total mortality of backcrosses at ages 3-4 was 89% and 82% at ages 4-5. They also calculated that splake had annual total mortality rates of 70% at age 2 and 95% at age 3. Spangler (1977) concluded that the survival of splake in South Bay (Lake Huron) beyond age 3 was minimal. Presumably, the high total mortality was due in large measure to sea lamprey depredation. Spangler and Berst (1976) presented evidence that lamprey predation occurred on backcrosses at age 3 and on some F_1 splake at age 2, and that all planted fish were vulnerable to lamprey attack when a size of 40 cm was reached.

The midsummer thermal distribution of backcrosses in South Bay was in the 8° to 18°C band with a mean of 12.4°C, and lake trout were in the 6° to 12°C band with a mean of 9.2°C (Spangler and Berst 1976). Martin and Baldwin (1957) reported that the distribution of F_1 splake in inland lakes on the Precambrian Shield was in or near the thermocline.

There has never been a splake program for Lake Michigan, nor is there likely to be one in the foreseeable future. Retired Fisheries Division Chief John Scott, in a March 28, 1983 memorandum to the Michigan Natural Resources Commission regarding future fishery management proposals, made no mention of splake and only a brief, uncommitted reference to brook trout for the Great Lakes. Token plants of splake were made in 1985 (8,900) and 1986 (8,600) in the west bay of Grand Traverse Bay. Extensive survey trawling targeted for yearling through 3-year-old lake trout in west bay in May of each year (1985-88) produced not a single splake or Assinica brook trout.

Atlantic Salmon

Atlantic salmon were once abundant in the Gulf of St. Lawrence and most of its tributaries, westward from Labrador on the north and Nova Scotia on the south, in the St. Lawrence River, and many of its tributaries upstream to Lake Ontario and Niagara Falls (Parsons 1973). Parsons (1973) gives 1898 as the year of extinction of Atlantic salmon from Lake Ontario.

As nearly as can be determined, the first Atlantic salmon were introduced into the Lake Michigan watershed in 1875, when Atlantic salmon fry were released into Dowagiac Creek, which flows into the St. Joseph River, a southeastern Lake Michigan tributary (Latta 1974). More recently 10,000 Quebec-strain Atlantic salmon were planted in the Boyne River in 1972. Releases of Atlantic salmon into the Boyne River were made annually from 1972 through 1976, in numbers ranging from 9,000 to 20,000 fish. From 1977-82, most Atlantic salmon stocking has been in the Little Manistee and Big Manistee rivers.

Schrouder (1975) summarized the life cycle of the Atlantic salmon thusly: "The Atlantic salmon in Michigan begins its spawning run in streams usually in late May and early June. It spawns early in the fall (September and early October). Females dig a redd in clean gravel with powerful strokes of the tail. Eggs deposited in the redd are fertilized and immediately covered with gravel by the female. The total number of eggs deposited by each female is roughly 1,540-1,760 per kg of body weight. The eggs hatch in late fall or early winter, and the alevins (25 mm salmon) live off the yolk sac until the mouth is developed. After the yolk is gone, the young salmon feeds on aquatic insects found in the stream. The young salmon, or parr, usually remain in the stream about 2 years before they lose their parr markings, smolt, and migrate into the Great Lakes. Adults reach sexual maturity at 3 to 5 years of age. Unlike Pacific salmon, the Atlantic salmon do not all die after spawning for the first time. Some may survive to spawn two or more times."

Evaluation of the Atlantic salmon plants in the Boyne River was restricted to those fish returning to the Boyne River for spawning. The available records show that 174 adults returned to the river in 1974, and 66 adults were captured in 1975. Weight and length measurements taken from Atlantic salmon at the Boyne River weir in August, 1975 were (S. Swan, MDNR, personal communication):

Age	Number	Length range (mm)	Mean length (mm)	Mean weight (g)
2	6	584-610	599	1,771
3	8	693-749	729	3,541
4	21	744-917	808	4,449

Many of the adult Atlantic salmon that returned to the Boyne River inexplicably died. At that time, indications were that some environmental pollutants, possibly PCB, affected the endocrine system that, when combined with the stress of gonad development, caused the mortality (S. Swan, MDNR, personal communication).

In the fall of 1983, 12 age-1.1 Atlantic salmon (1982 plant) were caught at the Little Manistee River weir, all of which were ripe males and averaged about 2.3 kg (Hay 1984). One Atlantic was also captured at the Little Manistee weir in 1984, but none in 1985-87. Of all of the Atlantic salmon releases made in the Manistee River system, Hay (MDNR, personal communication) considered only the 1982 plant to have been minimally successful. He speculated that the minor success may have been due to the relatively large number of Atlantic salmon planted in the Little Manistee (25,000) and Pere Marquette (20,000) rivers in that year. In sum, sporadic attempts in the past 100 years have failed to establish Atlantic salmon in Lake Michigan.

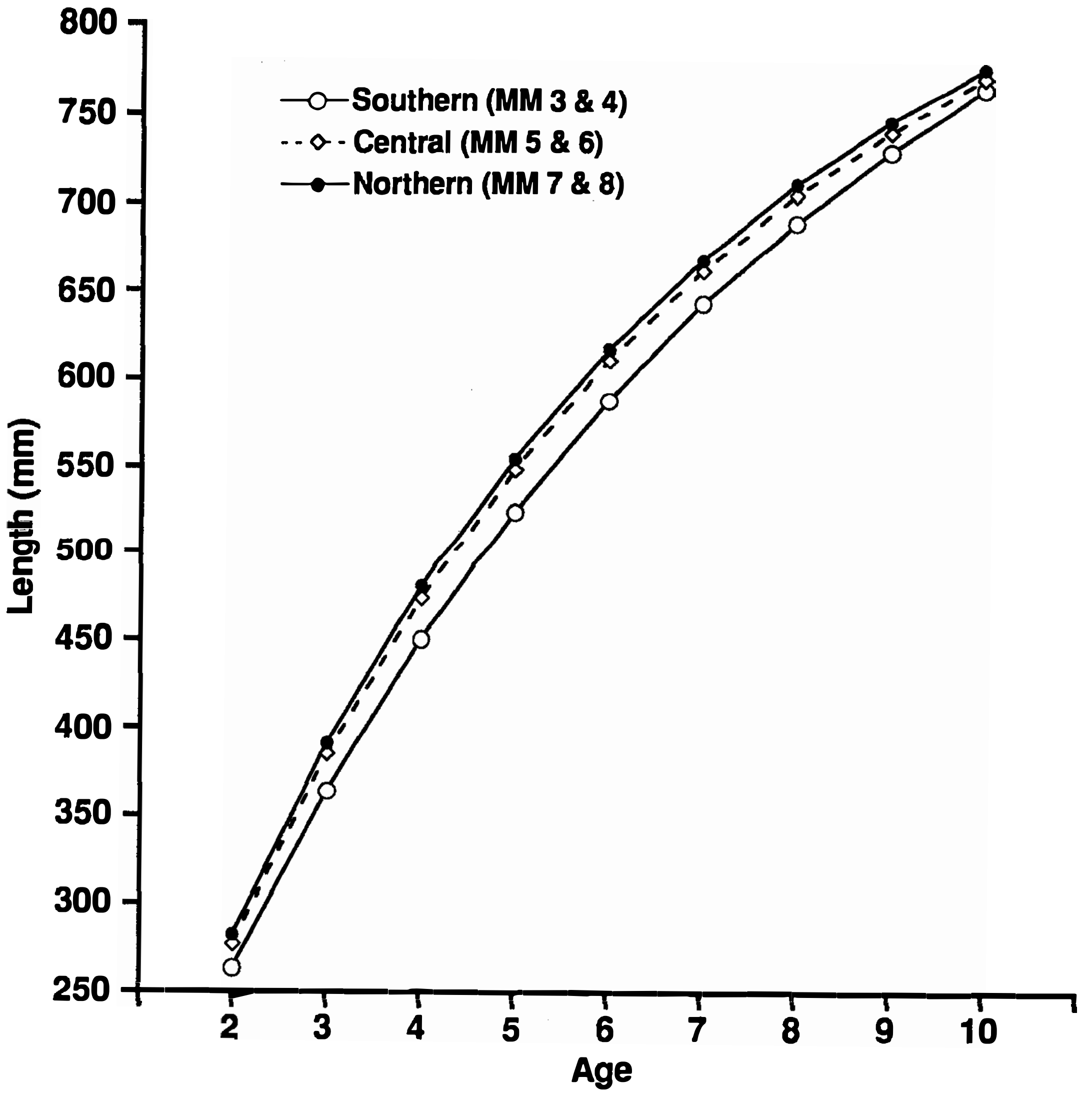

Figure 1. Predicted total length (mm) at age of lake trout caught in experimental gill nets in Lake Michigan by zone during the period 1985-87.

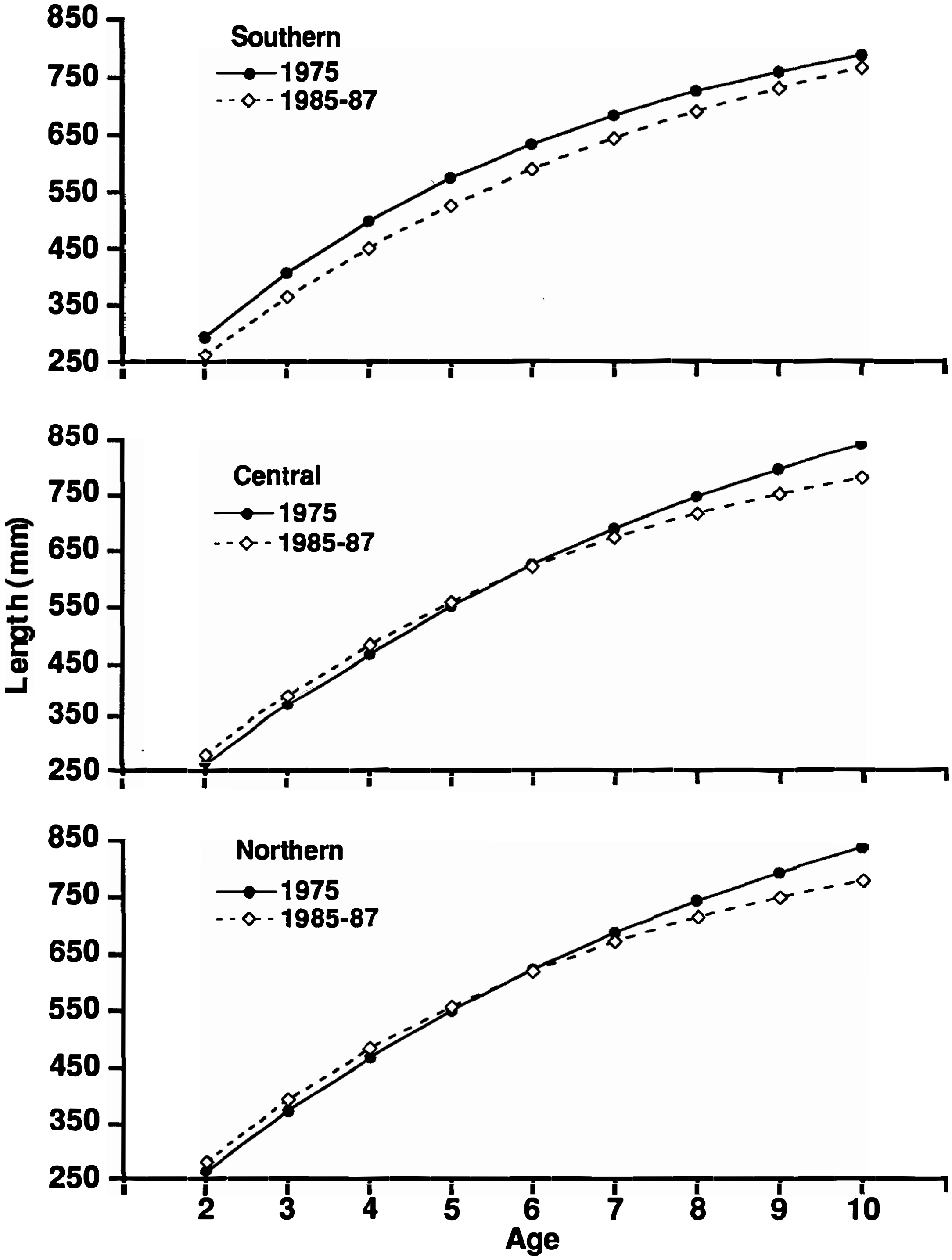

Figure 2. Predicted total length (mm) at age of lake trout caught in experimental gill nets in Lake Michigan by zone during 1975 and the period 1985-87.

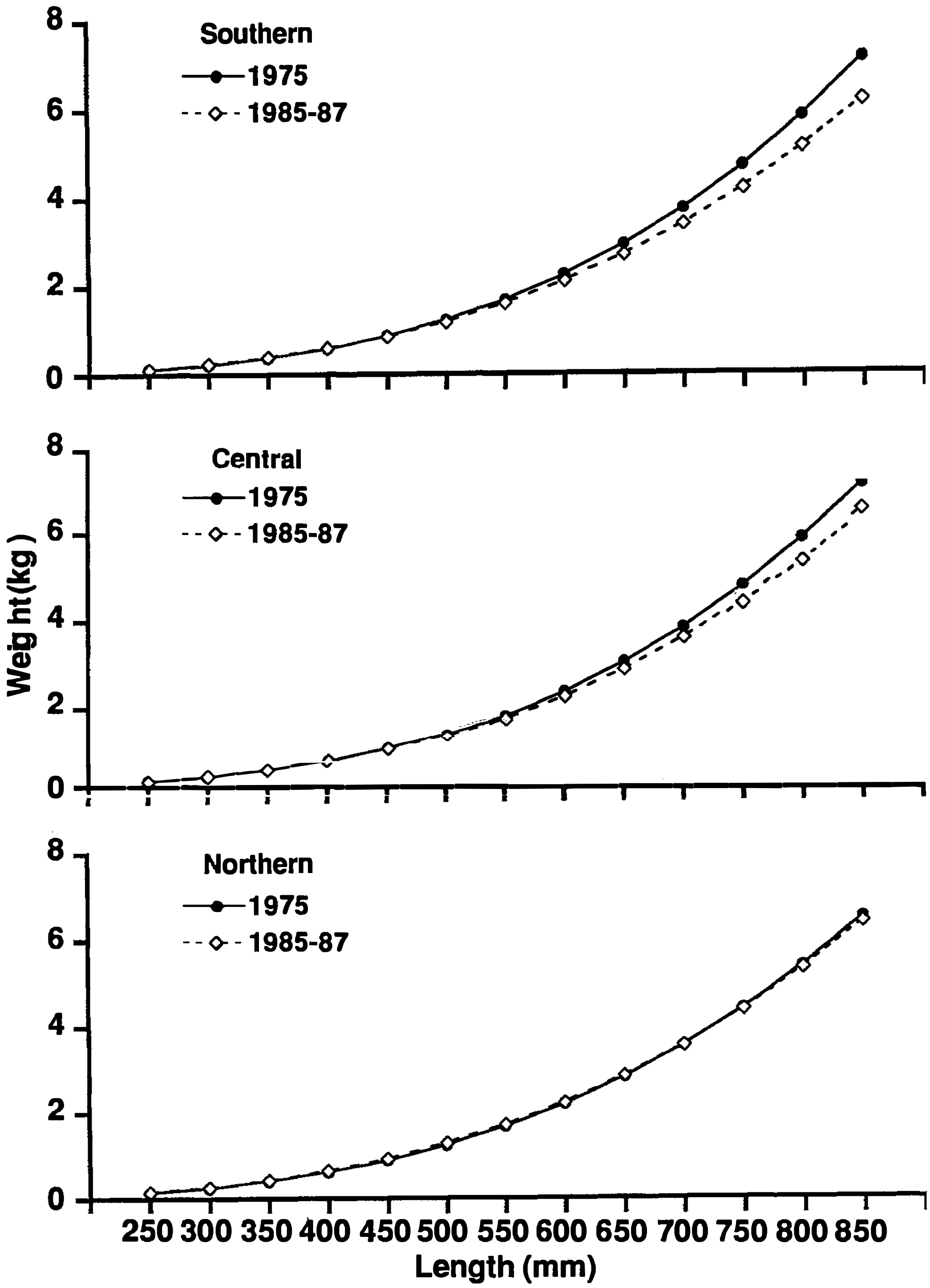

Figure 3. Predicted round weight (kg) at total length (mm) of lake trout caught in experimental gill nets in Lake Michigan by zone during 1975 and the period 1985-87.

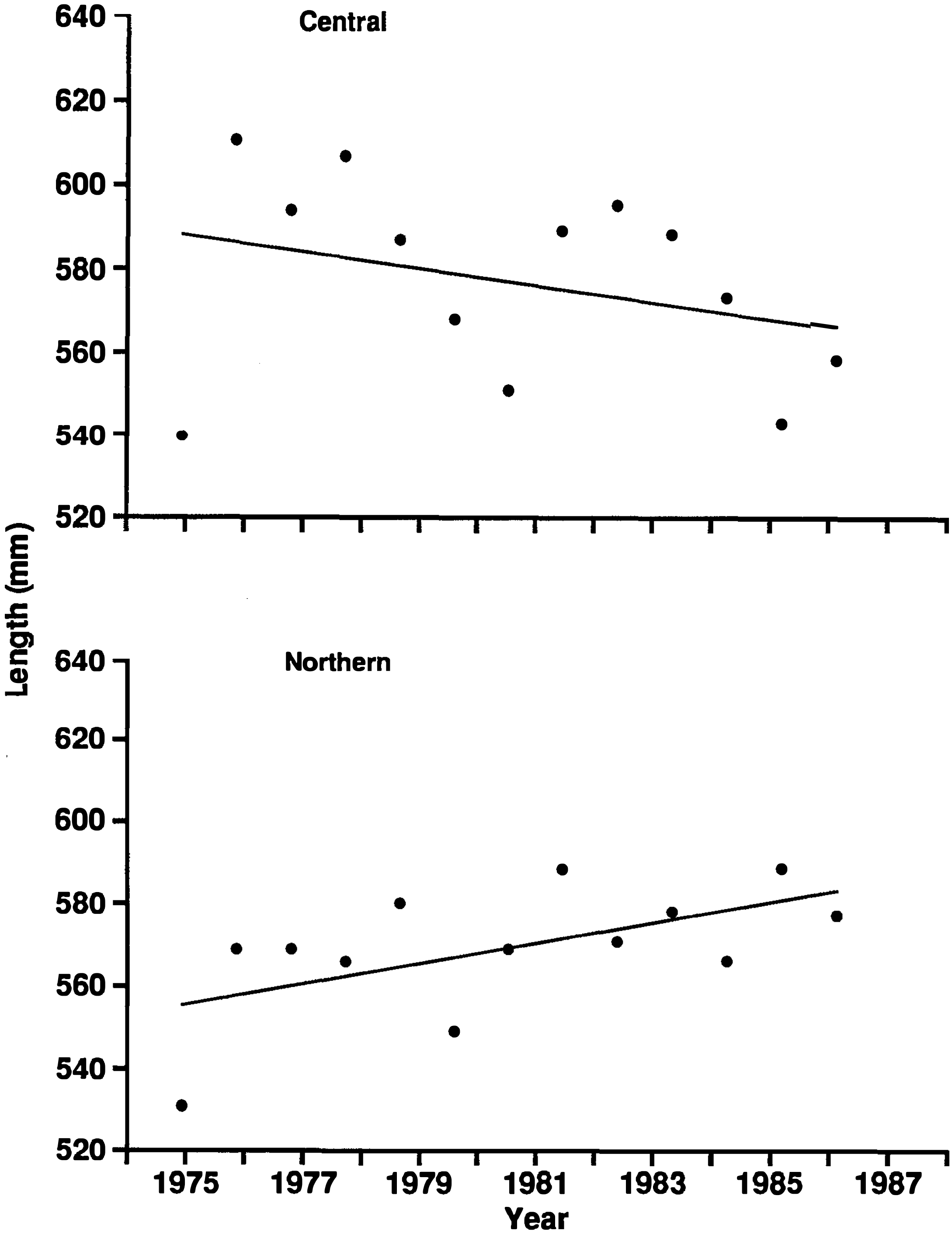

Figure 4. Trends in the mean total length (mm) of age-5 lake trout in Lake Michigan by zone during the period 1975-87.

