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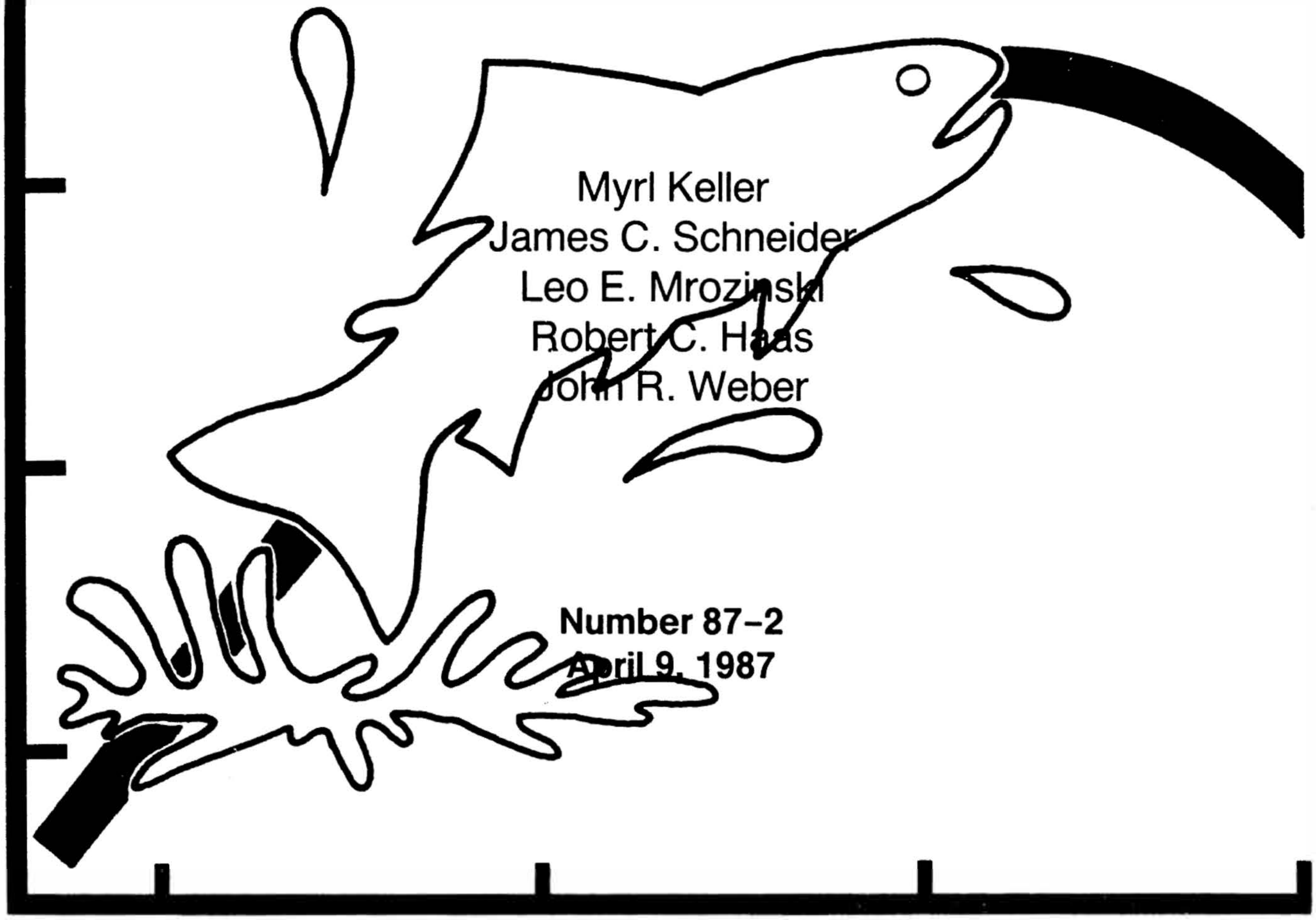
FISHERIES DIVISION

TECHNICAL REPORT

History, Status, and Management of Fishes in Saginaw Bay, Lake Huron, 1891-1986



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Michigan Department of
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ABSTRACT

The fish community in Saginaw Bay has changed radically over the past 150 years. The lake sturgeon became virtually extinct in the early 1900s and important lake trout, whitefish, walleye, and herring populations collapsed by the mid-1950s. Uninvited guests were smelt, sea lamprey, alewife, and most recently, white perch. Premeditated introductions of rainbow and brown trout, coho and chinook salmon, and the reintroduction of lake trout have resulted in a new species complex in outer Saginaw Bay. The walleye has been reestablished by stocking.