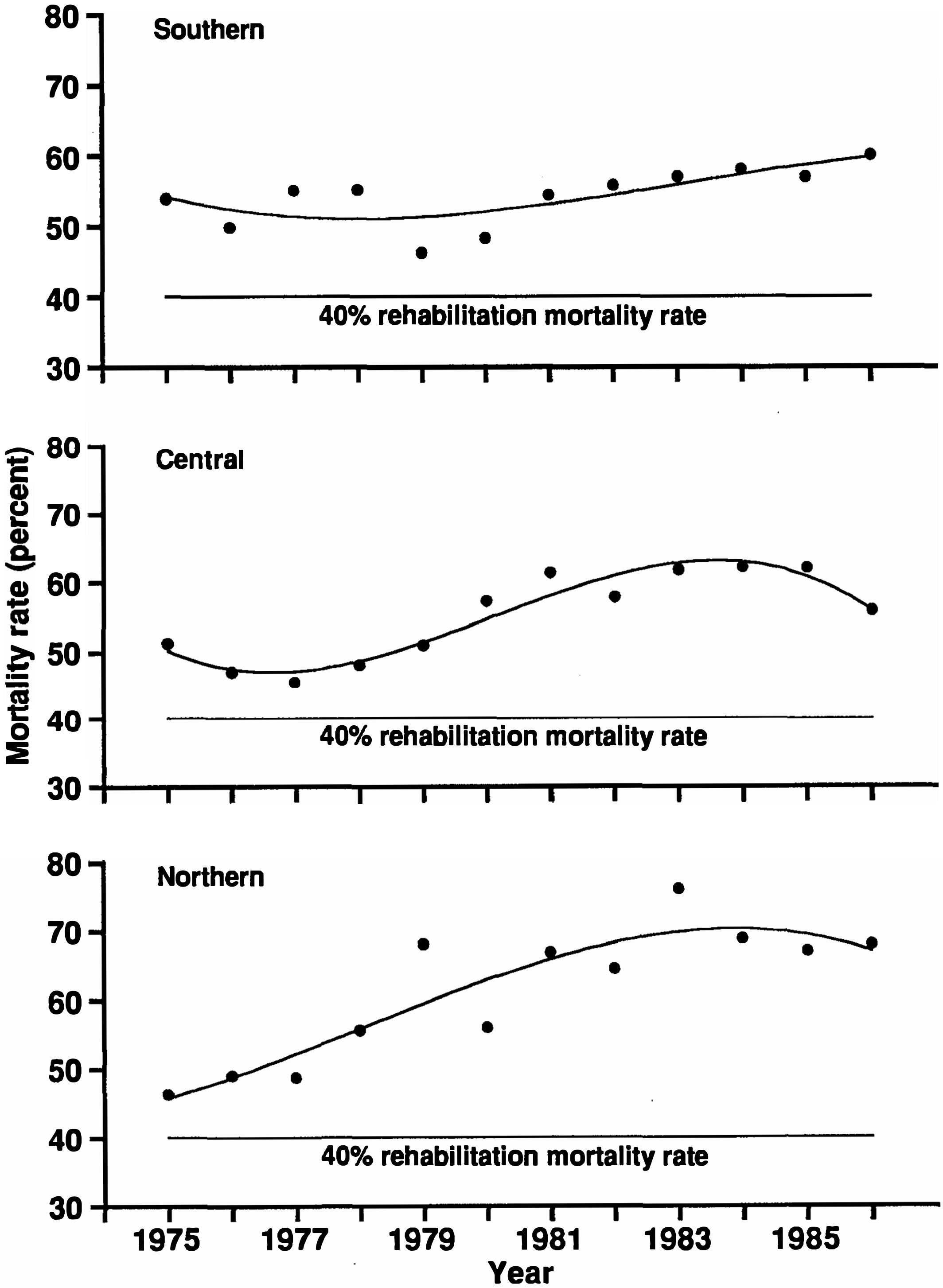

Figure 5. Trends in the annual total mortality rate (percent) of age-4 and older lake trout in Lake Michigan by zone during the period 1975-86.

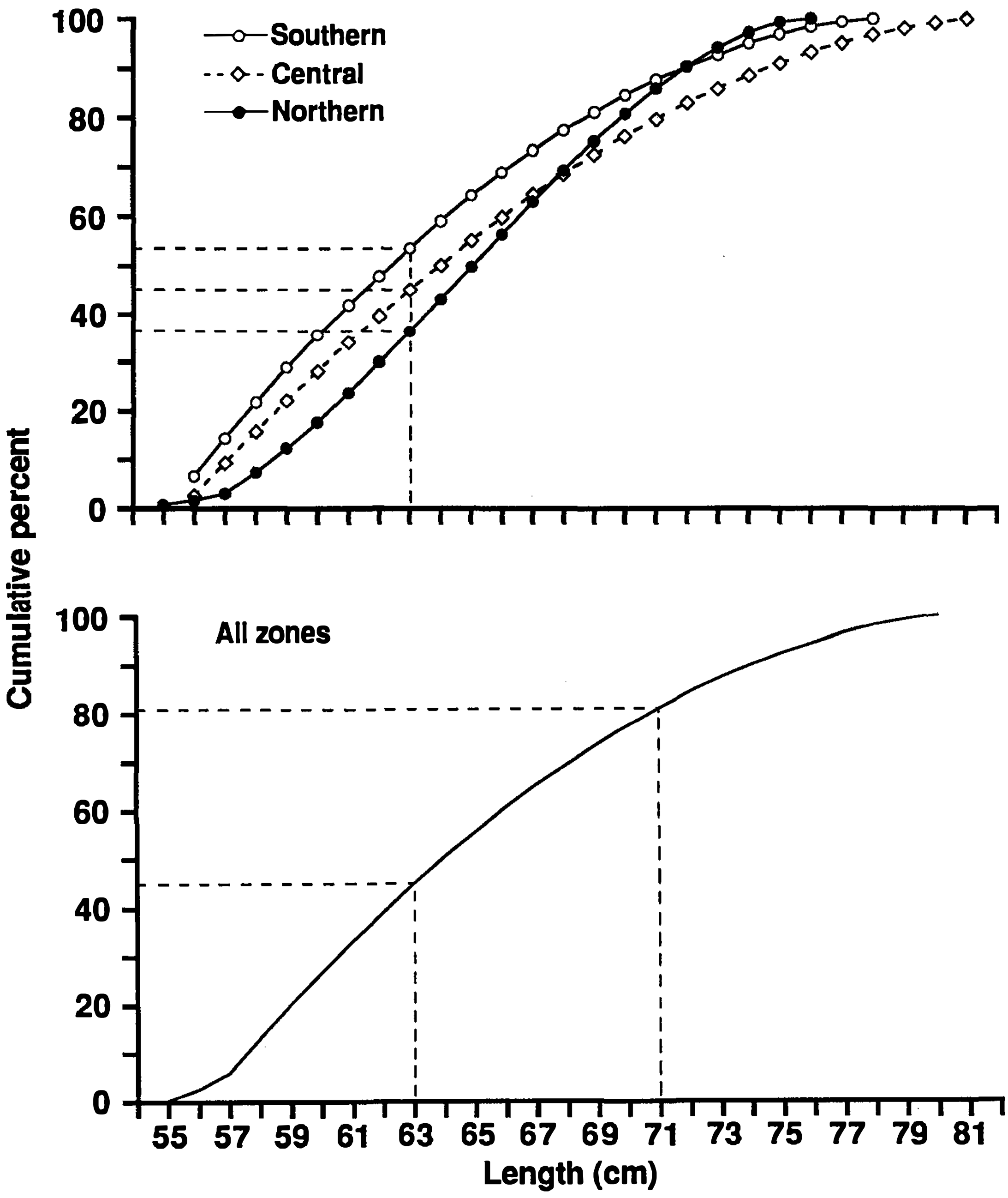

Figure 6. Cumulative percent distribution of total lengths (cm) of mature, female lake trout in Lake Michigan by zone during the period 1985-87.

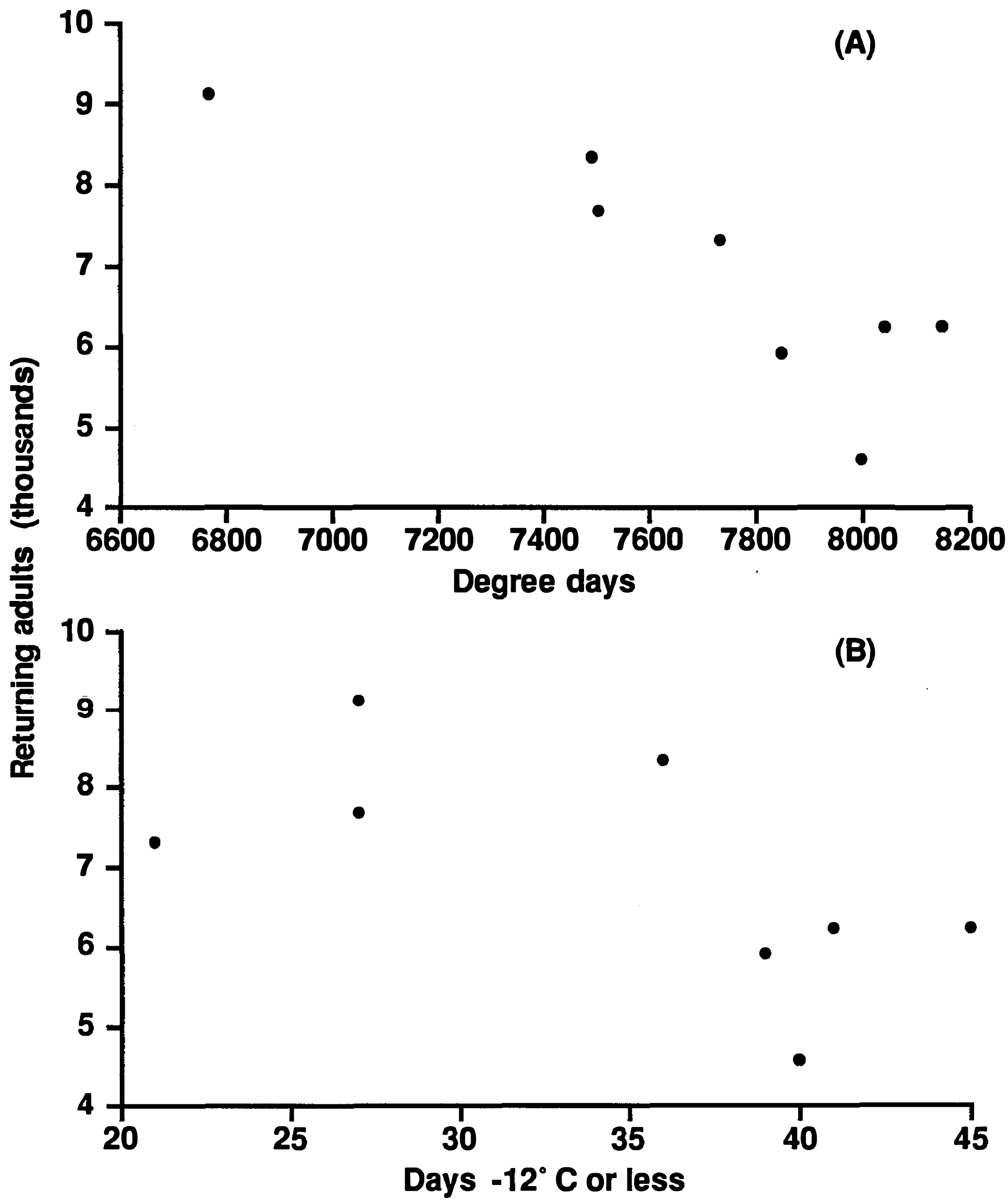

Figure 7. Relationships between the number of maiden adult steelhead returning per smolt cohort in spring to the Little Manistee River weir during 1978-85 and (A) the number of heating degree days during October-April of the presmolt winter, an index of smolt size, and (B) the number of days -12°C or less during January and February of the presmolt winter, an index of smolt numbers.

Table 1. Percent frequency occurrence of food items in the stomachs of coho salmon caught in eastern Lake Michigan by zone.[1]

	1983				1984			
Prey item	Southern	Central	Northern	All zones	Southern	Central	Northern	All zones
Alewife	3.5	16.1	33.7	16.9	12.2	27.8	17.1	17.2
Smelt	19.6	22.1	31.0	24.5	41.2	11.2	36.3	33.5
Bloater	0.3	21.6	16.6	8.2	0.8	16.6	17.6	11.4
Yellow perch	0.0	7.5	0.0	0.3	10.0	21.2	3.0	8.8
Sculpin	0.0	0.0	0.0	0.0	0.0	0.0	3.2	1.4
Ninespine stickleback	0.0	0.0	3.6	1.5	0.0	0.0	8.4	3.8
Other fish	0.0	4.6	0.0	0.5	0.0	11.7	0.9	2.5
Unidentified fish remains	2.0	1.9	10.0	5.9	14.3	3.7	10.4	10.5
Insects	0.6	0.6	0.9	1.7	15.0	7.4	2.7	8.0
Microcrustaceans	73.7	13.2	3.2	40.0	6.3	0.0	0.0	2.3

[1]Data from Kogge 1985.

Table 2. Number and percent return of adult coho to their natal streams in 1979.[1]

Recovery stream	Stream planted: St. Joseph-Black	Grand-Muskegon	Manistee area	Platte	Brewery	Thompson-Big Cedar
St. Joseph	1,757	37	20	4	1	---
Percent	99.9	12.7	1.8	<0.1	0.3	---
Grand	1	139	---	1	---	---
Percent	0.1	47.6	---	<0.1	---	---
Little Manistee	---	3	596	4	---	3
Percent	---	1.0	53.6	<0.1	---	0.8
Platte	---	113	495	25,775	297	74
Percent	---	38.7	44.6	99.9	99.7	20.6
Thompson	---	---	---	---	---	282
Percent	---	---	---	---	---	78.6
Total	1,758	292	1,111	25,784	298	359

[1]Data from Patriarche 1980.

Table 3. Percent frequency occurrence of food items in stomachs of chinook salmon caught in eastern Lake Michigan by zone.[1]

	1983				1984			
Prey item	Southern	Central	Northern	All zones	Southern	Central	Northern	All zones
Alewife	51.3	49.8	64.0	57.6	30.9	29.9	47.7	38.1
Smelt	22.1	14.0	19.5	19.5	16.0	10.4	17.3	15.5
Bloater	0.2	12.8	6.5	5.6	29.9	37.7	17.4	25.9
Yellow perch	1.0	1.9	0.0	0.6	10.2	6.3	1.5	5.6
Sculpin	0.0	1.2	0.0	0.2	0.0	0.0	0.0	0.4
Ninespine stickleback	0.0	0.0	1.9	0.9	0.0	0.0	3.6	1.6
Other fish	0.0	2.4	0.4	0.6	0.0	0.2	1.0	0.7
Unidentified fish remains	4.0	1.5	7.1	5.2	8.4	8.8	10.0	9.2
Insects	0.7	0.0	<0.1	0.2	0.6	0.0	1.2	0.4
Microcrustaceans	20.4	16.2	0.8	9.1	3.7	6.4	0.1	2.6

[1]Data from Kogge 1985.

Table 4. Estimated production of wild chinook smolts in Lake Michigan tributaries in 1979.[1]

Tributary	Number of smolts
Muskegon	349,700
Pere Marquette	146,700
Manistee	98,700
White	16,100
Platte	12,100
Jordan	5,400
Boyne	1,800
Total	630,500

[1]Data from Carl 1982a.

Table 5. Growth coefficients of lake trout caught in experimental gill nets during 1985-87 by Lake Michigan zone.[1]

	Weight-length parameters		von Bertalanffy coefficients		
Zone	Intercept	Slope	t_o	K	L_∞
Southern	-19.10	3.10	0.04	0.16	967
Central	-19.09	3.11	0.05	0.19	915
Northern	-18.68	3.04	0.04	0.19	915

[1]Weight in kilograms, length in millimeters.

Table 6. Predicted round weight (g) of lake trout by length group (mm) and Lake Michigan zone during 1985-87. Two standard errors in parentheses.

Length group	Southern	Central	Northern
200	70	72	78
	(3)	(2)	(3)
300	246	254	268
	(5)	(3)	(5)
400	600	620	644
	(7)	(5)	(8)
500	1,198	1,239	1,270
	(8)	(6)	(9)
600	2,110	2,182	2,213
	(10)	(14)	(18)
700	3,404	3,522	3,537
	(49)	(31)	(40)
800	5,151	5,333	5,311
	(98)	(62)	(80)

Table 7. Percent of Lake Michigan lake trout stomachs containing prey items.

Prey item	1931-32[1]	1966-67[2]	1983-84[3]
Alewife	0.0	43.3	65.7
Smelt	0.0	15.9	17.1
Coregonids[4]	19.4	0.1	10.7
Yellow perch	0.0	0.0	4.8
Sculpins	52.2	25.4	4.8
Other fish	11.5	---	4.0
Unidentified fish remains	15.8	---	11.4
Invertebrates	5.2	12.1	5.9

[1]Data from Van Oosten and Deason 1937.

[2]Data from Wright 1968.

[3]Data from Kogge 1985.

[4]Coregonids include ciscoes, chubs, and whitefish.

Table 8. Percent frequency occurrence of food items in stomachs of lake trout caught in eastern Lake Michigan by zone.[1]

Prey item	1983 Southern	1983 Central	1983 Northern	1983 All zones	1984 Southern	1984 Central	1984 Northern	1984 All zones
Alewife	64.3	68.2	54.3	64.3	60.4	48.7	59.9	58.2
Smelt	25.5	0.0	14.5	18.1	15.7	8.9	6.7	10.0
Bloater	0.0	1.2	0.0	0.3	4.0	11.9	12.5	9.6
Yellow perch	0.0	0.0	9.0	3.0[2]	5.9	13.5	1.0	4.7
Sculpin	1.4	3.7	9.0	2.7	1.2	4.2	4.7	3.5
Ninespine stickleback	0.0	0.0	0.5	0.9	0.0	0.0	3.1	1.6
Other fish	0.0	0.0	0.4	<0.1	2.1	0.2	0.7	1.0
Unidentified fish remains	0.0	15.7	8.1	3.9	10.3	10.2	8.1	9.1
Insects	0.8	3.7	3.7	2.2	0.1	1.8	2.8	1.7
Microcrustaceans	7.7	7.4	0.0	5.0[2]	0.0	0.1	0.1	0.1

[1]Data from Kogge 1985.

[2]This value was not reported and was assumed equal to the mean of the three seasons.

Table 9. Percentage of unclipped lake trout in the catch by year class and index station during 1983-87.

Year class	Little Traverse Bay area		Grand Traverse Bay		Good Harbor		Pt. Betsie		Big and Little Sable Points		Muskegon-Whitehall	
	Percent unclipped	Sample size	Percent unclipped	Sample size	Percent unclipped	Sample size	Percent unclipped	Sample size	Percent unclipped	Sample size	Percent unclipped	Sample size
1975	---	---	7.8	13	---	---	0.0	16	0.0	22	---	---
1976	---	---	15.8[1]	19	---	---	3.6	28	3.0	33	---	---
1977	0.0	11	4.8	62	4.2	24	0.0	47	3.1	64	---	---
1978	0.0	38	4.3	92	2.0	98	0.0	49	1.6	62	---	---
1979	1.0	97	3.3	211	2.6	195	4.1	97	1.2	84	0.0	14
1980	1.6	122	2.8	431	0.0	72	3.3	90	1.2	83	0.0	30
1981	0.0	108	12.9[1]	31	0.0	205	0.0	126	0.9	114	0.0	70
1982	2.8	106	0.6	462	0.3	786	1.9	259	0.0	260	0.0	240
1983	0.0	21	9.1	11	0.0	19	7.0[1]	43	0.7	150	0.6	157
1984	0.0	138	0.0	37	0.0	52	2.4	83	2.2	45	1.4	72
1985	0.0	12	---	---	---	---	---	---	---	---	---	---

[1]Chi-square significant at $P \leq 0.05$.

Table 10. Observed and predicted annual mortality rates of age 4 and older lake trout in Lake Michigan by zone and year.

Zone	Year	Observed annual total (A)	Predicted mortality rates: Annual total (A)	Instantaneous total (Z)	Instantaneous fishing (F)	Annual exploitation (U)
Southern	1975-76	0.539	0.542	0.781	0.497	0.345
	1976-77	0.499	0.524	0.742	0.458	0.323
	1977-78	0.552	0.514	0.722	0.438	0.312
	1978-79	0.553	0.511	0.715	0.431	0.308
	1979-80	0.463	0.513	0.719	0.435	0.310
	1980-81	0.484	0.521	0.736	0.452	0.320
	1981-82	0.545	0.531	0.757	0.473	0.332
	1982-83	0.558	0.544	0.785	0.501	0.347
	1983-84	0.570	0.559	0.819	0.535	0.365
	1984-85	0.580	0.573	0.851	0.567	0.382
	1985-86	0.570	0.587	0.884	0.600	0.398
	1986-87	0.601	0.598	0.911	0.627	0.412
Central	1975-76	0.513	0.503	0.699	0.415	0.299
	1976-77	0.472	0.476	0.646	0.362	0.267
	1977-78	0.458	0.473	0.641	0.357	0.263
	1978-79	0.482	0.487	0.667	0.383	0.280
	1979-80	0.510	0.514	0.722	0.438	0.312
	1980-81	0.572	0.547	0.792	0.508	0.351
	1981-82	0.613	0.580	0.868	0.584	0.390
	1982-83	0.578	0.609	0.939	0.655	0.425
	1983-84	0.617	0.627	0.986	0.702	0.446
	1984-85	0.621	0.628	0.989	0.705	0.448
	1985-86	0.620	0.607	0.934	0.650	0.422
	1986-87	0.559	0.559	0.819	0.535	0.365
Northern	1975-76	0.464	0.459	0.614	0.330	0.247
	1976-77	0.491	0.488	0.669	0.385	0.281
	1977-78	0.488	0.521	0.736	0.452	0.320
	1978-79	0.556	0.557	0.814	0.530	0.363
	1979-80	0.681	0.594	0.901	0.617	0.407
	1980-81	0.560	0.629	0.992	0.708	0.449
	1981-82	0.669	0.660	1.079	0.795	0.486
	1982-83	0.645	0.684	1.152	0.868	0.515
	1983-84	0.762	0.699	1.201	0.917	0.534
	1984-85	0.690	0.699	1.201	0.917	0.534
	1985-86	0.670	0.695	1.187	0.903	0.529
	1986-87	0.680	0.671	1.112	0.828	0.500

Table 11. Percent of lake trout mature by age, sex, and zone from Lake Michigan during 1985-87. Sample size is in parentheses.

Age group	Southern Males	Southern Females	Central Males	Central Females	Northern Males	Northern Females	All zones Males	All zones Females
2	0.0 (3)	0.0 (2)	0.0 (10)	0.0 (4)	0.0 (9)	0.0 (7)	0.0 (22)	0.0 (13)
3	0.0 (47)	0.0 (62)	0.7 (151)	0.0 (154)	0.5 (202)	0.0 (183)	0.5 (400)	0.0 (399)
4	0.0 (50)	0.0 (45)	2.9 (421)	0.8 (375)	12.1 (107)	0.0 (108)	4.3 (578)	0.6 (528)
5	10.4 (211)	6.9 (175)	38.5 (408)	37.2 (360)	52.3 (281)	29.7 (279)	36.2 (900)	28.1 (814)
6	48.6 (37)	56.8 (44)	77.0 (122)	75.7 (115)	82.2 (101)	78.9 (152)	75.0 (260)	74.6 (311)
7	92.3 (13)	78.6 (14)	91.3 (46)	98.2 (55)	97.8 (46)	80.8 (78)	94.3 (105)	87.1 (147)
≥8	100 (12)	100 (10)	100 (71)	100 (61)	100 (17)	100 (29)	100 (100)	100 (100)

Table 12. Percent of lake trout mature by length group (cm), sex, and zone from Lake Michigan during 1985-87.

Length group	Southern		Central		Northern		All zones	
	Males	Females	Males	Females	Males	Females	Males	Females
<55	0.4 (275)	0.0 (276)	0.8 (793)	0.0 (707)	4.4 (412)	0.5 (378)	1.7 (1,480)	0.1 (1,361)
56	16.7 (18)	44.4 (9)	51.0 (51)	19.5 (41)	57.6 (33)	14.8 (27)	47.1 (102)	20.8 (77)
57	43.8 (16)	80.0 (5)	59.6 (52)	37.1 (35)	69.6 (43)	12.8 (39)	61.3 (111)	27.8 (79)
58	60.0 (5)	50.0 (8)	66.7 (42)	70.3 (37)	61.8 (34)	20.0 (30)	64.2 (81)	48.0 (75)
59	62.5 (8)	66.7 (6)	74.3 (35)	69.4 (36)	62.2 (37)	40.0 (25)	67.5 (80)	58.2 (67)
60	44.4 (9)	57.1 (7)	82.4 (34)	76.5 (34)	88.6 (35)	45.8 (24)	80.8 (78)	63.1 (65)
61	66.7 (6)	71.4 (7)	78.3 (23)	80.0 (20)	87.5 (16)	50.0 (40)	80.0 (45)	61.2 (67)
62	100 (3)	0.0 (2)	93.1 (29)	90.5 (21)	90.9 (22)	80.8 (26)	92.6 (54)	81.6 (49)
63	90.0 (10)	0.0 (1)	100 (15)	91.3 (23)	92.9 (28)	62.1 (29)	94.3 (53)	73.6 (53)
64	100 (6)	100 (4)	100 (20)	95.2 (21)	100 (17)	72.2 (36)	100 (43)	82.0 (61)
65	100 (2)	63.3 (6)	100 (14)	94.1 (16)	92.3 (13)	88.6 (35)	96.6 (29)	89.7 (58)
≥66	100 (16)	100 (22)	100 (138)	97.3 (150)	98.7 (75)	95.9 (147)	99.6 (230)	97.8 (319)

Table 13. Mean annual percent age structure of the adult steelhead populations in the Little Manistee, Grand, and St. Joseph rivers during 1978-85.

River	Lake age				
	.1	.2	.3	.4	.5
Little Manistee	5	24	58	13	0
Grand	9	28	40	21	2
St. Joseph	6	32	43	18	1

Table 14. Mean length (mm) at age for adult steelhead from the Little Manistee, and the Grand and St. Joseph rivers (data pooled) during 1978-85.

River and region	Lake age			
	.1	.2	.3	.4
Little Manistee	445	648	732	782
Grand and St. Joseph (combined mean)	457	622	719	782

Table 15. Length (mm)-weight (g) regression parameters for adult steelhead from the Little Manistee, Grand, and St. Joseph rivers during 1980-85.[1]

River	Sample size	Parameter	
		Constant	Slope
Little Manistee	1,500	-9.59	2.71
Grand	732	-9.53	2.70
St. Joseph	1,961	-9.52	2.70

[1]Seelbach 1988.

Table 16. Mean total length (mm) and weight (g) by sex of pink salmon collected with electrofishing gear during 1985-87. Ninety-five percent confidence limits in parentheses.

	Male				Female			
Lake	Sample size	Length	Sample size	Weight	Sample size	Length	Sample size	Weight
Michigan	341 (5)	487	256 (38)	1,080	260 (4)	459	198 (36)	957
Huron	934 (3)	409	833 (14)	496	638 (3)	386	530 (15)	408
Superior	987 (3)	389	128 (24)	541	726 (2)	380	102 (20)	464

Table 17. Mean total length (mm) and number of eggs per female for pink salmon collected during 1985 and 1987. Ninety-five percent confidence limits in parentheses.

Lake	Sample size	Length	Number of eggs
Michigan	108 (6)	471 (67)	1,333
Huron	210 (6)	389 (45)	727
Superior	89 (5)	387 (63)	918

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ECONOMICS

Gale Jamsen

Angling on Lake Michigan has shown spectacular growth since the successful reintroduction of lake trout and the introduction of Pacific salmon in the mid-1960s. The recent history of fishing license sales serves to make the point (Figure 1). Since 1967, license sales to both residents and non-residents have increased by 50%. This increase in angling has been of considerable importance to the state's economy.

Fishing on the other Great Lakes has developed much like Lake Michigan, with a few years delay. Lake Michigan received most of the stocking in the early years because of its location, high quality fish habitat, and excellent food base for salmon and trout. In addition, Lake Michigan's many major tributaries provided good access for anglers seeking spawning salmon and trout.

Great Lakes angling during 1987 in Michigan waters was estimated to be nearly 15 million hours or slightly more than 3 million angler days (Rakoczy and Rogers 1988a and 1988b). Boat fishing accounted for 84% of the angling effort on the Great Lakes and their connecting waters. Of the total angler hours during the open-water season, 45% were spent on Lake Michigan to harvest 70% of the Great Lakes salmonids taken in the state. Seventy-one percent of these fish from Lake Michigan were chinook or coho salmon.

The success of the Great Lakes fishery resulted in substantial related public and private investments. Public investments include the development of boating facilities needed by Great Lakes anglers. An example is the string of 68 protective harbors and public marinas on the Great Lakes developed by the Michigan Waterways Commission to achieve their goal that no boater will be more than 15 miles from safety on the Great Lakes. Also, prior to 1967, very few launching ramps existed on the Great Lakes. With the impetus of the Great Lakes salmon and trout program, 158 launching facilities have been developed through construction grants to communities in Michigan.

Private investment is reflected in the sales of boats and boating accessories. Michigan ranked fourth among the states in sales of boats and accessories (192 million dollars) in 1983 and fourth in total sales (286 million dollars) which includes boats, outboard motors, trailers, and accessories (Spotts 1986). Other private investments have been in the Great Lakes charter-boat industry and the support facilities necessary to satisfy angler demands. By 1986, charter boats in Michigan numbered approximately 1 thousand. The industry barely existed 20 years ago. Also, substantial investment in motels and other tourism facilities occurred in many Great Lakes port communities largely in response to the growth in the fishery.

Although methods of estimating the economic value and economic impact of recreational angling have been available for the past 20 to 30 years, most valuation concepts have only become usable by managers in the last 5 to 10 years. Further research in this field is still very active. Recently, an entire issue (May 1987) of the Transactions of the American Fisheries Society was devoted to the social assessment of fisheries resources. This issue reported on a symposium exploring potentials for more fully using the problem-solving abilities of the social sciences in fishery management. Evaluations needed by fishery managers in the Great Lakes region served as the focus of the symposium. Symposium participants stressed the use of such evaluations to document human preferences both for general choices, such as, species preference, as well as preferences for more difficult choices such as stocking locations and numbers.

However, Talhelm and Libby (1987) caution that we must reject the notion of a perfect uniform quantitative total value assessment because such a system would have to account for such a wide diversity of human values. Value concepts must include "held" values such as social equity and conservation ethics, and "assigned" economic values such as those used in benefit-cost analyses. It is difficult to reconcile the variety of economic and non-economic human values in ways that eliminate subjective judgement in public choices. Economic and social assessments at best can provide partial evaluations of fishery management choices.

Most assessments that have been done on the Great Lakes provide measures of economic values assigned by anglers for their angling or measures of their impacts on port communities. Recently, the MDNR Fisheries Division began broadening such assessments to include angler market analyses. This section summarizes the results of several economic assessments of the Great Lakes fisheries and presents some results from the market analysis of Lake Michigan anglers. Also included are summaries of the economic value and impact of the Lake Michigan sport fishery. Economic value measures the benefits anglers derive from fishing in Lake Michigan. Economic impact describes the effects of angling activity on local economies.

Great Lakes Recreation Economics

Glass and Muth (1987) describe economic valuation techniques currently being utilized in the field of fisheries noting that many past efforts have not carefully followed economic theory, and thus have not been suitable to management situations. Many of the methods they describe have been applied to the Great Lakes fishery resource. Most of the economic analysis of Great Lakes angling has been done for Michigan but estimates of sport fishery values for other states bordering the Great Lakes have also been attempted. This section is based on Talhelm's (1987) review of these efforts. He probed into the accuracy of the estimates and tried to clarify the confusion over results from different economic valuation methods.

A 1979 Great Lakes Fishery Commission supported study reviewed all economic values and economic impacts of sport and food fishing on the Great Lakes in the United States and Canada (Talhelm et al. 1979). Talhelm (1987) updated the review as of 1985. Economic impacts in 1985 were substantial. Anglers in the United States and Canada spent 1-2 billion dollars, with a best estimate of 2 billion dollars, to catch Great Lakes fish. About half of this total was spent for long-term outlays for boats, vehicles, and other angling related equipment. The other half was for trip related outlays for food, lodging, transportation, angling supplies, and other trip expenses. Total spending averaged about $36.50 per angler day; about $17.50 for trip expenses and about $19.00 for long-term outlays. The total economic impact of this spending on the regional economy was 2-4 billion dollars. About 35% of this total, or 1.4 billion dollars (range 0.7-1.4 billion dollars), was personal income. About 75,000 worker-years were attributable to the sport fishery in 1985; 64,000 in the United States and 11,000 in Canada. Since the last assessment of Great Lakes angling values in 1979, the economic value to anglers using the entire Great Lakes more than doubled.

Hushak (1987) used input-output analysis and benefit-cost analysis to assess the impacts of Lake Erie angling on the Ohio economy. Input-output analysis, a form of regional economic analysis, estimates employment and income effects of changes in the use of the fisheries resource. For 1981, he estimated the gross economic value (total willingness to pay) for Lake Erie sportfishing by Ohio anglers at 139 million dollars and net economic value (net willingness to pay) at 30 million dollars. These estimates value the choice of all versus none of the fishery. The estimated income generated by Lake Erie sportfishing in 1981 was 30 million dollars for northern Ohio, or 43 million dollars for the entire state. He also estimated that for each 1 million dollars of dockside value of fish reallocated from commercial fishing to sportfishing increased regional income up to 2.4 million dollars. Input-output analysis is becoming more popular, but a negative factor is that economic impact estimates are often misinterpreted as estimates of economic value (i.e., willingness to pay). Again, economic impacts are shifts in economic activity, whereas economic values estimate direct benefits and costs.

Two studies from Michigan State University (MSU) focused on the economic impacts of angling for Great Lakes fish. They dealt with the legal salmon snagging fishery at five designated sites (Mahoney et al. 1985) and the Great Lakes charter-boat industry in Michigan (Mahoney et al. 1986).

Key findings from the 1985 MSU charter-boat study included:

1) Anglers (239,000) hiring charters were estimated for the nearly 1,000 charter boats licensed in Michigan.

2) Out-of-state charter anglers (67,000) comprised 28% of the total.

3) Total spending excluding charter fees was 21 million dollars, including 7 million dollars by visitors from out-of-state whose primary reason for visiting was charter fishing.

4) Total statewide investment by charter-boat firms was estimated at 31.2 million dollars.

Findings from the 1986 MSU study on salmon snagging included:

1) Salmon snagging effort totaling 74,321 days at five sites was estimated for 23.5 thousand licensed salmon snaggers.

2) Total snagging expenditures were estimated at 3.5 million dollars with out-of-state anglers accounting for 1.2 million dollars.

3) Average trip expenditures were $127 ($46 per day) for trips lasting an average of 2.8 days.

4) Fifty-six percent ($71) of the average trip expense occurred near the fishing site.

Boating is another important recreational activity on the Great Lakes that frequently is associated with angling. It has shown explosive growth on the Great Lakes since the early 1970s (Table 1). The resurgence of fishing on the Great Lakes has been a significant factor in the increase. Stynes et al. (1983) and Talhelm et al. (1988) documented the economic impacts of boating in Michigan. Their conclusions were:

1) Michigan registered boat owners spent over 1 billion dollars on boating in 1981 and 1.75 billion dollars in 1986.

2) Average expenditures in 1981 were $1,787 per boat per year.

3) Out-of-state boat owners spent 41.5 million dollars in Michigan in 1981.

Since 1981 boating growth has continued at a rapid pace. Great Lakes boating increased 63% from 1974 to 1980 and another 41% from 1980 to 1986.

Lake Michigan Sport Fishery Economic Impacts

To arrive at an overall economic impact from sportfishing for Lake Michigan, the Great Lakes-wide average angler expenditure in 1985 of $36.50 per angling day determined by Talhelm (1987) was assumed to be a reasonable proxy for a day of Lake Michigan fishing. In 1986 and 1987, anglers fished approximately 1.4 and 1.1 million days, respectively, on the Michigan waters of Lake Michigan. Thus, a conservative estimate for the impact of the Lake Michigan sport fishery in 1986 and 1987 would be approximately 51 and 40 million dollars, respectively.

To assess the economic impact of angling on communities located on the Lake Michigan shore, the Michigan Sea Grant Program supported studies for key areas on the Great Lakes. Six counties on Lake Michigan were surveyed. From south to north they were Ottawa, Muskegon, Manistee, Benzie, Grand Traverse, and Delta (Jordan and Talhelm 1983a, 1983b, 1984a, 1984b, 1984c, and 1985). A summary of these six reports is presented in Table 2. An important finding of these studies was that expenditures by non-residents of each destination county had a substantial positive economic impact on the local economy. Following is a more detailed review of the findings in each report.

Ottawa County

During the 1-year period from October, 1981 through September, 1982, anglers spent almost 4.6 million dollars in Ottawa County fishing 237.8 thousand days for Great Lakes fish. Non-residents of the county spent almost 2.5 million dollars, generating total sales of 5-6 million dollars in the county. Lake Michigan boat fishing (including charters) off Grand Haven and Holland were by far the most significant fisheries, contributing 71% of the non-resident economic impact. Boat fishing accounted for almost 90% of the non-resident impact.

Muskegon County

From October, 1981 through September, 1982, anglers spent about 1.8 million dollars fishing 168.9 thousand days in Muskegon County while angling for Great Lakes fish. Non-residents of the county spent about 0.6 million dollars, generating total county sales of 1.2 million dollars and increasing personal income by about 0.4 million dollars. The boat fisheries of Muskegon and

Whitehall/Montague were by far the most significant, contributing 77% of the economic impact. An important finding was the low number of non-residents fishing. The largest proportion of non-residents among boat anglers occurred at Whitehall/Montague (25%). Of those, 60% came from adjacent counties (Oceana, Newaygo, and Kent).

Manistee County

During the period October 1982 through September 1983, anglers fished 185 thousand days and spent an estimated 3.1 million dollars in Manistee County. Non-residents of the county spent about 2.6 million dollars, generating sales of over 5.2 million dollars and personal income of over 1.8 million dollars. The boat fishery (including charter fishing) contributed 81% of the economic impact in Manistee County. Non-residents were attracted most by the boat fishery and angling opportunities on the Big and Little Manistee rivers.

Benzie County

Anglers were estimated to have spent 2.3 million dollars while fishing 117,200 days in Benzie County from October, 1982 through September, 1983. Non-residents of the county spent about 2.1 million dollars, generating sales of over 4.3 million dollars and increasing personal income by over 1.5 million dollars. The boat fishery (including charter fishing) contributed 78% of the economic impact from angling for Great Lakes fish. The boat fishery and the Betsie and Platte River fisheries drew the largest proportion of non-residents.

Grand Traverse County

From October, 1982 through September, 1983, anglers fished 26,000 days and were estimated to have spent over $180,000 fishing for Great Lakes fish in Grand Traverse County. Non-residents of the county contributed $56,000, generating total county sales of about $141,000 and increasing personal income by almost $50,000. Non-resident impacts were relatively low because few anglers traveled this far north to fish. In contrast, the economic impact attributable to non-residents was 50 times greater in Ottawa County.

Delta County

Anglers were estimated to have spent over $266,000 in 52,300 days of fishing for Great Lakes fish in Delta County. Non-residents of the county spent about $51,000, generating sales of about $128,000 and increasing personal income by about $45,000. The majority of the economic impact (80%) was evenly distributed between boat and shore fishing. Ice fishing accounted for the remaining 20%. The situation in Delta County was similar to that in Grand Traverse County. Few non-residents traveled to the county for fishing. Thus, the economic impact from this group was about 1/50 of that generated by non-residents fishing in Ottawa County.

Lake Michigan Sport Fishery Market Analysis

The Fisheries Division of the MDNR long felt the need to understand the clientele they serve so as to design management strategies that improve services to users of the fisheries resource. An in-depth market analysis study was designed jointly by Fisheries Division staff and recreation research staff from MSU. Information by mail survey was obtained from a representative sample of nearly 11,000 licensed anglers in 1983 and 1984.