Commercial fisheries, established in the Saginaw Bay area in the 1830s, reached peak commercial production in 1902 at 14.2 million pounds, then declined to about 2 million pounds in 1986. The Bay's fish community and commercial catch were relatively stable up to the 1930s with lake herring, walleye, yellow perch, suckers, and to a lesser extent, lake trout, and whitefish predominating. Presently, the commercial fishery with much reduced effort pursues channel catfish and yellow perch (a meager catch of 68 thousand pounds in 1986) and a few low-value species.

Saginaw Bay's historical sport fishery, mostly near shore, is impossible to quantify. From May to November 1986, a creel census established that 73 thousand walleyes and 1.8 million perch, plus other species, were caught in 2.2 million angler hours. In 1984, anglers took more pounds of yellow perch than commercial producers by a 6:1 ratio.

Fluctuations in the Bay's fish populations are attributed to combinations of abuse, habitat degradation, sea lamprey predation, and alewife and smelt competition. As examples, the demise of the lake trout is charged to the sea lamprey and excessive commercial exploitation; the disappearance of the herring is attributed to alewife competition and overfishing; and the collapse of the walleye population was believed due to degradation of the spawning grounds. Yellow perch abundance has fluctuated dramatically over the century due to commercial fishing and to poorly understood factors.

We conclude that the Saginaw Bay ecosystem has been unbalanced for at least 30 years. Top predators are too sparse in number and in kind; forage fishes are far too abundant; the zooplankton has probably shifted to unfavorably small organisms due to intensive grazing by forage fishes; degraded habitat probably still limits natural reproduction by walleye and the recovery of the burrowing mayfly population; and bottom feeding fish (suckers and carp) are too abundant and may be competing with young yellow perch and walleye. To restore ecosystem balance, we recommend that the walleye be restored as the dominant piscivor; that the channel catfish, another key predator, be increased by reducing commercial fishing mortality and increasing the minimum size limit to 18 inches; and that consideration be given to establishing the Great Lakes muskellunge. Concentrations of commercial fishing gear should be reduced to alleviate conflicts with sportsmen and prevent mortality of sport species.

INTRODUCTION

The Saginaw Bay area is recognized throughout the Great Lakes system as having a very productive ecosystem. The area, in the heartland of Michigan's agriculture offers a mixture of outstanding recreational opportunity and progressive industries. However, in recent years considerable attention has been focused on the decrease in environmental quality and loss of natural resources. Particular emphasis has been placed on the Bay itself and its fisheries resource.

The Michigan Department of Natural Resources (MDNR) has active fisheries research and management programs on the Bay. These programs include monitoring sport and commercial catches, tagging principal species, stocking predatory species, and studying fish community interactions. The research is aimed at understanding long-term trends in fish population dynamics. The MDNR also supports short-term university research on various phases in the life history of fishes.

Changes in the biological and chemical characteristics of Saginaw Bay have been particularly apparent over the last 50 years (Freedman 1974). For example, the basic fertility of the Bay has increased measurably; turbidity has increased to a level that beds of higher aquatic plants are absent in some locations; striking changes have occurred in the density and composition of phytoplankton; and the benthos community has shifted to the more pollution-tolerant species, particularly in the lower end of the Bay.

Fish communities and their habitats in Saginaw Bay have also been drastically changed over the past 150 years by a series of cultural stresses imposed by man. These stresses have included commercial overexploitation of many indigenous fish stocks, eutrophication through nutrient loading, watershed and shore erosion, invasion by marine species, tributary stream destruction, marsh drainage, and chemical contaminants like PCBs and dieldrin that have raised concern about human health and dampened enthusiasm for fishing. Some stocks of fish have virtually disappeared and new species have filled the void, usually with explosive results. The lake sturgeon became extinct in the early 1900s. Lake trout, whitefish, walleye, and herring populations collapsed by the mid-1950s. In the last decade, lake trout and walleye have partially recovered due to stocking and other management measures have stimulated whitefish abundance. However, it appears that lake herring have been replaced by alewife and smelt invaders. Between 1870 and 1920, rainbow trout and brown trout were successfully introduced into the upper Great Lakes. These sport species, along with the introduction of coho salmon and chinook salmon in the 1970s, have provided a new species complex in the outer Bay. Of the remaining principal species, carp, suckers, and catfish continue to rise in abundance and yellow perch populations have fluctuated with changes in regulations and abundance of predatory species. White perch, a marine invader, have recently been observed in the Bay but its status in the community has yet to be determined.

The purpose of this paper is to provide a history and current status of the major fish stocks in Saginaw Bay. We will point out causes of fluctuations in abundance in the Bay fish community. Methods to reestablish a balanced predator-prey relationship essential to achieving a stable and productive resource base will be presented. Although we will make mention of those species that occupy the outer cool-water sector of the Bay, the primary emphasis will be placed on the shallow, warmwater inner Bay fish populations.