The study had multiple objectives including assessing angler expenditures, characteristics, preferences, and behavior (Spotts 1986). Another objective was the development of criteria for market segmentation of Michigan's anglers to better serve the angling public (Kikuchi 1986). The data from the MDNR survey are currently being utilized at The University of Michigan to develop an econometric model for angling in Michigan. Results from these analyses will be forthcoming in the next 2 years. Future surveys are now being planned by the MDNR Fisheries Division staff to refine the models being developed and to determine the impact of angling on the Michigan economy.

As mentioned above, MDNR Fisheries Division conducted an in-depth study of anglers and angling in Michigan in 1983-84. For the purpose of this report, all anglers fishing Lake Michigan were selected for further study. Results (Tables 3-8) are presented by destination zones developed for other sections of this report on Lake Michigan.

Average expenditure data for Lake Michigan fishing produced an overall average of $44.67 (Table 3), indicating a day of fishing on Lake Michigan may be somewhat more valuable than an average day ($36.50) on the Great Lakes derived by Talhelm (1987). Expenditures at the fishing site accounted for 53% of the total spending (Table 4). Out-of-state visitors spent over twice as much on their fishing trips as Michigan residents (Table 5). Increased promotion of this market segment could have very favorable effects on Great Lakes fishing ports.

Characteristics of angler fishing trips showed a high proportion (53%) of 1 day trips in the southern zone (Table 6). A good highway system makes southern Lake Michigan very accessible to large numbers of anglers living in urban centers. Charter boat usage was high in both the central and southern zones. Since charter-boat trips are less frequently made, they would amount to a much smaller proportion of the total effort. Also, since more than one species can be targeted at a time, the percent of anglers targeting a list of species is not additive.

Lodging choices by anglers traveling more than 1 day varied markedly by zone fished (Table 7). The rental cabin played an important role in providing accommodations for anglers fishing from the Traverse City area to the north and throughout the Upper Peninsula.

Angler characteristics suggested that Lake Michigan anglers are fairly affluent and prefer trolling on their private boats for salmon and trout (Table 8).

In conclusion, it can be said that Lake Michigan anglers, who number 449,000 and fish an average of 1.5 million days per year, have had a substantial economic impact on the major ports that support the sport fishery. It is believed that Lake Michigan angling in future years will continue at about current levels, since all indications are that the fishery has peaked after 20 years of growth and has now leveled off.

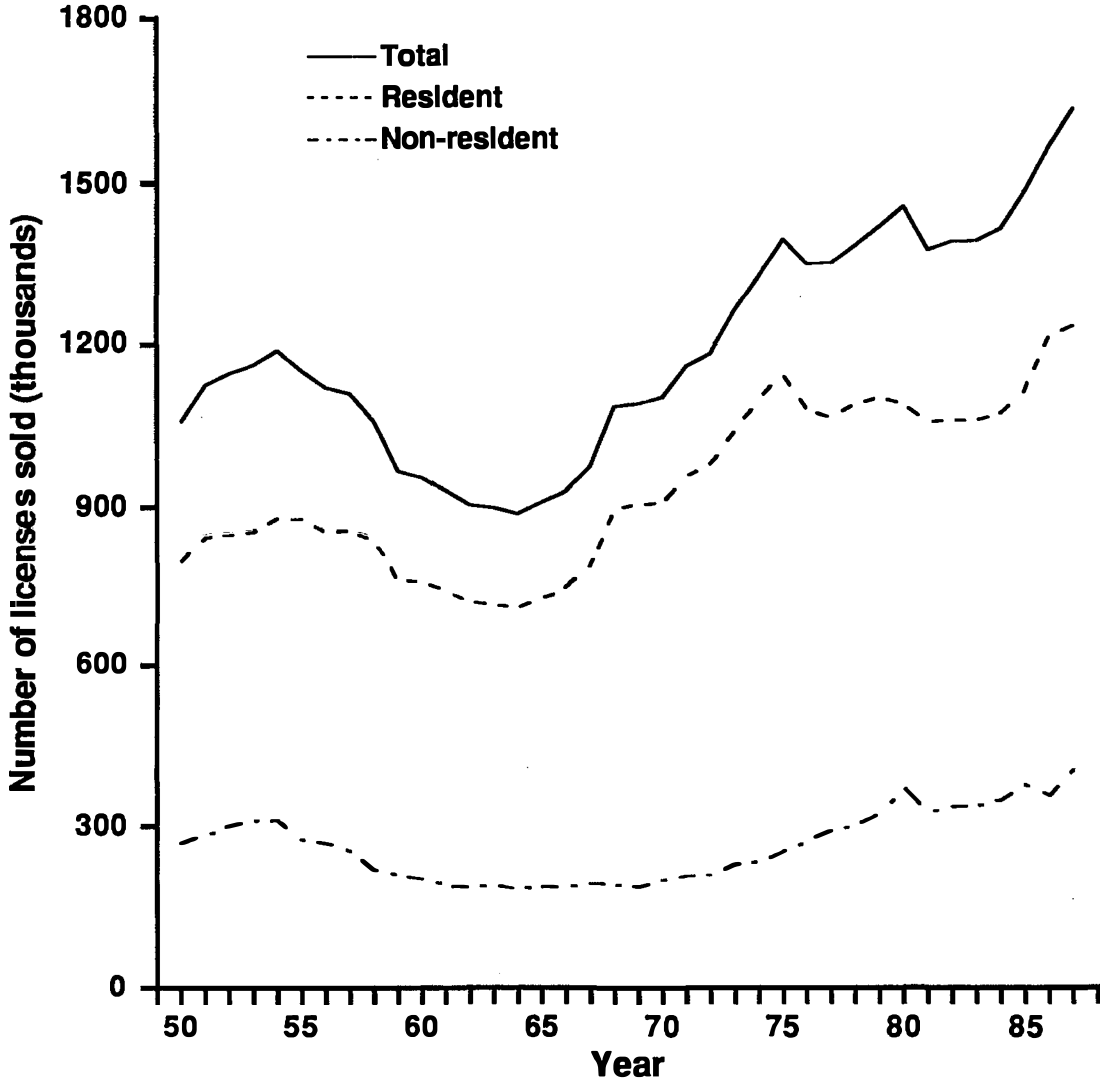

Figure 1. Number (thousands) of resident, non-resident, and total fishing licenses sold in Michigan during 1950-87.

Table 1. Great Lakes boating activity in Michigan during 1974-86.

Year	Boat days (millions)
1974	3.3
1977	4.4
1980	5.4
1986	7.5

Table 2. Expenditures (dollars) and economic impacts of angling on Lake Michigan by selected destination counties.

	County/study period					
Characteristic	Ottawa 10/81-9/82	Muskegon 10/81-9/82	Manistee 10/82-9/83	Benzie 10/82-9/83	Grand Traverse 10/82-9/83	Delta 1/83-12/83
Total angler spending	4,600,000	1,800,000	3,100,000	2,300,000	181,000	266,000
Total spending per day	19.34	10.66	16.76	19.62	6.96	5.09
Total fishing days	237,800	168,900	185,000	117,200	26,000	52,300
County non-residents						
Spending	2,500,000	600,000	2,600,000	2,150,000	56,400	51,000
Spending per day	24.53	17.86	20.31	22.66	14.46	12.75
Economic impact[1]	5,000,000	1,200,000	5,200,000	4,300,000	141,000	128,000
Fishing days	101,800	33,600	128,000	94,900	3,900	4,000
Increased personal income to county residents	1,800,000	400,000	1,800,000	1,500,000	50,000	45,000

[1]Assumes a multiplier of 2.0.

Table 3. Average trip expenditures (dollars) by zone for anglers fishing Lake Michigan during 1983.

Expense category	North	Central	South	Lake wide
Fishing equipment	24.26	40.04	39.81	37.40
Charter fees	0.97	27.38	18.02	18.50
Lodging	62.12	33.01	14.86	28.63
Restaurants	33.94	32.08	25.17	28.93
Groceries	40.20	30.23	15.11	24.30
Boat fuel	12.22	20.18	8.87	13.27
Auto fuel	31.37	37.59	12.67	24.19
Boat rental	3.64	3.86	1.11	2.45
Entertainment	8.09	10.33	5.00	7.32
Other expense	9.77	15.97	9.06	11.54
Total	226.58	250.67	149.68	196.53
Average per day	33.32	43.98	53.46	44.67

Table 4. Average trip expenditures (dollars) by location and zone for anglers fishing Lake Michigan during 1983.

	Expenditure location			
Zone	At home	Enroute	At site	Total
North	43.87	47.09	135.62	226.58
Central	51.29	60.13	139.25	250.67
South	57.30	23.70	68.68	149.68
Lake wide	53.10	39.90	103.53	196.53

Table 5. Average trip expenditures (dollars) by zone for residents and non-residents of Michigan who fished Lake Michigan during 1983.

Zone	Residents	Non-residents	Total
North	150.32	503.15	226.58
Central	205.24	360.63	250.67
South	103.40	243.29	149.68
Lake wide	144.38	314.86	196.53

Table 6. Characteristics of angler fishing trips by zone on Lake Michigan during 1983.[1]

Characteristics	North	Central	South	Lake wide
Travel days	6.8	5.7	2.8	4.4
Fishing hours	14.8	18.5	9.5	13.5
Fishing party size	2.4	2.6	2.9	2.7
One-way travel (hours)	4.2	5.4	2.6	3.8
One-way distance (miles)	197.0	255.0	117.0	177.0
One day trips	35	16	53	37
Private boat usage	65	56	61	60
Charter boat usage	1	21	24	19
Shore/ice fishing	27	21	15	19
Fishing method (trolling)	41	64	72	64
Targeting chinook salmon	25	82	65	64
Targeting coho salmon	19	73	63	59
Targeting lake trout	17	32	37	32
Targeting rainbow (steelhead)	19	27	31	28
Targeting yellow perch	42	9	18	19

[1]Values in top part of table expressed as means. Values in bottom part of table expressed as percent.

Table 7. Lodging (percent usage) for anglers on overnight trips by zone when fishing on Lake Michigan during 1983.

Type of lodging	North	Central	South	Lake wide
Hotel/motel	3	23	22	17
Second home	23	9	14	14
Friend's/relatives	23	24	24	24
Rental cabin	30	7	5	13
Lodge	1	1	3	1
Campground	19	28	24	25
Other facility	1	8	8	6
Average length of lodging (nights)	3.6	3.6	1.4	2.5

Table 8. Characteristics and preferences of anglers by zone fishing Lake Michigan during 1983.[1]

Characteristics	North	Central	South	Lake wide
Angler age	45	43	40	42
Angler income (dollars)	22,611	25,694	29,107	26,939
Angler family income (dollars)	26,667	31,464	35,026	32,519
Sex (males)	97	93	94	94
Married	79	78	87	82
Spouses fishing	51	55	53	53
Boat ownership	47	38	48	44
Own property near water	28	23	20	22
Race (white)	86	89	87	89
Prefer Great Lakes fishing	72	62	67	66
Prefer trolling	29	44	36	38
Prefer private boat fishing	70	53	66	62
Prefer to catch salmon	22	53	40	42

[1]Values in top part of table expressed as means. Values in bottom part of table expressed as percent.

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MANAGEMENT OF SALMONID FISHERIES

Myrl Keller and Kelley Smith

Historical Overview

In recent years, fishery agencies bordering Lake Michigan have been successful in resolving, to varying degrees, some management problems. Certainly the successful control of sea lamprey in the lake is a monument to cooperative international effort. Establishment of a new salmonid sport fishery and the partial rehabilitation of some native species are other proud accomplishments. The fishing agreement between the state and three Michigan Indian tribes in 1985 has partially segregated commercial and sport interests. However, many issues remain unresolved because they continue to generate problems which are intractable with existing management philosophies.

The highly migratory nature of most salmonid species has been a major factor contributing to the ineffectiveness of the diverse regulations passed by state legislatures to manage Lake Michigan's salmonid stocks. This free movement of fish across state boundaries has created further barriers to successful management because of the uncoordinated efforts of the various agencies in specifying regulations which, more often than not, have been based on self-interests rather than biological fact. The necessity of uniform regulations has been recognized since the first realization that native stocks were being depleted from Lake Michigan. Although some progress has been made over the past century in the innumerable hearings, meetings, and conferences of committees, boards, and commissions, the gains have never succeeded in attaining common or compatible management practices throughout the lake.

Increasingly rapid changes in the composition of the Lake Michigan fish community have also frustrated many attempts to achieve uniform management practices and goals. These modifications were influenced by intensive fishing, the establishment of new species, and by physical and chemical alterations of the environment. In the absence of uniform lake wide controls, biological, economic, and political chaos has been common.

For the most part, sport fishers and the state-licensed commercial fisheries do not exploit the same species. Salmon, trout, perch, walleye, and bass have been reserved for the anglers, whereas chubs and whitefish generally are considered commercial species. Exceptions are whitefish in Grand Traverse Bay, where the stock is fished by both anglers and Indian commercial fishermen, and smelt in Green Bay, where there is a pound net fishery in the spring. Indians fishing commercially under treaty rights are essentially free to exploit nearly all fish species within the waters of Lake Michigan allocated to them under terms of the 1985 negotiated settlement. Some conflicts between sport and commercial fisheries do arise. Where the two coexist, there frequently is direct physical interference between the stationary commercial gear and the terminal tackle of the mobile sport fishery.

Indirectly, conflict of interest arises when intense exploitation of a forage species removes a large proportion of that food supply, which might otherwise be consumed by the predatory salmonine populations. Although not the result of direct pursuit, salmon and trout frequently become entangled in commercial gear, and the losses can be of large magnitude.

The past difficulties in providing fish and fishing opportunities have often been caused by an inability to identify the harvestable surpluses and allocate them to competing users. For most salmonid stocks, present management decisions will have to be based on the best scientific studies available. An understanding of society's needs, and measures of value associated with those needs, are fundamental to determining the allocation of stocks in a manner which would maximize public benefit.

1987 Chinook Salmon Fishery

Three major factors contributed to the poor salmon fishery during 1987; the geographical distribution of chinook salmon during 1987, poor survival of the 1984 (and possibly the 1985 and 1986) year class, and the possibility of increased mortality in the lake due to disease.

The poor chinook salmon fishery experienced by southern and central Lake Michigan anglers during the spring and early summer of 1987 was, in part, due to a change in the geographical distribution of that species. Sport catch statistics for 1987 indicated that angler catch rates for chinook salmon decreased in the southern and central sections of the lake, while they increased in the north. Angler harvests of chinook were reported at some northern ports as much as one month earlier in the season (late May and early June) during 1987 than in previous years. It is possible that chinook salmon did not concentrate in the southern end of Lake Michigan during the winter months but remained scattered throughout the lake. This would be in response to, at least in part, the abnormally mild winter (1986-87) and warm spring and early summer weather.

Poor survival of the 1984 year class of chinook salmon also appears to have contributed to the decrease in harvest and catch rates of that species during both the 1987 and 1988 seasons.

The return of the 1984 year class at age 0.3 to the sport fishery was much lower than the return of the 1982 and 1983 year classes at that same age. Age-0.3 chinook are the most important age group in the sport catch, making up from 35-54% of the total harvest. Weir harvest statistics also confirmed the poor survival of the 1984 year class, indicating that this plant was always below average in number returning since 1985.

It is not known for certain what caused the increased mortality of the 1984 year class of chinook salmon in Lake Michigan nor when it occurred. Some biologists speculate that the hatchery product may be inconsistent from season to season. Preliminary data from the Lake Huron sport fishery indicated returns of the 1984 year class were similar to other year classes. Since chinook salmon stocked in lakes Michigan and Huron came from the same hatchery system, it is doubtful the failure of this year class was due to a change in the hatchery product. Hatchery practices have improved through the years and smolt quality is probably as good as in the early years of the salmon program.

A final factor which may have affected the 1988 sport fishery was an outbreak of disease. During April and May 1988, dead and dying chinook salmon began washing ashore along southeastern Lake Michigan. These mortalities were first noted after a severe storm with 50 mile per hour winds in southern Lake Michigan. MDNR's fish pathologist concluded that most (if not all) of the fish that were examined had gross signs of acute bacterial kidney disease (J. Hnath, MDNR, personal communication). Immediately after the first few fish began to wash ashore, air surveys were conducted in order to determine the magnitude and extent of the problem. Results of these surveys indicated that the magnitude appeared small, possibly affecting less than 1,000 fish in Michigan's waters (D. Johnson, MDNR, personal communication). Most of the dead and dying fish were concentrated in the southern section of the lake, generally between Chicago, Illinois and Muskegon, Michigan. However, mortalities were confirmed as far north as Charlevoix, and also by biologists in Wisconsin and Indiana. Some of the fish found in the north may have been part of the southern Lake Michigan die-off. Dead carcasses could have been carried north by strong south to north lake currents (D. Johnson, MDNR, personal communication). Total losses in all waters of Lake Michigan were estimated at 7,000-8,000 fish. This may or may not have had a significant impact on the 1988 chinook sport fishery (D. Johnson, MDNR, personal communication).

Hatchery Practices and Product Quality

The Pacific salmon program for the Great Lakes was initiated in 1964, and has been recognized as the best fish management action of this century. Because salmon smolts were released into an environment which was free of predators and abundant with forage, the results were spectacular. Survival and adult returns were beyond all expectation. Shortly after the implementation of this program, Michigan became self-sufficient in providing smolts for stocking because millions of coho and chinook salmon eggs could be collected year after year. Indeed, supplies were so plentiful that eggs were made available to all of the surrounding Great Lakes states for their own salmon programs.

Michigan built the Platte River Anadromous Fish hatchery where the bulk of the salmon could be reared. Eventually, annual production stabilized around 6.0 million chinook and 2.8 million coho smolts. As experience was gained in the rearing of Pacific salmon, hatchery production became very predictable and quality smolts have been produced year after year. Estimated survival of smolts remains high, very high by ocean standards, with values ranging from 15-30% based on returns to the sport fishery and harvest weirs.

The pessimistic view would state that 70-85% of the hatchery production perished. However, this is the norm for fish populations which are subjected to the forces of natural selection in the lake environment. Competition, disease, predators, and various other natural and man-induced environmental factors all take their toll on individuals and stocks. This selection process results in the survival of those individuals whose genetic makeup allows them to cope with the daily stresses of lake life. They have demonstrated their ability to survive and it is from these fish that progeny are obtained for a new generation of smolts, thus guaranteeing the continuing quality of the product.

Because hatchery practices have continually improved, smolt quality is presumed to be as good as in the earlier years of the salmon program. If the number of fish surviving from smolt to adult has decreased, it is most likely due to both increased man-made stresses and indiscriminate losses, along with presently unknown environmental factors affecting fish health.

Bacterial Kidney Disease

Bacterial kidney disease (BKD) is a slowly progressive bacterial disease of fish caused by *Renibacterium salmoninarum*, a gram positive diplobacillus. It is common in Pacific salmon, but is also found in many other salmonid species. BKD is the cause of serious saltwater losses of salmon on the Pacific coast (Meyer et al. 1983). The disease is transmitted both through the water from fish to fish, and from adult fish to their progeny through infections within the egg.

BKD is known to occur naturally in Great Lakes and hatchery salmonid populations as a latent pathogen. Factors causing the disease to become active are poorly understood, but are thought to be in response to environmentally induced stress. The incidence of acute infections of BKD in Lake Michigan chinook salmon over the past 3 years has increased. In 1986, all chinook salmon checked for BKD at the Little Manistee weir tested negative. During 1987 and 1988, 20% and 80%, respectively, of pooled chinook salmon samples taken at the Little Manistee harvest weir tested positive (J. Hnath, MDNR, personal communication). The severe cases of BKD observed in chinook during 1988 may be the result of either an unknown environmental stress or possibly an unknown virus which reduced the ability of the fish to fight the infection (J. Hnath, MDNR, personal communication).

Although BKD was apparent in all the chinook collected and sent to the MDNR pathology laboratory during the spring 1988 die-off, it was very possibly not the primary cause of death (J. Hnath, MDNR, personal communication). The major factors resulting in this mortality, in all likelihood, include 1) the presence of BKD, 2) the presence of the acanthocephalan worm (*Echinorhynchus salmonis*) in all chinook, and 3) other stress(es) which contributed to the overall lack of resistance of the fish.

BKD is not impossible to control, but the necessary methods for reducing the negative impact of this disease are extremely difficult and expensive. BKD can not be eliminated, but some success in controlling the disease has been achieved by researchers on the west coast. The procedures used include the following.

1) Put young fingerling fish on an antibiotic therapy program which should be completed at least 10 days before plant out. This does not eliminate BKD, but does greatly reduce its effects, giving these fish a head start at plant out in fighting the disease.

2) Capture returning adults 2 months before they spawn and inject them monthly with an antibiotic. This will allow the antibiotic to enter the egg during its development, thus reducing the effects of the disease on the egg. The eggs can not be treated effectively after they have developed.

3) Only sex products from those fish which have a level of BKD below some predetermined critical maximum are used in producing progeny for the hatchery system.

Using this methodology, west coast agencies have tripled adult returns to spawning areas as compared to groups that were not placed through this rigorous program.

Management of the Forage Base

Although the future success of the salmon and trout sport fisheries depends heavily on the proper management of a diverse forage base, management agencies have not cooperatively allocated these forage species as the principle food source of the salmonid fish populations. In some jurisdictions, alewives, bloater chubs, and smelt are commercially harvested for a few cents per pound and used as pet food. Although the total standing stock of forage (about 811 million pounds) in Lake Michigan appears to be adequate to support the present levels of salmonid populations, there are concerns by some biologists about the instability of alewife stocks (D. Stewart, State University of New York, and S. Brandt, University of Maryland, personal communication).

Annual lake-wide fish stock surveys conducted by the National Fisheries Research Center, Great Lakes, documented a decrease in alewife abundance by a factor of six from 1981 through 1983. There have been two plausible explanations for the alewife decline. Kitchell and Crowder (1986) argued that the planting rates for salmon and trout had become too high, resulting in a level of predation so intense that alewives could no longer compensate for the increased mortality and the populations collapsed. The USFWS offered an alternative hypothesis (Research Information Bulletin 1988). Based on their studies of alewife dynamics during the 1970s, they estimated that Lake Michigan alewife populations could support increases in predator populations. Because the alewife decline began prior to the massive infusion of predators, they concluded that the decline was caused by stress from an increase in climatic severity and that alewife populations would recover if climatic conditions moderated.

Cold water and reduced plankton abundance limits alewife productivity as evidenced by their inability to maintain more than a sparse, albeit persistent, level of abundance in Lake Superior. The periodic die-offs in the Great Lakes and other freshwater systems have also been linked to unusually cold temperatures. Excessive cold has been shown to have its greatest effect on young fish, with the smaller alewives in a year class suffering the highest mortality over the first winter. Cooler growing seasons accompanied the cold winters of 1976-77 to 1981-82 when alewives declined so rapidly. However, climatic conditions have moderated since 1983, and alewife density has again increased in Lake Michigan. By the fall of 1987, yearling and older alewives had rebounded to 80% of their average 1973-81 level of abundance.

In the past, estimates of available forage in Lake Michigan were largely determined by standardized bottom trawls. This technique provides good estimates of minimum fish abundance and changes in relative abundance from one year to the next. However, bottom trawling samples only a limited portion of the water column. It largely misses pelagic fishes and is also subject to unknown bias because of net avoidance. Although trawls are essential for collecting information on species composition, life history, and ecology, they can not be used to measure, on a fine scale, the spatial and temporal distributions of fish populations. To compensate for these problems, a multi-agency effort was initiated in the fall of 1987 to assess forage fish abundance for the entire main basin of Lake Michigan using trawls and state of the art acoustic technology. Preliminary results from this study show that alewives comprise 114.4 million pounds of the forage biomass, bloater chubs 610.8 million pounds, and smelt 85.6 million pounds, for a total standing stock of 810.8 million pounds (S. Brandt, University of Maryland, and R. Argyle, USFWS, personal communication). Inclusion of the Green Bay alewife population would increase the standing stock by 46.3 million pounds.

Models have been developed by a number of researchers to compare the relative impact of predatory salmonids on different forage species (e.g., see Stewart et al. 1981; Eck and Brown 1985). Although of benefit to management, the simulation results have been viewed with skepticism because input to the models was not based on lake-wide salmonid feeding habits and food preferences. Only seasonal data from specific areas of the lake were utilized in the models, resulting in conflicting answers to the question of alewife instability.

More recently, bioenergetics simulations based on data from the 1987 acoustic study on Lake Michigan have predicted that the annual demand on the forage base by coho salmon is 15.8 million pounds, 74.1 million pounds by chinook salmon, 21.2 million pounds by lake trout, 18.5 million pounds by brown trout, and 15.9 million pounds by rainbow (steelhead) trout (S. Brandt, University of Maryland, personal communication). The 1987 stocking levels were used in the model to estimate predator abundance along with the assumption that 80% of the salmonid diet was alewife. The latter may be too high. A more realistic estimate of alewife abundance in the diet may range from 50-60% (N. Kevern, Michigan State University, personal communication).

Recent diet studies indicate that adult chubs (over 6 inches in total length), which comprise 311 million pounds of the total 811 million pounds of forage biomass in Lake Michigan, are not utilized by salmonid predators as a food source. Thus, the consumption rate of available forage by salmonid predators is approximately 29% (145.5 million pounds eaten out of a total of 499.8 million pounds available). This does not take into account the unknown recruitment of salmonids which are naturally produced. Natural reproduction by salmonids (other than lake trout which are not yet reproducing) could conservatively contribute an additional 10-15% to the standing stock of predators lake wide. However, it must be again noted that the forage biomass estimate of 810.8 million pounds is conservative because it only includes alewives, bloater chubs, and smelt. Other potential forage species, for example sculpins, sticklebacks, trout-perch, and shiners, have not been included in the bioenergetics analyses of the Lake Michigan predator-prey systems.

Although it can not be conclusively demonstrated that salmonids will utilize the abundant bloater chubs and smelt in the absence of alewives, there is some evidence that they will. Before invasion of the alewife, lake trout fed heavily on sculpins and bloater chubs. In Lake Huron, smelt are the predominant food organism sustaining salmonid populations (R. Svoboda, MDNR, personal communication). The changing species composition of the fish-forage base has been reflected to some degree in the diet of eastern Lake Michigan Pacific salmon (Kogge 1985). A shift in the diet occurred from 1983 to 1986 when the consumption of alewife decreased and that of bloater chubs rose (Kogge 1985). More recent diet studies indicate a continued reliance by the major salmonine predators on alewives, although young bloater chubs and other forage species are found in the diet (R. Elliott, Michigan State University, personal communication).

Additionally, it has been observed recently that older rainbow (steelhead) trout in the lake feed predominantly on terrestrial insects in the surface film during the spring and summer months. The European waterflea, a newly introduced cladoceran, has also been reported as a regular item in the rainbow (steelhead) trout diet during summer.

Despite the apparent contradictions in available evidence, it would be prudent to manage for a well-balanced forage base to ensure a stable, high-density salmonid population. Alewives, bloater chubs, smelt, and sculpins should be designated and managed for the purpose of securing this required, diverse mix of forage. Based on studies in Wisconsin, 15% of the total annual mortality experienced by alewife is directly attributable to commercial exploitation (S. Brandt, University of Maryland, personal communication). Therefore, it must be concluded that a reduction or, in all likelihood, termination of commercial operations targeting on these forage species is inherent to the success of this management proposal.

Salmonid Stocking Levels

During the 1980s, an average of 15 million salmon and trout were planted annually in Lake Michigan. In the early 1980s, the MDNR became concerned about reports of significant changes in the forage base and perceived declines in the average size of sport caught salmonids. Empirical evidence suggested that the escalating predator levels, which had occurred over the years in all states' waters, might have been responsible for an apparent negative impact on forage abundance and species composition. This prompted the MDNR to conduct a review of its pre-1985 salmonid stocking program. Although limited data were available for assessing both the predator-prey dynamics and the adequacy of the forage base to support commercial fisheries and existing salmonid stocking rates, the MDNR chose to manage conservatively and reduced its stocking levels in 1985 to achieve a 10% reduction in forage consumption. Wisconsin followed by reducing its stocking efforts in 1987. It was estimated that these actions resulted in a 8.5% reduction in the total consumption of forage species by predators in Lake Michigan.

Given the present composition and estimated abundance of forage in Lake Michigan and the current demand by predators, it is possible that a larger salmonid population could be supported than is currently inhabiting the lake. However, in light of the instability of the alewife populations over the past 10 years, it is necessary to know if the other forage species could sustain increased levels of predation in the event of a total alewife collapse. The recent recovery of the bloater chub populations lends credence, at least for this species, to that very premise. Provided the production of remaining forage species would follow the same trend and compensate for alewife instability, and that predators would switch readily to the new forage structure, a decline of the alewife stocks would not necessarily be catastrophic, and might even be beneficial, to the system. For example, assuming the above changes took place when a reduction in alewife biomass occurred, the salmonid diet would become more diverse and, therefore, create a more stable predator-prey interaction within Lake Michigan. Also, reduced alewife numbers have stimulated the recovery of other native species such as yellow perch and emerald shiner.

An additional concern voiced by some biologists is based on the idea that excessive stocking could result in high mortalities or poor growth of stocked salmonids. Presently, there is no evidence to support this notion. There is no indication of density-dependent mortality on salmonid stocks in Lake Michigan. The growth of lake trout, rainbow (steelhead) trout, and brown trout in the lake has remained relatively stable for the past 10-15 years. Since 1983, the growth of Pacific salmon appears to be at an equilibrium with the present lake environment. Year-to-year changes in size-at-age seem to be dependent on climatic conditions during critical life stages and annual fluctuations in the composition of the forage base.

The total number of salmonids stocked in Lake Michigan by all agencies was reduced by 15.7% during the period 1979 to 1987 (from 15.9 to 13.4 million fish, respectively). Precise knowledge concerning the ability of Lake Michigan to support a plant equivalent to or exceeding the 1979 level does not exist and is greatly needed. However, it is plausible that the system can support additional numbers of salmonids based on the limited information currently available. Therefore it is recommended that the lake wide stocking level be adjusted to maximize predator usage of available forage species based on the biological and ecological constraints of the predator-prey interactions within the lake. The criteria forming the basis for this proposal include 1) only 28% of the estimated forage biomass is currently consumed by salmonid predators, 2) research has demonstrated that salmonids will utilize to some extent other forage species when alewife abundance declines, 3) alewives, bloater chubs, smelt, and sculpin will be designated and managed as forage species, 4) an eventual reduction or termination of both commercial exploitation and indiscriminate losses of the designated forage species will be achieved, and 5) the capabilities for accurately estimating forage abundance evolve to the point of allowing real time adjustments to stocking rates based on forage availability.

Indiscriminate Losses

With the realization of the current and future stresses imposed by man on the Lake Michigan salmonid fishery, it is becoming increasingly evident that the traditional approaches to management of the Great Lakes are in conflict with maintenance of a high quality sport fishery. Development, incidental mortality in commercial operations, and open access policies in some waters, along with impacts on fisheries from other water uses (e.g., Consumers Power/Detroit Edison Companys' Pump Storage Plant at Ludington, Michigan), have resulted in often severe, indiscriminate losses of the fishery resource.

Certain types of highly efficient commercial fishing gear, and more specifically the manner in which they are commonly employed, do create problems that compromise present management objectives. The non-selectivity of gill nets and, to a lesser degree, trawls and trap nets results in an incidental but sometimes significant loss of non-target species. This problem must be addressed by the Lake Michigan management jurisdictions.

In 1970, Michigan banned the use of gill nets by state licensed commercial fishermen in waters less than 240 feet deep because of the incompatibility of this gear with plans to develop the salmonid sport fishery. The extent of movement by salmonids into other states' waters was not realized at this time and these management agencies did not employ this regulation. However, Indiana reported that their 20 licensed gill-net operations killed an estimated 76,000 young chinook salmon incidental to fishing for yellow perch during the period August 21 to November 26, 1985 (D. Brazo, IDNR, personal communication). In 1986, Illinois reported that 44,700 salmon and trout were killed by their five commercial gill-net operations (R. Hess, IDC, personal communication). Presently, Wisconsin has 110 licensed commercial operations in the main basin of the lake and 46 in Green Bay. In 1987, it was estimated that at least 110,000 salmonids were killed in commercial fishing gear in Wisconsin waters of Lake Michigan (M. Talbot, WDNR, personal communication). Indiana has recently banned gill nets in favor of trap nets. Illinois and Wisconsin are reviewing the problem.

In northern waters of Lake Michigan, there is an active tribal commercial fishery employing primarily gill nets, but some trap nets are also used. The catch of lake trout in this fishery is documented, but the catch of the other salmonids is sketchy. Michigan has six licensed commercial fishing operations in the main basin of the lake and 25 in Green Bay. They are regulated in such a manner as to minimize salmonid losses. However, some mortalities of non-target species do still occur and efforts are being made to develop methods to reduce these losses.

Average annual incidental salmonid catches from gill nets in Canadian waters of Lake Huron over a 9-year period (1979-87) were 71,414 fish (McNeil et al. 1988). Recent undercover investigations of commercial fishery activities in the upper Great Lakes have revealed that substantial quantities of sport fish have been illegally harvested and marketed during the past few years. In 1983, an interagency law enforcement operation intercepted 120,000 pounds of illegally harvested lake trout from 40 fishermen. This figure was thought to represent approximately 5% of the Chicago market and suggests that as many as 2 million pounds of illegal lake trout from lakes Michigan and Superior may be marketed annually in Chicago (Great Lakes Law Enforcement/Fisheries Management Workshop 1983). Current estimates of these illegal withdrawals of valuable sport fish rival the legitimate harvest by anglers in some areas of the Great Lakes.

These indiscriminate losses are very serious concerns, not irrational attacks on commercial fishing. There is stubborn resistance from managers and the commercial industry alike to adopt regulations aimed at resolving these problems. This in turn has created hostility and, worse, diminished public trust in fishery management. Calls for completely outlawing the offending commercial gear are now fairly common. Frustrated citizens have bypassed the fisheries management systems altogether and resorted to quick-fix legislation, which is an unhealthy situation.

Commercial fishermen and managers must change their thinking on gear, acknowledge the problems, and make use of technology and ingenuity to adapt fishing gear and/or its use to eliminate indiscriminate losses. Refusing to deal with these issues is simply intensifying problems for fishermen, the resource, and the current system of management.

The indiscriminate losses of adult trout and salmon, due to turbine-induced mortalities from operation of Consumers Power/Detroit Edison Companys' Ludington Pump Storage Plant (LPSP), represent a reduction of fish stock available to Michigan anglers of slightly more than 5% of the catchable population (D. Jester, Jr., MDNR, personal communication). The State of Michigan has brought civil action to recover past and predicted future damages for destruction of its fishery resources by the operation of the LPSP. The list of other indiscriminate losses could continue, such as sea lamprey predation, disease, and illegal harvest by sport anglers, but the point has been made. These sources of fish mortality have caused lost sportfishing opportunities and can be curtailed only by cooperative lake-wide management regulations.

Lake Trout Management

The native stocks of lake trout in Lake Michigan supported the world's largest fishery for the species before their extinction in the 1950s. Recovery of this lost lake trout resource by reestablishing self-sustaining populations has been the goal of a continuing state and federal program that began in Lake Michigan during the 1960s. However, the task of rehabilitating lake trout stocks has proven far more difficult and complex than was originally anticipated.

Even though there have been 53 million lake trout stocked in Lake Michigan over the past 2 decades, natural reproduction by the species has been virtually nonexistent in the lake. Although survival of stocked trout has been good from plant-out to the pre-recruit stage, the reasons for reproductive failure are poorly understood. However, exploitation is excessive on both immature and adult fish, which may have prevented trout stocks from attaining the required number of spawners for adequate egg deposition. Stocked lake trout make up a significant percentage of the salmonid sport catch lake wide and are a major species in the tribal commercial fishery. Increasingly stringent regulations have been placed upon the sport fishery in a futile attempt to reduce fishing mortality and thus increase the number of spawning fish.

An ongoing integrated pest management control program was developed to suppress the sea lamprey which is now approximately 10% of its former peak level of abundance. There have been increases in hatchery production capability and in the development of broodstocks to test different strains of lake trout.

The USFWS policy on lake trout stocking clearly states that lake trout produced in national hatcheries for the Great Lakes are to be used to restore depleted stocks, with the goal of achieving self-sustainability. The USFWS further recommends that stocking sites for lake trout should be selected to maximize the chance for successful reproduction. Thus, distribution of federally produced lake trout has been centralized in areas such as refuges where stocked fish, resultant spawning populations, and their progeny will receive maximum protection in a high quality habitat. Refuges are viewed as regions encompassing high-quality, historic spawning reefs which are, theoretically, large enough to encompass the home range of lake trout planted therein. Fishing for and possession of lake trout by all means and all user groups is prohibited in refuges. In the 1985 Indian-state fishing agreement, two lake trout refuge areas were established. One is in the north sector of the lake, the other in the central area and includes both Michigan and Wisconsin waters. The offshore refuges, with their reduced accessibility, have received most of the available young lake trout in the past 3 years.

In the last decade, research on lake trout, important forage stocks, and environmental quality has intensified with hopes of improving the lake trout rehabilitation efforts. Through the forum of the GLFC, an interagency lake trout technical committee was formed. The technical committee has prepared long-range plans aimed at providing self-sustaining lake trout populations. The stocking of lake trout has been shifted from major sport fishery localities into refuge and rehabilitation zones with the hopes of maximizing the chances for reproductive success. Despite these monumental efforts, rehabilitation has fallen short of anticipated goals, and the present management of Lake Michigan's lake trout stocks can be characterized fairly as put, grow, and catch.

The present policy to create self-sustainable lake trout stocks has been criticized by biologists and sportfishing groups alike as being an unachievable goal. Some argue that the existing predator-prey relationships are in balance with other salmonine species that grow and mature faster than lake trout and are more highly regarded by anglers. Others sense that, because of the policy, Lake Michigan has become a test tube for lake trout rehabilitation while management of other important salmonids is being ignored. Charter captains, who depend seasonally on lake trout, argue that angling interests are not considered under the new allocation and priority process of stocking. This can only mean the sportfishing community is destined to suffer in the near future (D. Grinold, Michigan Charter Boat Association, Lansing, personal communication). Most sportfishing interests feel that the lake trout should be managed for a put, grow, and take fishery, as are salmon.

The ecosystem is complex and ever changing in the man-altered environment of Lake Michigan, which now has a fish species composition significantly altered from pre-lamprey days. The development of a multi-million dollar sports fishery on the planted stocks is real and here to stay. Stability of the high quality sport fishery can only be sustained through a multi-species mix of trout and salmon. However, the existing federal lake trout policy is not totally compatible with this plan. Although the idea of reestablishing lake trout stocks is a noble one, the viability of such an attempt is dependent upon the integration of this process with the MDNR's plans for managing salmonids to maximize public benefit.

The last 20 years' experience in Lake Michigan lake trout management has clearly revealed that attainment of full, lake wide sustainability of the species is open to question. It will remain so unless tough regulations are imposed to decrease fishing mortality. However, such a move would be, for practical purposes, unacceptable to all user groups. Finally, the judicious stocking of lake trout in one refuge should be sufficient to determine whether or not self-sustainability can be achieved.

If continued adherence is expected with the federal lake trout stocking plan, modifications to the policy are required for the purposes of pursuing rehabilitation. These changes include allocation of the hatchery product between user groups, and implementation of a 28-inch minimum size limit to increase escapement of mature fish or a complete closure of the fishery for all groups in order to maximize the biomass of spawning lake trout. If these alterations are not implemented, then the states must cooperate in planting their own lake trout for management of the sport fishery to be successful.

Therefore, based on the foregoing discussion, it might be necessary for the managing agencies bordering the lake to cooperatively establish a new lake trout policy that would 1) allow the experiment of self-sustainability to continue on a much reduced scale, 2) include lake trout in the total salmonid management plan to maintain the quality of the sport fishery, and 3) establish uniform, lake wide regulations on sport and commercial fisheries for the purpose of improving the fishery resource.

Charter Fishery

Lake Michigan sportfishing has become a major industry in most Michigan ports since the inception of the salmonid program. The growth of the charter fishing industry has been especially dramatic. The number of Michigan licensed charter fishing operations working Lake Michigan has increased from 177 boats in 1976 to 639 boats in 1986, an average of about 46 boats per year. The number of charter fishing operations licensed by all agencies with Lake Michigan access has increased an average of 98 boats per year, from 415 in 1976 to 1,197 in 1984.