Description of the Bay

Saginaw Bay is a 51-mile (82-km) long inlet of Lake Huron on the Michigan shoreline. The Bay's 1,143 square miles (2,960 km²) of surface area (5% of Lake Huron) are about equally divided by a broad, shallow constriction into inner and outer bays (Fig. 1).

The inner Bay, much of which is peripherally marshy, has a mean depth of 15 feet (4.7 m) and maximum depth of 46 feet (14 m). As is the case with many shallow bays on the lower Great Lakes, the inner Bay remains greatly enriched with industrial, domestic, and agricultural waste and runoff. Its major tributary, the Saginaw River, drains a large industrial-urban complex (6,500 square miles) and is the primary source of Bay pollutants (Freedman 1974). However, frequent wind mixing of the water column (the Bay usually does not thermally stratify for long periods) and a flushing rate of 186 days normally assure adequate levels of dissolved oxygen for fish. The inner Bay is ice covered from mid-December through early March.

The outer Bay has a mean depth of 48 feet (15.6 m), a maximum depth of 133 feet (40.5 m), and contains about 70% of the total volume of the Bay (Beeton et al. 1967). The outer Bay shorelands are generally rocky on the east side, sandy on the west side, and have very few marshes. The outer Bay has favorable mixing of waters with Lake Huron proper which provides high dissolved oxygen levels during summer stratification.

The Bay has several small islands, the most prominent of which are the Charities. North, Heisterman, and Maisou islands lay southwest of Sand Point, and form the outer edge of Wildfowl Bay. Defoe, Pitcher, and Lonetree islands continue southwestward towards Fish Point and form the outer edge of Sebewaing Bay. These sub-bays are very shallow, productive bodies of water believed to be nursery grounds for many species of fish. The Coryeon Reef is a sand and gravel bar off the eastern shoreline and west of the island group stretching from Charity Island southwest almost to the Saginaw River.

Eshenroder (1977) provided a useful summary of the physicochemical conditions of Saginaw Bay. Freedman (1974) discussed algae and zooplankton data from various surveys of Lake Huron and Schneider et al. (1969) described the benthos. MDNR surveys with trawls, trap nets, and gill nets (unpublished) were used to document the occurrence of fish species in Saginaw Bay and to provide an estimate, albeit somewhat subjective, of their relative numerical abundance (Table 1). In addition, 22 other species have been observed and verified in Saginaw Bay samples since 1950 (Table 2). The yellow perch was ranked the most abundant species (27% of the fish community) and the bluntnose minnow was ranked as the least abundant (0.0003%).

History of the Bay Fishery

Commercial fisheries were established in the Saginaw Bay area in the 1830s (Lanman 1839). The early fisheries, located near shore and on major rivers tributary to the Bay, used spears, seines, and gill nets. Pound nets, hooks, and trap nets followed as fishers became mechanically equipped and moved to deeper offshore waters. Fish production rapidly increased in the late 1800s and peaked in 1902 at 14.2 million pounds (Fig. 2). Since then production has gradually declined to a low of 1.4 million pounds in 1974 (Hile and Buettner 1959; Baldwin and Saalfeld 1962; and MDNR commercial fish records). Present commercial fish production remains below historical levels, and the fishery generally pursues a few low value species with much reduced effort.

The Bay's fish community and commercial catch were relatively stable up to the 1930s. Lake herring was the predominant species with annual catches ranging from 1 to 8 million pounds. Walleye, yellow perch, and suckers were also abundant, each providing annual catches of 1 million pounds. Whitefish and lake trout, although not as plentiful in the Bay as Lake Huron proper, were still important with average annual catches of 50,000 and 30,000 pounds, respectively. The only exceptions to a stable fish community in the 100-year period prior to the 1930s were the deliberate eradication of sturgeon and the introduction of carp in 1874.

A decline in lake trout production, due to overfishing and sea lamprey predation, occurred in the late 1930s (Anon. 1969). The average commercial production for 1935–44 was 25–30% of earlier catches, and by 1955 lake trout were extinct in the Bay. The story of the lake trout is discussed further in a later section.

A combination of heavy exploitation by the deep trap net fishery in the 1930s followed by lamprey predation also appears to have led to a decline in abundance of whitefish. In the period 1930–34 whitefish constituted 15% (1,282,000 lbs/yr) of the total catch in the Bay. In the early 1940s whitefish were scarcely caught and in the 1950s they were rarely caught. Severe reduction in fishing power, ban on gill nets, and sea lamprey control since the 1970s have stimulated a comeback of whitefish stocks. In 1986 the commercial trap net permit fishery in the outer Bay produced 213,588 pounds. Whitefish were also taken in the inner Bay during spring and fall periods incidental to fishing for rough fish. The occurrence of whitefish in the lower end of the Bay was witnessed in 1986 for the first time since the 1930s and indicates an expanding population in the outer Bay.