A recent study of Michigan's sportfishing charter fleet obtained comprehensive information on the characteristics and size of the industry (Mahoney et al. 1986). The majority of captains were part-time operators. The average charter boat made 45 half-day trips and 20 full-day trips, with an average of four customers per trip during the 1985 fishing season. This implies that approximately 166,000 people fished Michigan's waters of Lake Michigan on charter boats during this period. However, the actual number of individual customers is probably far less than this because of repeated visits to the same or another operation. Regardless, 92% of the boat parties caught at least one fish on their charter trip.

The average Michigan charter operation generated $23,000 in local spending (not including charter fees) during 1985 by persons whose primary purpose for traveling was charter fishing on Lake Michigan. If the 1.78 multiplier, used by the Michigan Travel Bureau to assess local direct and indirect spending, is applied to the charter fleet, the actual expenditures come to $41,000 per boat. This leads to the conclusion that Michigan's Lake Michigan charter industry created customer expenditures of $26.2 million, excluding local direct and indirect spending by the captains themselves.

It is obvious that charter fishing is an important element of Michigan's tourism industry. However, assuming that the rate of growth of the industry remains constant through 1996, the number of operations in Michigan would be 1,100, with over 2,300 lake wide in all states combined. The demand on the salmonid resource created by such a large fleet could be such that there would be no available surplus for the nonprofessional angler. For example, an analysis of only Michigan's 1985 and predicted 1996 charter industry leads to this very conclusion. Assuming that 6 and 10 fish were boated during a half-day and full-day trip, respectively, and utilizing the results from Mahoney et al. (1986) discussed above, the total harvest by charter customers during 1985 was at least 300,000 salmonids. If limit catches had been achieved (i.e., 5 fish per person or 20 per boat regardless of trip length), then the potential withdrawal by Michigan charter customers during this period would have exceeded 800,000 salmonids. The same scenario predicts a harvest capability of between 500,000 and 1.4 million fish in 1996 (assuming a 6 and 10 fish harvest for half and full day trips versus possible limit catches, respectively) if industry growth remains constant over the next 10 years.

The estimated annual salmonid harvest from Michigan's waters of Lake Michigan has ranged from 800,000 to 1 million fish in the past 5 years. This makes it quite evident that the Lake Michigan salmonid resource would not be able to withstand the predicted pressure exerted by such a large industry, not to mention the future potential demand of the nonprofessional segment of the angling society.

The policy of the MDNR is to manage the fishery resource for maximum public benefit. This criterion mandates equitable allocation of the available resource between the public sport angling factions. Expansion of the present charter fleet in Michigan not only preempts this policy but would, in all likelihood, put an unobtainable demand on the fishery resource and greatly reduce the economic viability of the industry. Thus, the open-access policy for new charter operations should be reviewed for Michigan's waters of Lake Michigan. The need for changing this policy to one of limited entry with a maximum number of licenses should be determined through further study of the industry and its impact on salmonid withdrawals. Any ceiling on the number of licenses issued should be established based on the findings of this research.

This would hopefully create a more equitable allocation of the fishery resource, fewer conflicts between public angling groups, greater economic stability within the industry, and higher individual profits, while still maintaining a high quality, charter fishing experience.

Tournament Fishing

Tournament fishing on Lake Michigan began with the development of the salmonid resource. Communities, product manufacturers, and service and recreational organizations have all used tournament fishing on a large scale to promote their personal interests. Although a wide variety of self-imposed regulations have been used in tournaments at various locales, only a few have encouraged the idea of conservation ethics.

Because of the potentially controversial nature of both tournament fishing and sponsorship interests, future direction of this activity needs review, especially as it relates to the management goals for the entire sport fishery. Some national fishing organizations have taken the position that competitive angling events never reward participants in any way and, in many instances, assess severe penalties for all fish killed during the tournament. The no-kill rules adopted by some tournament groups and sponsors (e.g., B.A.S.S. members) should become mandatory for such events. Techniques which have been used successfully to reduce tournament associated fish mortalities, including the use of cameras or observers to record the catch followed by immediate release, should be adopted by all tournament organizers. The idea of conservation ethics is just as important in tournaments as in any other angling experience.

Direction of Future Management

Concept of common stocks.--The historical evolution of the Lake Michigan fish community is analogous to that of the shepherd and his sheep seeking new pasture lands for grazing. The lake was comparable to the pasture with an abundance of green grass (the untapped forage base), the introduced salmonids are the sheep, and the various agencies act in the role of shepherds. Originally, growth of the flock exceeded all expectations. However, as the system stabilizes in terms of available grass and the number of sheep being raised, some predetermined equilibrium level will be approached based on both the decisions made to manage the pasture and the response of the flock to the external forces applied via these management efforts. If sound management practices are applied and stability is attained, then the flock should do well far into the future. Even with just casual tending, this is what has occurred in the Lake Michigan pasture land to the point that the most productive recreational fishery in the North American continent, if not the world, has been achieved over the past 20 years.

However, the demand on this flock is ever increasing and the pasture is continually changing. Since the flock is free to move throughout the pasture, it is obvious that they, the grazing rights, and therefore the pasture are not under the control of a single shepherd, but must be shared with others. This leads one to the conclusion that Lake Michigan should be treated as a common pasture containing a common flock which must be allocated between a multitude of user groups, four states, and the tribes. Consequently, the common stock concept compels all agencies to cooperate in developing lake wide research and uniform management plans if the future success of the salmonid sport fishery is to be assured.

Joint strategic plan.--A joint strategic plan for the management of Great Lakes fisheries has been prepared and endorsed by all agencies bordering the lakes (Great Lakes Fishery Commission 1980). The plan identifies underlying obstacles which have thwarted past management efforts, suggests broad strategies to resolve them, and proposes a coherent set of procedures to initiate implementation. Although the purpose of the plan was to assist fishery and environmental jurisdictions in dealing with management problems unique to the Great Lakes, it has not been completely implemented. The fundamental plan, if utilized, would require that 1) a consensus must be achieved when management actions would significantly influence the interest of one or more jurisdictions, 2) fishery management agencies must be openly accountable for their performance, 3) fishery agencies should be a part of the decision-making process when the activities of environmental management agencies impact fishery resources, and 4) fishery agencies must cooperatively develop means of measuring and predicting the effects of fishery and environmental management decisions.

These strategies have broad application to the Lake Michigan fishery resource and require the immediate attention of the states bordering the lake since they share common stocks and similar management problems. Implementation of a plan which utilizes these strategies might best be accomplished by limiting discussions to the salmonid sport fishery and only between representatives of the four states adjacent to Lake Michigan. Initial focus should center attention on management of the forage base, consisting primarily of alewives, bloater chubs, smelt, and sculpin upon which the salmon and trout program was established. A cooperative long-term lake wide management plan for salmonid stocks should be prepared by the bordering states and presented to the international forum of the GLFC.

Sea lamprey.--The predatory sea lamprey, a native of the Atlantic Ocean, was first recorded in Lake Ontario in 1835. Completion of the Welland Canal in 1825, which connects the Hudson River to Lake Ontario, allowed this species to invade the Great Lakes system. By 1921, lamprey were found in Lake Erie and have since spread throughout the remaining three Great Lakes. Lamprey, along with overexploitation, were responsible for the collapse of native fish stocks in the upper lakes during the 1950s.

In 1955, the United States and Canada ratified the "Convention on Great Lakes Fisheries" and the Great Lakes Fishery Commission (GLFC) was established. One of the major tasks of the GLFC is to formulate and implement programs for eradicating sea lamprey populations from the Great Lakes. The sea lamprey management plans provided by the GLFC to date have been successful in reducing the impact of this species on Great Lakes fish stocks.

Sea lamprey control was, and will continue to be, basic to any fishery management plans aimed at restoring, maintaining, and enhancing Great Lakes fish stocks. To date, the Great Lakes fishery restoration program has created annual economic activity estimated in the billions of dollars, with the Lake Michigan salmonid sport fishery and related businesses benefiting most from these programs. Without sea lamprey control, the fishery restoration program would never have succeeded.

The GLFC's funding for sea lamprey control is shared by the United States (69%) and Canada (31%), with each jurisdiction sharing half of the costs for other operations and administration. The GLFC has recently announced that, because of funding short falls, it will cut back the sea lamprey control program starting in 1990. It has been estimated that this reduction will allow sea lamprey numbers to double in the lower four Great Lakes with a corresponding decrease (upwards of 50%) in trout and salmon populations by the year 2000. This poses a serious threat not only to the fishery resources of the Great Lakes, but also to the quality of life in the Great Lakes region. A complex variety of businesses, which constitute the sport and commercial fishing enterprises and tourism infrastructure in the Great Lakes area, will be in serious jeopardy.

The beneficiaries of the sea lamprey control program are not only the fishery resources themselves, but also the user groups and economies of the jurisdictions bordering the Great Lakes. The cooperating agencies, local governments, and private enterprises continue to increase their investments in the fishery resources. The two federal governments must fully fund lamprey control and research in order to ensure the continued quality and enhancement of our fishery resources, and to guarantee that the benefits of past and future investments will not be lost.

Water quality.--Lake Michigan is a unique and valuable resource shared by four states. Public interest in protecting this fragile ecosystem has expanded to cover all facets from invertebrate to vertebrate species, habitat degradation, water loss or diversion, and all forms of pollutants which invariably end up in the water and sediments of the lake. These concerns affect people in all bordering jurisdictions implying that Lake Michigan is truly a regional resource and should be managed in a context which crosses political boundaries.

As a major shareholder in Lake Michigan, the State of Michigan will be the keystone in any regional water management initiative. The state has played a leadership role in the protection and development of Lake Michigan, supporting regional actions including the adoption of a Great Lakes Charter in 1985 and the Great Lakes Toxic Substances Control Agreement signed in 1986. The four bordering states and the U. S. Environmental Protection Agency worked together to develop a Lake Michigan Toxic Pollutant Control/Reduction Strategy. Many of these actions are currently being implemented.

However, there is much to be accomplished to fully protect the Lake Michigan ecosystem from all sources of degradation. Controlling municipal pollution sources, phosphorous, and nonpoint source pollution are major challenges facing Great Lakes decision-makers. Recognition of what is potentially the greatest problem, toxic pollution, is relatively new. As a result, appropriate control technologies have yet to be identified. The sheer volume of toxic compounds and the variety of pathways of contamination frustrate many attempts to develop solutions.

Indirect sources of pollution also pose a threat to the quality of Lake Michigan water. For example, wastes often enter the lake system through uncontrolled disposal which leaches into the ground water. Contaminated sediments pose several problems due to the resuspension of toxic substances which results from dredging and continual natural recycling of the water column. In addition, all of the Great Lakes are particularly susceptible to airborne pollutants due to their large surface area and proximity to major industrial centers.

Ecological factors, such as the natural or man-induced invasion by non-native species, habitat changes, and random variations in organism populations, must also be recognized for their particular impact on the quality of Lake Michigan. Cost-effective and realistic management can only come through interagency cooperation in utilizing an ecosystem approach to address these concerns on Lake Michigan.

Cooperative action and ecosystem management is vital to protect Lake Michigan and ensure adequate water supplies into the future. However, the challenge of managing Lake Michigan cannot be met solely by government, industry, the scientific community, or the public, but requires cooperation of all four. This group needs to commit itself to addressing critical problems and identifying development opportunities. Michigan will need to continue its leadership role in supporting policies and laws that strengthen regional stewardship. By acting in concert with all concerned groups, Michigan can help to establish a comprehensive water management process that will protect the Great Lakes for present and future generations.

Conservation ethics.--The Lake Michigan sport fishery is generally available to anglers of all age groups and social and economic classes. There are approximately 2 million anglers who currently fish in Michigan, of which 449,000 fish Lake Michigan (Talhelm 1988). Development of the Lake Michigan salmonid program has been termed a resource miracle and the growth of the sport fishery has exceeded all expectations. Assuming growth of this fishery continues along historical trends, it is inconceivable that the Lake Michigan fishery resource will be able to respond proportionally to the future demand of anglers. Increasing fish plants as pressure dictates could work for a while, but this is a very short sighted solution because maximum levels will eventually be reached due to any of a myriad of constraints (e.g., hatchery capacity, forage base availability, carrying capacity of the system), and the demand of anglers will quickly outstrip available surplus. As a consequence, Lake Michigan anglers must become more conscious of, accept, and finally begin to practice new conservation ethics in their sport fishery. If all demands are to be met, future management decisions will need to stress both the art of fishing and the enjoyment of the total fishing experience rather than dwelling on the numbers of fish harvested.

A basic premise of future fishery management should embrace this very concept. The enjoyment of the experience should not be measured in terms of full fish boxes, but rather by the challenge and skill required to catch a particular species in an aesthetically pleasing environment. Current philosophies of both managers and anglers must change to keep pace with the dynamic fisheries in Lake Michigan. This inevitable path into the future, which has already been observed in many fisheries throughout the world, was summarized by Courtland L. Smith (1986), who wrote:

"*Fisheries are viewed as organisms that have a life cycle. The typical life cycle begins with an initial emphasis on food production, next a growing interest in recreation develops, and finally comes aesthetic uses. As commercial productivity and the number of commercial and recreational users increases, conservation requires more stringent management measures. Food production opportunities decline and recreation uses expand. Substituting cultured stocks for natural ones increases the quantity of fish available, but usually the life cycle process continues. To adjust to life cycle and evolutionary changes, management needs to separate conservation decisions from allocation issues, manage to include as much of the stock's range as possible, control effort growth, and keep expectations reasonable.*"

Salmonid Research

The concomitant evolutions of science and technology create new understanding, principles, and techniques required in managing any renewable resource. Fisheries managers have been and always will be dependent on the results of research studies to provide methodology for the successful management of fishery resources. Whether it be determining the effects of specific regulations on a species through computer simulations or the emergence of new technology in measuring more accurately some aspect vital to improving an entire lake community, innovative research is the basis upon which management goals are based. During the current review of the fishery program in Lake Michigan, it has become obvious that there are critical gaps in our knowledge of the salmonid resources and community interactions in Lake Michigan which preclude certainty in our management decisions. Although the data collected has been voluminous, as witnessed by the size of this report, many of the important processes occurring in the lake communities have been neglected.

A major portion of the Great Lakes research program in Michigan has been devoted to monitoring commercial operations targeting on bloater chubs and whitefish, assessing the impacts of commercial netting on lake trout, and monitoring and evaluating the efforts to rehabilitate lake trout stocks. More recently, the 1985 settlement between the State of Michigan and local Indian tribes required a monumental effort by Great Lakes biologists. With this settlement has come the additional task of supplying catch and effort statistics from the state's commercial and sport fisheries to the federal and tribal biologists in a cooperative effort to determine annual total allowable catches for specific areas in Lake Michigan. However, the time has come to shift the research programs away from the traditional commercial interests and lake trout rehabilitation efforts. Because it is the policy of the MDNR to manage the sport fisheries for maximum public benefit, it is now mandatory to set a new direction for research that focuses on the valuable salmonid stocks prized by anglers who are paying for the management of the fishery resources.

Biology

Very little is known about the biology of salmonids inhabiting Lake Michigan. Although a large amount of data have been collected on growth and sport harvest through the MDNR's Great Lakes creel survey, most of the remaining aspects of salmonid lake life have not been studied. Future research should be aimed at the following categories.

1) *If stocking levels are to be adjusted such that predator-prey interactions are balanced, then the contribution of natural reproduction by each salmonid species must be determined. This knowledge may also allow for reduced hatchery production in the future. Wild recruitment can only be estimated through the use of a large-scale marking program in which all agencies planting a particular species become active participants.*

2) *Annual acoustic surveys to estimate the available forage biomass are desperately needed to make further (real time) refinements in stocking levels of predators. Maintenance of the predator-prey balance in Lake Michigan is inherent to the success of the sport fishery into the future.*

3) *Critical early life stages must be studied for each of the salmonid species. Factors affecting the survival and growth of smolts must be analyzed to predict and improve the surplus of fish available to anglers. It is also necessary to determine stock-recruitment relationships (for species dependent upon natural reproduction) to improve models that could be used in estimating standing stocks and to predict the effects of specific regulations on the fishery.*

4) *If the effects of predator levels on the forage base are to be used in management criteria, food habits of all species during various life stages, seasons, and throughout the Lake Michigan basin must be understood. This knowledge is also critical in determining the forage preference of specific salmonids, and whether or not salmonids will switch to other species if the abundance of a preferred prey is limited.*

5) *Assessment of hatchery practices, from egg-take to the planting of smolts, should be undertaken to ensure the availability of the highest quality product possible. This entails a wide array of research projects including the possible effects of timing on egg-take operations and genetic selection, a quality control program to monitor parameters affecting young fish during their hatchery life, the effects of different diets on the survival and growth of fish during both hatchery life and after planting (smolting) occurs, the determination of appropriate stocking size to achieve the highest survival for each species, and the development of new strains to succeed existing ones, to fill niches currently uninhabited, or to create new fisheries. The knowledge gained will continue the success of hatchery managers in producing new generations of salmonids.*

6) *The necessary data for estimating fishing and natural mortality must be collected and used in developing population dynamics models. At a minimum, fishing mortality should include quantitative estimates of hooking deaths, and sea lamprey effects should be treated as a separate component of natural mortality. The models will allow managers to determine and implement the best technique for solving specific fishery problems. Such data are especially important in estimating the impact of new fisheries (e.g., the offshore fishery for rainbow (steelhead) trout) on current stocks.*

7) *More precise methods of aging fish are necessary to assess long-term trends in growth rates. Such trends will be useful as indicators of stress due to low forage availability or other environmental causes. Accurate estimations of current growth rates are also important components in the management models.*

8) *The spatial and temporal distribution of the various salmonid stocks, along with seasonal movement patterns, are required to fine tune stocking locations, classify individual stocks, and determine the number of fish harvested in the originating and other state's waters.*

9) *The monitoring of new exotics must be undertaken as they are introduced into the lake community. Their distribution and effects on both species composition and interactions must be watched closely by managers. This will allow remedial measures to be utilized which would hopefully prevent deleterious changes to the ecosystem.*

Ecology

An understanding of the ecological aspects of the fish communities in Lake Michigan is also paramount to the successful management of the resource. For example, habitat quality and preference, predator-prey interactions, inter- and intra-specific competition, and stock identification are all necessary if the future viability of the lake ecosystem is to be maintained. The following studies need to be implemented on Lake Michigan.

1) *Further refinement of the predator-prey interactions occurring in the lake is required to determine appropriate stocking levels of salmonids. This will also allow continued assessment of the impact of predators on specific forage species through the use of bioenergetics models.*

2) *The effects of inter- and intra-specific competition on both salmonid and forage species during critical life stages should be studied. This information is vital to fishery managers, especially in light of newly introduced species that might have drastic impacts on the current structure and balance of the lake ecosystem.*

3) *Environmental quality should be monitored and improved whenever possible for the benefit of both salmonid and forage species inhabiting Lake Michigan. Also, habitat preferences for these species need to be clearly defined in conjunction with the predatory and competitive interactions observed within the system. Since these interactions can only occur when species have overlapping spatial distributions and, in the case of competition, the added constraint that some resource is limiting, a description of the niches utilized by each species is essential to understanding predatory and competitive relationships.*

4) *Identification of individual stocks should be determined for those species that have significant natural recruitment. This would allow more clearly defined management decisions to be made based on the dynamics of the individual stocks and their relationships with other stocks. Both marking and electrophoretic studies should be implemented to obtain this information.*

Economics

It is very important for managers to know and understand the social and economic aspects of the people they serve. Management proposals can often have profound economic impacts on individuals or communities which must be taken into account at some time during the decision making process. Although major efforts have been implemented to determine the economic impact of the Lake Michigan fisheries, more research is required to complete the picture. The effects of the charter industry, commercial operations, and the sport fishery on the Michigan economy need to be calculated so that managers have another criterion upon which to base their decisions. Methodologies should be developed that would allow defined economic indicators to be updated on a regular basis, thus giving managers some idea of the possible effects new decisions might have on the specific clientele involved.

Implementation

It is obvious that a tremendous amount of research is required before answers can be given to so many of the questions posed by both managers and user groups. The assurance of stable salmonid stocks and a high quality sport fishery in Lake Michigan for future generations is predicated upon knowledgeable management today. This can not occur until priorities are restructured in such a way that the major thrust of the research effort focuses upon salmonid stocks important to the sport fishery. The common stock concept and the complex interactions between species inhabiting Lake Michigan require that future research studies be developed which incorporate the idea of treating the lake as a single community. This in turn necessitates full cooperation and coordination of research and management efforts and goals between the four states bordering the lake. University, federal, and private participation in implementing many of these proposals will be needed to accomplish the goals outlined above. This is especially true for those studies dealing with the estimation of natural reproduction, large scale movements, survival, diet preferences, forage biomass estimates, and predator-prey interactions.

Various components of these research proposals are intertwined, although specific categories have been distinguished for the purpose of this discussion. Most of the pertinent information needed to manage the salmonid stocks at this time could be obtained through a large scale marking program and an annual acoustic survey of the forage biomass. Therefore, cooperative efforts in the near future should give highest priority to establishing and deploying these two projects.

The cost of this program inevitably will be very high. Because of the sheer size of Lake Michigan, expenditures just for the purchase and maintenance of the equipment required to collect these data will be immense. However, this fact alone should not prevent management agencies from pursuing these goals. The proposal to implement research that is coordinated between the states, universities, and federal agencies, along with the private sector, will reduce the overall costs to individual groups by deleting duplication of both effort and equipment purchases. New priorities must be set and new funds allocated for the express purpose of attaining the knowledge necessary for sound management of the Lake Michigan fishery resource far into the future. To fail in this endeavor is inconceivable. Success must be guaranteed, the reward being the realization that following generations will be able to enjoy the quality fishing which has been available for the past 20 years.

Management Recommendations

The Lake Michigan sport fishery for chinook salmon in 1987 was atypically poor, a condition which has prompted this review of current fishery programs on Lake Michigan. This charge was assigned to a Task Force of Fisheries Division personnel and representatives from major user groups. The goals of this Task Force are 1) to consolidate the voluminous information available on Lake Michigan's fisheries and fish stocks, and 2) to present management and research recommendations designed to reestablish the quality of the fishery enjoyed in bygone years.

In all likelihood, the Lake Michigan sport fishery is now on the threshold of the aesthetic age. Therefore, it has become evident that in order to maintain the quality fishery to which we have become accustomed, changes in our management plans, including some reductions in catch limits, are necessary to achieve equitable allocation of the Lake Michigan fishery resource. The following recommendations for future management of the Lake Michigan fishery resource are based on the idea that stocks are interjurisdictional and, therefore, should be managed within the context of the entire ecosystem to maximize public benefit.

1) *Establish uniform management goals for salmonid stocks between the states.*

2) *Establish uniform sport and commercial fishery regulations between the states.*

3) *Implement a "Joint Strategic Plan" between the states for the management of salmonid stocks which includes the following criteria.*

   a) *Consensus decisions.*

   b) *Accountability performance.*

   c) *Environmental management.*

   d) *Information exchange.*

4) *Manage alewife, bloater chub, smelt, and sculpin populations as the principle food source of salmonid stocks.*

5) Seek opportunities to expand annual lake-wide salmonid stocking.

a) Adjust stocking levels to maximize predator usage of available forage species based on the biological and ecological constraints of the predator-prey interactions within the lake.

b) Establish rigorous hatchery practices and procedures to guarantee future product quality.

c) Seek cooperative long-term goals for planting salmonids in Lake Michigan with the other state agencies.

d) Maintain close scrutiny on the predator-prey dynamics within the lake and commit to improved evaluation methods lake wide in conjunction with the other state agencies.

6) Develop a new cooperative lake trout policy.

Short range goals:

a) Extend the lake trout season to Labor Day (May 1 to Labor Day; 2 fish limit) to be compatible with Wisconsin.

b) Continue the experiment of self-sustainability on a reduced scale.

c) Include lake trout in the total salmonid sport fishery plan.

Long range goals:

a) Pursue and achieve the goal of self-sustainable lake trout stocks throughout Lake Michigan.

b) If necessary, implement stocking of state-raised lake trout to maintain the salmonid species mix in the sport fishery.

c) Reduce the demands on hatchery facilities in rearing and maintaining broodstocks by obtaining eggs from fish that have demonstrated their capability to survive the rigors of lake life. The broodstock program for lake trout should be de-emphasized and replaced by collecting eggs directly from spawning stocks in the lake.

d) If and when state fish are raised and planted for a sport fishery, increase the daily catch or possession limit from 2 to 3 fish (lake or stream), with a year- round open season.

7) Reduce indiscriminate losses of salmonid stocks to enhance sportfishing opportunities.

a) Increase enforcement of regulations.

b) Remove damaging commercial gears under state jurisdiction from salmonid waters.

c) Pursue recovery of all losses incurred from industrial or other activities which are detrimental to salmonid stock health.

8) Sea lamprey control.

a) The current level of funding for sea lamprey control on Lake Michigan should be expanded to ensure continued low levels of lamprey populations in the lake.

b) New technology for controlling lamprey should be a top priority in sea lamprey research. Major emphasis should be centered on obtaining natural or biological controls rather than chemical. Research funding and capabilities should be increased and improved to implement the required studies.

9) Cooperative action and ecosystem management are vital to protecting Lake Michigan's natural resources, improving water quality, and ensuring adequate water supplies into the future.

10) If the continuation of state-licensed commercial fisheries on species other than valuable sport or designated forage fishes is desirable, it is mandatory to employ gear which minimizes losses of non-target stocks. The industry must apply new technology and ingenuity in developing this gear.

11) Charter industry.

a) The need for discontinuing the open-access policy on licensing charter fishing operations and creating a limited entry policy will be determined through future studies of the industry and its impact on salmonid withdrawals. A ceiling on the number of charter licenses will be established based on the findings of this research.

b) The charter catch limit on any trip should be restricted to only that of customers. Captain and mate rods may be used to achieve this limit.

c) Mandatory reporting of catch-by-species and effort data should be instituted as soon as possible.

12) Tournament angling events should encourage conservation ethics by establishing rules that minimize killing of salmonids.

13) Implement aquatic resource education programs and promote conservation ethics.

14) Implement the proposed Salmonid Research Plan cooperatively between bordering management agencies, universities, federal agencies, and the private sector.

15) Salmonid sportfishing regulations on Lake Michigan and tributary streams should comply with the 1988 Michigan Fishing Guide restrictions on hook and line angling with the following changes.

Short range goals (1989):

a) On Lake Michigan and its connecting waters, the size limit for trout and salmon shall be 10 inches and the possession limit shall be 5 fish singly or in combination but no more than 3 of any one species except pink salmon, nor more than 2 lake trout or splake.

b) On Lake Michigan streams from the last Saturday in April to September 30, the size limit on trout and salmon shall be 7 inches in the Upper Peninsula and 8 inches in the Lower Peninsula and the possession limit shall be 10 in any combination but no more than 3 over 16 inches unless they are pink salmon. At all other times of the year on streams open to extended trout and salmon fishing, the size limit shall be 16 inches and the possession limit shall be 3 trout or salmon in any combination.

c) The seasonal restriction on harvest of lake trout and splake shall be May 1 through Labor Day.

Short range goals (1990):

a) On Lake Michigan and its connecting waters, the size limit for trout and salmon should be 10 inches and the possession limit should be 3 fish singly or in combination for any species except pink salmon, and no more than 2 lake trout or splake.

b) On Lake Michigan streams from the last Saturday in April to September 30, the size limit on trout and salmon should be 7 inches in the Upper Peninsula and 8 inches in the Lower Peninsula and the possession limit should be 10 in any combination but no more than 3 over 16 inches unless they are pink salmon. At all other times of the year on streams open to extended trout and salmon fishing, the size limit should be 16 inches and the possession limit should be 3 trout or salmon in any combination.

c) The seasonal restriction on harvest of lake trout and splake should be May 1 through Labor Day.

Long range goals:

a) The 1988 sportfishing regulations on daily catch or possession limit for salmonids on Lake Michigan and its tributaries with extended trout and salmon seasons should be reinstituted for any species when catch rates and abundance levels warrant such action.

b) The seasonal restriction on harvest of lake trout and splake should be discontinued with the daily catch and possession limit raised to 3 fish (lake or stream).

c) Endorse and commit to the termination of legalized snagging in all waters of the State of Michigan.

Summary

The inland and Great Lakes fisheries in Michigan support economic activity of approximately 2 billion dollars annually (D. Jester, Jr., MDNR, personal communication). The MDNR spends about 22.5 million dollars per year on fisheries programs, the bulk of which is generated through the sales of sportfishing licenses. This gives a benefit to cost ratio of about 89:1. However, many state businesses profit from the available fishery resources (e.g., food, gas, commodities, real estate, lodging, and rentals, to name a few) but pay no direct fees to help support the program. The proposals recommended in this review, which are needed to enhance the quality of the Lake Michigan salmonid fishery, will require a stronger commitment to management and research. The present level of funding for fisheries programs in the state is not adequate to fulfill these goals, and implementation of the strategies is dependent upon the generation of new monies. Fishery managers' skills are directly proportional to the quality and quantity of their resources.

This review should start a new era during which the future philosophies and methodologies used to manage Lake Michigan will be redirected and committed to enhancing the salmonid resources so important to our quality of life. Implementation of the proposals herein for Lake Michigan is expected to have initial impacts on the other Great Lakes surrounding Michigan. But each lake is a separate entity with its own unique ecosystem and should be managed as such. Although cooperation between jurisdictions is mandatory to making new management decisions and regulations within each lake, it is also highly desirable for Michigan to maintain as much uniformity in regulations as possible between the Great Lakes.

The questions and managerial challenges proposed within this report should provide the impetus for bordering states to cooperatively initiate a long range management plan. This report is by no means the final word on salmonid management, but should act as a springboard to launch us in the new direction needed to protect and enhance this valuable resource far into the future.

"What's best for the fish is best for the fishers"

Keller, 1987

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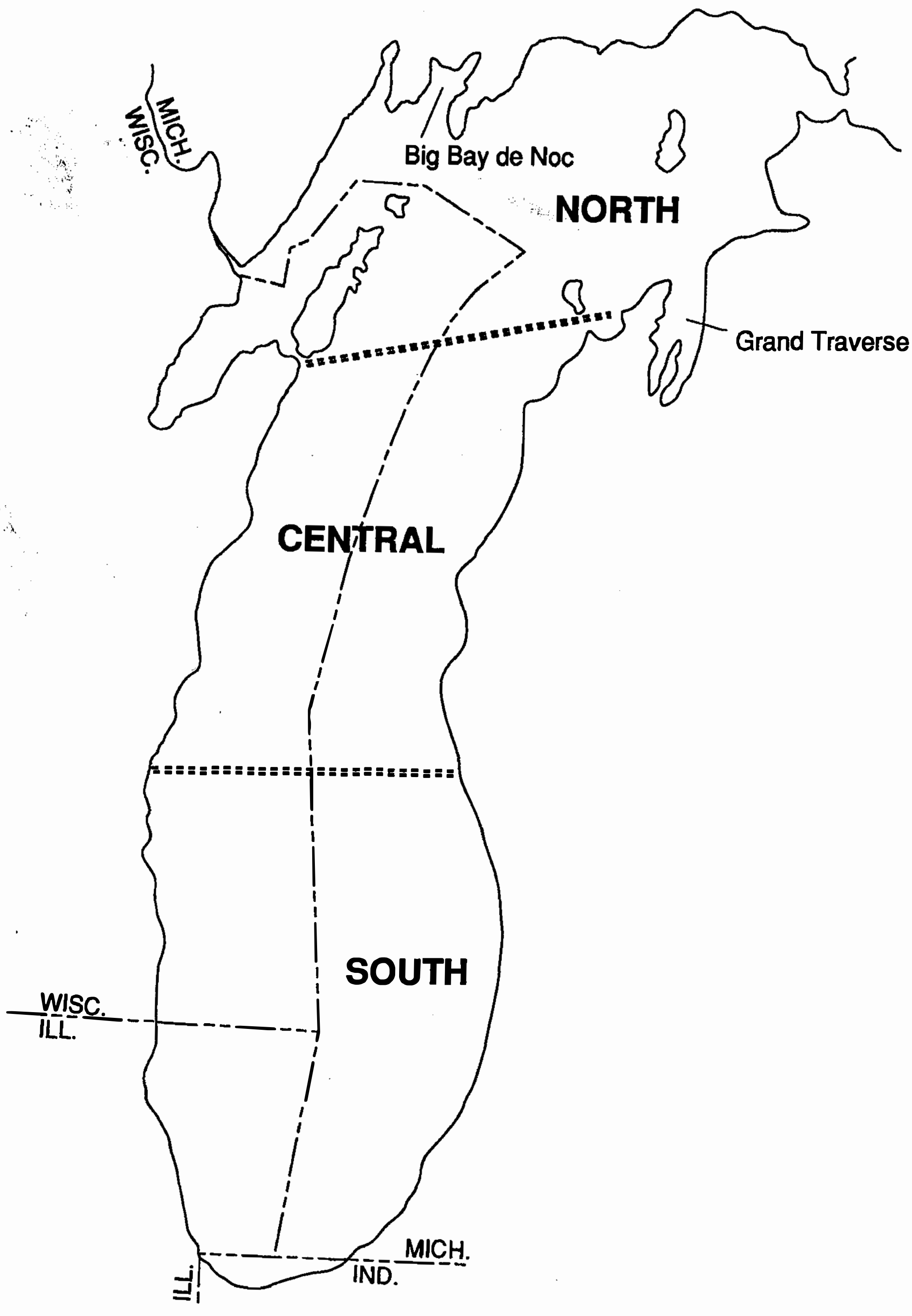
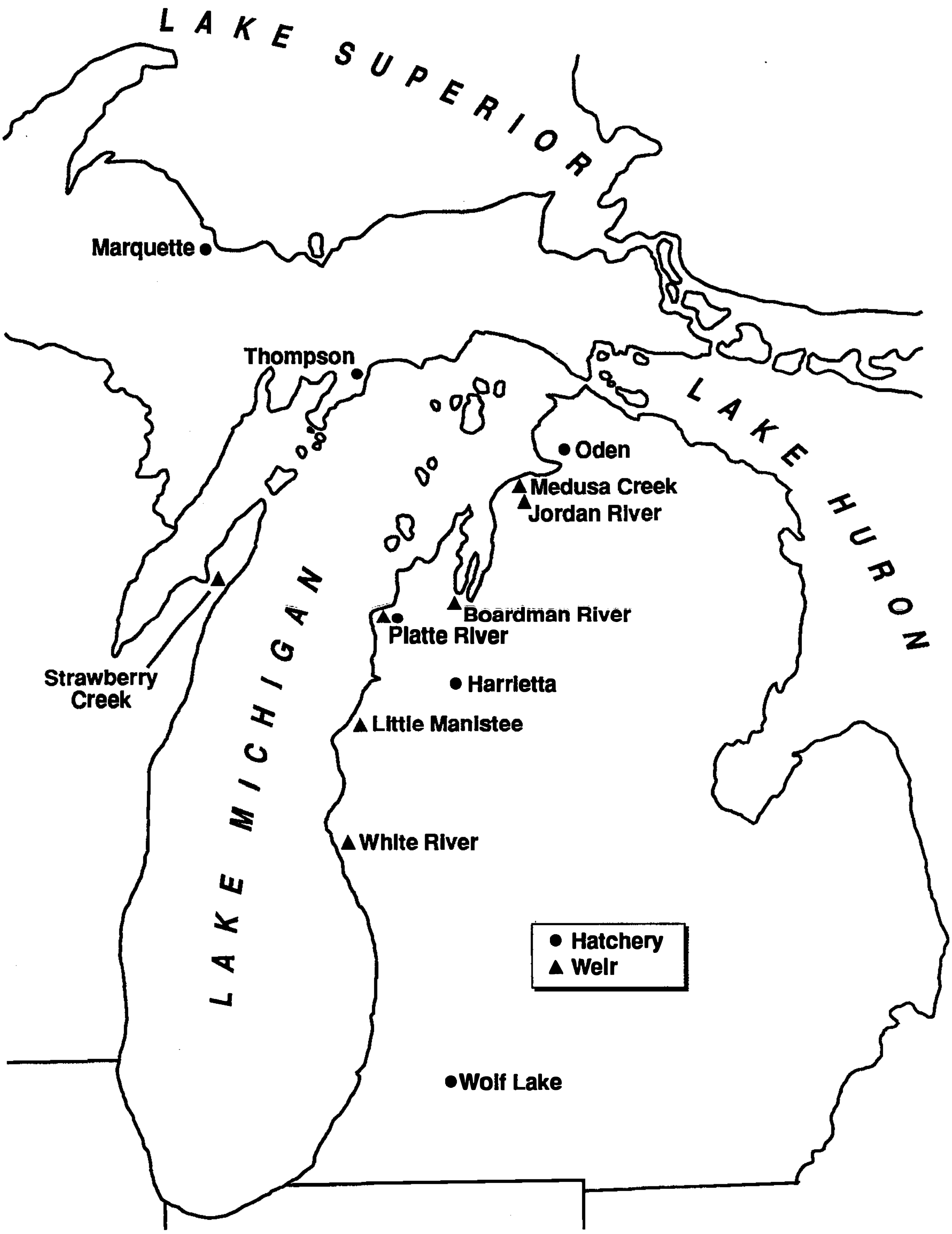
APPENDICES

Appendix A. Common and scientific names of Lake Michigan fish species including extinctions and introductions.

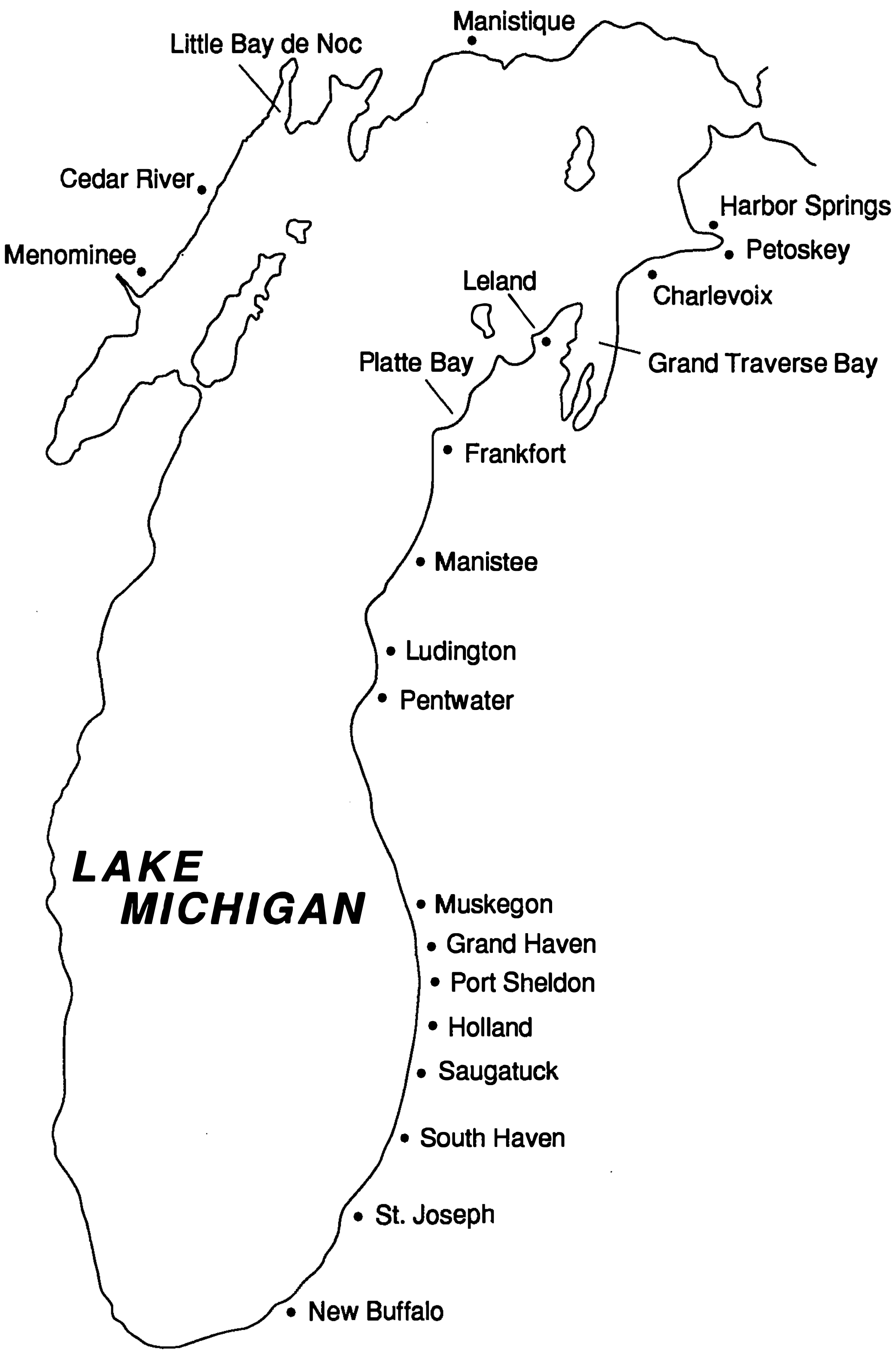
Common name	Scientific name
Lake sturgeon	*Acipenser fulvescens*
Alewife	*Alosa pseudoharengus*
Freshwater drum	*Aplodinotus grunniens*
Longnose sucker	*Catostomus catostomus*
White sucker	*Catostomus commersoni*
Longjaw cisco	*Coregonus alpenae*
Lake herring	*Coregonus artedii*
Lake whitefish	*Coregonus clupeaformis*
Bloater	*Coregonus hoyi*
Deepwater cisco	*Coregonus johannae*
Kiyi	*Coregonus kiyi*
Blackfin cisco	*Coregonus nigripinnis*
Shortnose cisco	*Coregonus reighardi*
Shortjaw cisco	*Coregonus zenithicus*
Slimy sculpin	*Cottus cognatus*
Spoonhead sculpin	*Cottus ricei*
Carp	*Cyprinus carpio*
Northern pike	*Esox lucius*
Johnny darter	*Etheostoma nigrum*
Threespine stickleback	*Gasterosteus aculeatus*
Channel catfish	*Ictalurus punctatus*
Bullheads	*Ictalurus* spp.
Burbot	*Lota lota*
Smallmouth bass	*Micropterus dolomieui*
Deepwater sculpin	*Myoxocephalus thompsoni*
Emerald shiner	*Notropis atherinoides*
Spottail shiner	*Notropis hudsonius*
Pink salmon	*Oncorhynchus gorbuscha*
Coho salmon	*Oncorhynchus kisutch*
Rainbow (steelhead) trout	*Oncorhynchus mykiss* (formerly *Salmo gairdneri*)
Chinook salmon	*Oncorhynchus tshawytscha*
Rainbow smelt	*Osmerus mordax*
Yellow perch	*Perca flavescens*
Trout-perch	*Percopsis omiscomaycus*
Sea lamprey	*Petromyzon marinus*
Round whitefish	*Prosopium cylindraceum*
Ninespine stickleback	*Pungitius pungitius*
Atlantic salmon (ouananiche)	*Salmo salar*
Brown trout	*Salmo trutta*
Brook trout	*Salvelinus fontinalis*
Lake trout	*Salvelinus namaycush*
Splake	*Salvelinus namaycush x Salvelinus fontinalis*
Walleye	*Stizostedion vitreum vitreum*



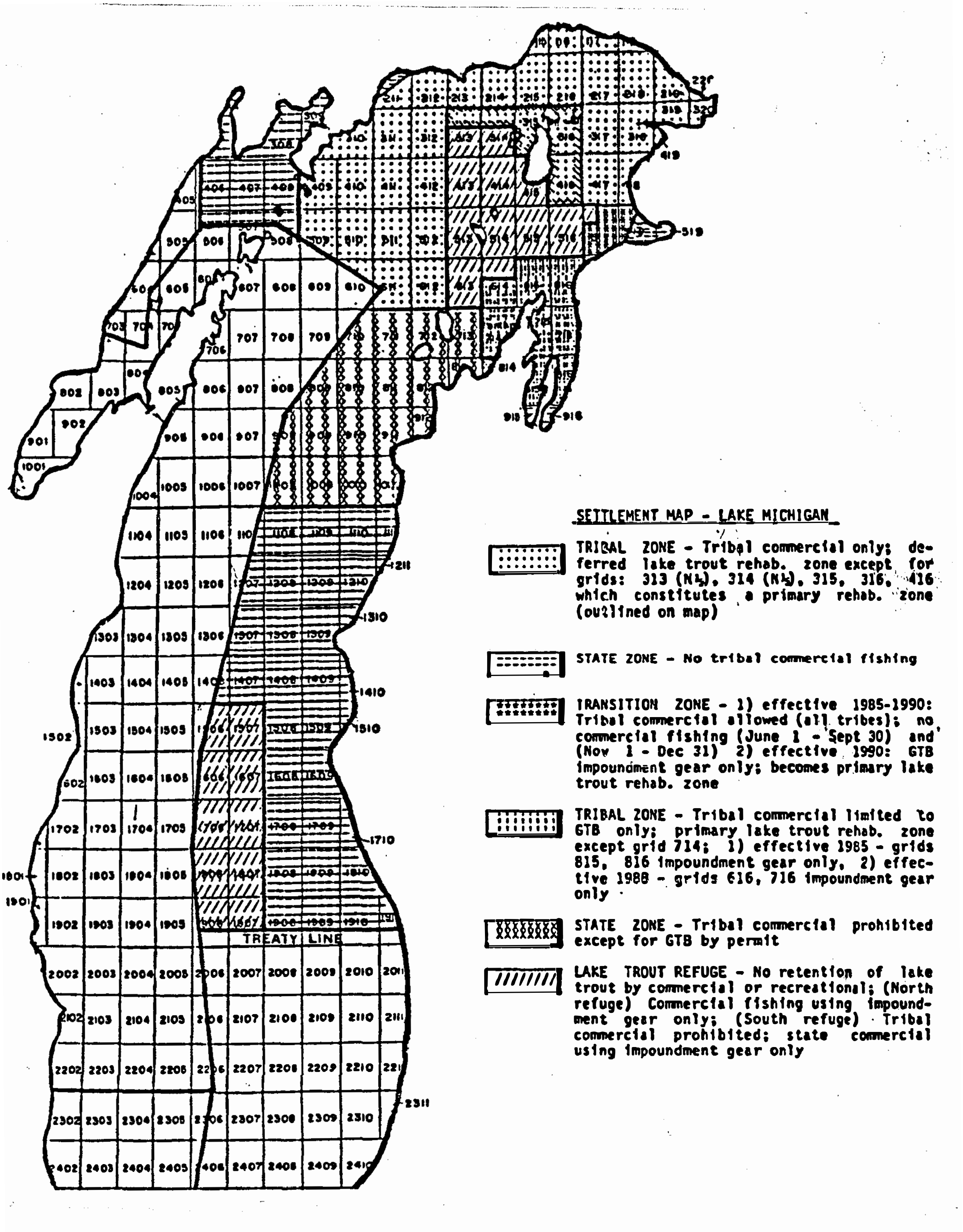
Appendix B-1. State boundaries in Lake Michigan and zone designations used in this report.



Appendix B-2. Hatchery and weir locations.



Appendix B-3. Ports on Lake Michigan sampled in the State of Michigan's creel survey.



Appendix B-4. Lake trout refuge areas and tribal commercial fishing waters as determined in the 1985 negotiated settlement.

Appendix C-1. Size limits for commercial fisheries operating in Lake Michigan for the 1988 fishing season.

Species	Michigan	Wisconsin	Illinois	Indiana[1]	Tribal[2]
Lake trout; siscowet	Not to be taken at any time	Not to be taken at any time	Not to be taken at any time	Not to be taken at any time	17"
Coho, chinook salmon	Not to be taken at any time	Not to be taken at any time	Not to be taken at any time	Not to be taken at any time	No size limit
Lake sturgeon; muskellunge; brown, brook, rainbow (steelhead) trout; Atlantic salmon largemouth, smallmouth bass; northern pike	Not to be taken at any time	Northern pike 20" All others not to be taken at any time	Not to be taken at any time	Not to be taken at any time	Not to be taken at any time
Walleye	Not to be taken at any time	Not to be taken at any time	Not to be taken at any time	Not to be taken at any time	15"
Yellow perch	Not to be taken at any time	8" northern Green Bay 7.5" southern Green Bay	No size limit	8"	8"
Whitefish	17" licensed; 19" by permit	17"	Not to be taken at any time	18"	17"
Chubs	No size limit	Not to be taken any time in Green Bay No size limit elsewhere	No size limit	Not to be taken at any time	No size limit
Catfish	15"	16"	15"	10"	No size limit
Alewives; bullheads; burbot; gizzard shad; menominees; smelt; suckers; white bass	No size limit	No size limit	No size limit on bullheads, smelt, and suckers All others not to be taken at any time	White bass not to be taken at any time No size limit on all others	No size limit

Appendix C-1. Continued:

Species	Michigan	Wisconsin	Illinois	Indiana[1]	Tribal[2]
Others	No size limit on carp, sheepshead, and buffalofish All others not to be taken at any time	Carp by permit only All others not to be taken at any time	No size limit on carp, sheepshead, buffalofish, bowfin, American eel, mooneye, goldeye, carp-suckers, gar (except alligator gar) All others not to be taken at any time	Chain pickerel, tiger muskellunge, yellow bass, striped bass, hybrid striped bass, sauger, saugeye, spotted bass, bluegill, rock bass, redear sunfish, crappie, American eel, paddlefish, and lake herring not to be taken at any time No size limit on all others	No size limit

[1]Changes in Indiana regulations are pending.

[2]Size limits for subsistence fishing are set by each individual tribe.

Appendix C-2. Gear and quota restrictions for commercial fishery operations in Michigan, Wisconsin, Illinois, Indiana, and Tribal waters of Lake Michigan.

Michigan

Trap nets and pound nets may be used in depths less than 15 fathoms in Lake Michigan January through October and during December, except trap nets and pound nets may be used only for taking smelt and alewives January through May in waters north of a line extending from the mouth of the Ford River in Sections 21 and 22, T 38 N, R 23 W, to Peninsula Point in Section 24, T 38 N, R 21 W, Delta County.

Gill nets with meshes 2 1/2 inches to 3 inches, stretched measure, may be used in depths greater than 40 fathoms north of a line extending due west from Grand Haven Harbor; and in depths greater than 30 fathoms south of a line extending due west from Grand Haven Harbor only at such times as to coincide with an open season on chub established by the natural resources commission.

Quotas are established annually for all chub and whitefish operations by area.

Wisconsin

Gill nets

1. With a mesh size of not more than 1 3/4 inch stretched measure for taking smelt only.
2. With a mesh size of not less than 2 3/8 inch and not more than 2 1/2 inch stretch measure in southern Green Bay only.
3. With a mesh size of less than 2 1/2 inch stretched measure may not exceed 30 meshes in depth in Lake Michigan after July 1, 1988.
4. With a mesh size of not less than 2 1/2 inch and more than 2 3/4 inch stretched measure:
    a. For chubs in Lake Michigan, in the northern and southern chub fishing zones only.
    b. For other legal fish species in Lake Michigan and Green Bay.
    c. May not exceed 18 meshes in depth when set in waters less than 150 feet (25 fathoms) deep in Lake Michigan outside the northern chub fishing zone after July 1, 1988.
    d. May not exceed 60 meshes in depth when set in waters 150 feet (25 fathoms) deep or deeper or within the northern chub fishing zone.

5. With a mesh size of 2 3/4 inch or less stretched measure may not exceed 60 meshes in depth in Lake Michigan through June 30, 1988, and in Green Bay.

6. With a mesh size of not less than 4 inches and not more than 4 1/2 inch stretched measure:

   a. Only in southern Green Bay in water less than 30 feet (5 fathoms) deep.

   b. Only for taking rough fish and northern pike.

   c. From May 20 to March 9, except during the closed season for whitefish.

   d. Not more than 30 meshes in depth.

7. With a mesh size of not less than 4 1/2 inch and not more than 6 1/2 inch stretched measure:

   a. In those waters of Lake Michigan lying north of a line extending from the mid-channel marker buoy of Bailey's Harbor on 135° bearing.

   b. In Green Bay.

   c. Only during the open season for whitefish.

   d. May not exceed 30 meshes in depth for one-half of the total length of these nets set at any time by a licensed commercial fisher, and the remaining half may not exceed 50 meshes in depth.

8. With a mesh size of not less than 6 1/2 inch stretched measure:

   a. Only for taking rough fish.

   b. Only during the open seasons for whitefish and yellow perch.

   c. Not more than 12 meshes in depth.

9. With a mesh size of 4 inches or larger stretched measure, not to exceed 12,000 feet may be used by each licensed commercial fisher at any one time.

10. Shall be lifted a minimum of:

    a. Once every 24 hours (1 day) in open water less than 150 feet (25 fathoms) deep for mesh sizes larger than 2 3/4-inch stretched measure in Lake Michigan and for all mesh sizes in Green Bay.

    b. Once every 120 hours (5 days) in open water 150 feet (25 fathoms) deep or deeper for mesh sizes of not more than 2 3/4-inch stretched measure in Lake Michigan.

    c. Once every 48 hours (2 days) in commercial ice fishing.

Entrapping nets

1. Drop nets and fyke nets:

   a. Only during the open season for yellow perch, except by permit issued under s.NR25.10 (4).

   b. May be used up to 30 drop nets of fyke nets in aggregate by each licensed commercial fisher, that being the maximum number of pots allowed.

   c. Shall be lifted a minimum of once every 72 hours (3 days).

2. Pound nets and trap nets:

   a. Only when the pot or crib is set, placed or operated in water not more than 78 feet (13 fathoms) deep.

   b. May be used up to 12 pound nets or trap nets in aggregate by each licensed commercial fisher, that being the maximum number of pots or cribs allowed.

   c. Shall be lifted a minimum of once every 120 hours (5 days).

   d. Shall be removed from the water or shall have the fish holding or pot portion rendered inoperable during the closed season for whitefish.

Seines

1. With a mesh size of not less than 3-inch stretched measure.

2. Not less than 75 feet in length.

Trawls

1. In southern Green Bay:

   a. Only for taking fish species for which there is no minimum size limit, and which are legal in other commercial fishing gear.

   b. Only in water more than 24 feet (4 fathoms) deep.

   c. Only north of a line from the southernmost point of Little Tail Point to the Green Bay navigation channel entrance light.

2. In Lake Michigan:

   a. Only in waters 60 feet (10 fathoms) deep or deeper bounded by a line beginning at a point where 44° 30' north latitude intersects with the Wisconsin shore of Lake Michigan, then proceeding east along 44° 30' north latitude, to its intersection with

87° 10' west longitude, then proceeding south along 87° 10' west longitude to its intersection with 44° 10' north latitude then proceeding west along 44° 10' north latitude to its intersection with 87° 20' west longitude, then proceeding south along 87° 20'west longitude to its intersection with 43° 50' north latitude, then proceeding west along 43° 50' north latitude to its intersection with 87° 40' west longitude, then proceeding north along 87° 40' west longitude to its intersection with 44° 00' north latitude, then proceeding west along 44° 00' north latitude to the Wisconsin shore of Lake Michigan and then north along the shore to the point of beginning. This area can also be described as all of grids 1105, 1205, 1304, 1403, 1404, and parts of grids 1104, 1204, and 1303.

b. Only for taking forage fish as provided in s.NR 25.06(2)(c) except:

   1) Whitefish which exceed the size limit described in s.NR 25.05(2) may be taken during the open season for whitefish described in s.NR 25.05(1) provided they amount to no more than 1.5% by weight of the boat's total daily catch.

Quotas are established annually for all chub, yellow perch, whitefish, and forage fish operations by area.

Illinois

Licensed commercial fishermen may take bloater chub and yellow perch in Lake Michigan only with gill nets that have meshes of not more than 2 3/4-inch diagonal stretched measurement nor less than 2 3/8-inch diagonal stretched measurement. All gill nets used to take such fish in waters of 20 fathoms (120 feet) or less in depth shall not have a vertical width of more than twenty (20) meshes.

Quotas are established annually for all chub and yellow perch operations by area.

Indiana

1. It is unlawful to fish at any time a total of more than twenty thousand (20,000) feet of gill net.

2. It is unlawful to take fish with gill nets having stretched mesh larger than two and three-quarters (2 3/4) inches or smaller than two and one-quarter (2 1/4) inches.

3. It is unlawful to use gill nets having a vertical width of more than twenty-four (24) meshes deep to take fish.

4. It is unlawful to set a gill net in water less than twenty-five (25) feet deep; less than one-half (1/2) mile from any pier, harbor, public beach, or boat launching ramp or the Michigan City reef located approximately 3,000 feet offshore and 11,000 feet northeasterly from the harbor lighthouse at Michigan City, LaPorte County, N 41° 44' 79" and W 86° 52' 61"; or less than one (1) mile from the mouth of Black ditch, Burns ditch, the detached breakwater near the mouth of Trail Creek.

Special fishing permits may be issued by the director of the division under this section as follows:

1. A temporary or annual permit may be issued to take fish with a mesh size as determined by the director of the division.

2. A temporary or annual permit may be issued to take fish in an otter trawl, a mid-water trawl or another trawl.

3. A temporary or annual permit may be issued to take fish in stationary impoundment nets.

Effective January 1, 1989, it will be unlawful to take fish with gill nets.

No quotas are established for any operations for any species.

Tribal

Commercial Gear Restrictions

The following are permitted gears for tribal commercial fishing activity, except as otherwise restricted by these regulations:

1) Large-mesh gill nets (having a stretched measure of 4 1/2 inches or greater), and

2) small-mesh gill nets (having a stretched measure of 2 1/2 through 3 inches), and

3) impoundment gear (e.g., trap, pound, fyke, and hoop nets), and

4) seines, and

5) hooks.

Use of any other gear, mesh size, or method of capturing fish by commercial fishers is prohibited unless authorized by the Management Authority.

Quotas (total allowable catch (TAC)) are established annually by operation and area.

Subsistence Fishing Activity

The following fishing gears shall be permitted in all subsistence fishing activity:

1) A single large or small-mesh gill net, as defined in Section 2 0 and 2 P of these regulations, not to exceed 300 feet in length, except that in the St. Marys River system (as defined in Section 7.4 A of these regulations) a single gill net shall not exceed 100 feet in length; the tying together of single gill nets to form a gang of nets is prohibited, and

2) impoundment gear as defined in Section 2 Q, and

3) hooks, and

4) spears, and

5) other gears as authorized by the tribes.

Quota is established at a 100 pound possession limit based on combined weight of all species.

Appendix D-1. 1987 sportfishing regulations on Lake Michigan by state for lake trout.

Regulation	Michigan	Indiana	Illinois	Wisconsin
Season	May 1 to August 15 EXCEPT no open season in the northern or southern lake trout refuges	All year	All year	May 1 to Labor Day EXCEPT closed all year between Sturgeon Bay and Algoma
Size limit	10 inches	10 inches	10 inches	10 inches
Creel limit (daily)	No more than 2 lake trout or splake in a combination of 5 trout or salmon	No more than 2 lake trout in an aggregate of 5 trout or salmon	Not more than 3 lake trout in a collection of 5 trout or salmon	5 in total of trout or salmon, only 2 may be lake trout
Gear	No more than 2 lines nor more than 4 hooks or baits may be used	3 lines but not more than 2 single hooks, artificial baits, or harnesses for live bait on each line	Trolling - not more than 3 poles and lines with not more than 2 hooks or lures on each line	Each angler may fish with a total of 3 baits, lures, or hooks

Appendix D-2. 1987 sportfishing regulations on Lake Michigan by state for chinook salmon, coho salmon, rainbow (steelhead) trout, brown trout, pink salmon, Atlantic salmon, brook trout, and splake.

Regulation	Michigan	Indiana	Illinois	Wisconsin
Season	All year	All year[1]	All year	All year
Size limit	10 inches	10 inches[1]	10 inches	10 inches
Creel limit (daily)	5 in any combination with other trout or salmon, but no more than 2 lake trout or splake	5 singly or in aggregate with other trout or salmon, of which not more than 2 can be lake trout	5 trout or salmon singly or collectively, not more than 3 of which may be lake trout	5 in total of trout or salmon, only 2 may be lake trout
Gear	No more than 2 lines nor more than 4 hooks or baits may be used harnesses for live	3 lines but not more than 2 single hooks, artificial baits, or than 2 hooks or lures bait on each line	Trolling - not more than 3 poles and lines with not more on each line	Each angler may fish with a total of 3 baits, lures, or hooks

[1]Brook trout and splake are not specifically mentioned as regulated sport fish in Indiana waters of Lake Michigan.