The ciscoes, an association of seven distinct species of coregonines (sub-family consisting of lake whitefish, round whitefish, lake herring, and chubs) lived primarily in the deeper water niche of the outer Bay. The two largest species of chubs were exploited heavily by the early fishery and were greatly reduced by the turn of the century (Smith 1968). Smaller chubs apparently replaced the larger species and by the 1950s there remained only one species, the bloater chub. The bloater suffered from competition with the alewife, whose population exploded in the early 1950s. However, in the last decade, the bloater chub has shown some improvement. The lake herring demonstrated similar trends of depletion, and by 1952 production fell to 30% of the 1930–34 catch figures. From this period on, lake herring catches dropped even more dramatically and never recovered, probably the result of competition with the alewife.

Walleye were a prized commercial species in the Bay. The stock collapsed abruptly in the 1940s, leaving the fishery without a high-value species. Several explanations of the walleye collapse in the Bay have been tendered, including overfishing, closing of Bay City Hatchery, environmental degradation, and sea lamprey predation. The history and current status of walleye will be covered in more detail later in this report.

Of the remaining principal species, there has generally been no scarcity in the Bay in recent years. Yellow perch, smelt, suckers, carp, and catfish, all of which are considered abundant, will be discussed in detail as separate segments of this paper.

In 1966, the Michigan Department of Natural Resources 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 by a series of sweeping changes. First, the commercial harvest of northern pike, lake trout, and walleye was prohibited beginning in 1966, 1967, and 1970, respectively. Then the overcapitalized commercial fishery on the Bay was reduced in number from 45 licenses in 1970 to 27 in 1986. The commercial fishery was further regulated by designating fishing areas and the type and amount of gear used and, in addition, quotas were placed on some species. Generally the commercial fishery has been shifted to gear selective for those species termed "rough fish". Other changes during this period of recovery, financed largely by funds from sportfishing licenses required for the first time in 1967, were renewed stocking of predatory species and expanded fisheries research.

Saginaw Bay's past recreational fishery is much more difficult to quantify than its commercial fishery. The early sport fishery was generally localized in near-shore areas for yellow perch, largemouth bass, and northern pike. Yellow perch were the most sought after species and provided good catches during spring spawning runs and through the ice during winter months. The ice fishery for perch in the 1950s was very active on Wildfowl and Sebewaing bays, and it was not uncommon to count, during the peak season, in excess of 1,000 anglers on weekend days. Also during the 1950s spring smelt dipping drew large crowds to river mouths such as the East Branch of the Au Gres, site of the famous Singing Bridge. The walleye did not provide a sport fishery in the Bay until recently.

In 1969–82, the MDNR conducted an annual statewide mail creel census of Michigan's fisheries. The census sampled about 1% of the licensed anglers. Although the census overestimated the catch fivefold, it provided a good index of significant species in the Saginaw Bay catch. Yellow perch, largemouth bass, and northern pike continued to be important in the 1970s; however, centrarchids, ictalurids, and salmonids had also entered the catch. The mail survey statistics showed that the Bay fishery comprised from 24 to 43% of the total Lake Huron sport-fish effort.

Since the mid-1970s there have been several partial, direct-contact creel censuses of the fishery (Ryckman and Lockwood 1985; Ryckman 1986). In 1986 the MDNR initiated an intensive program to monitor the sport fishery on Lake Huron, including all of the Bay. Monitoring personnel interviewed sportfishers, made aerial counts of fishing effort at predetermined times, and collected biological data from the catch. The historically important sport species continued to predominate, although in the outer Bay five salmonid species (chinook salmon, coho salmon, lake trout, rainbow trout, and brown trout) made significant contributions to the catch. Walleye and catfish provided excellent catches in the inner Bay and 13,900 walleye were caught on the Saginaw River system, the first significant catch from the River in at least 60 years. Also in 1986 it was determined that 60% of the total Lake Huron fishing effort was in the Bay.

Walleye

Historically, Saginaw Bay supported the second largest walleye population in the Great Lakes. An extensive commercial fishery, the catch of which often exceeded 1 million pounds of walleyes annually, began in the 1830s (Schneider 1977). Walleyes were captured by seine when in or near certain rivers, by fyke net in the Saginaw River, by commercial spear fishermen on the ice of the inner Bay, and by offshore trap net and pound net. The first three types of fisheries had dwindled by the turn of the century; the offshore fishery dramatically collapsed in the 1940s as catch fell from 2,050,000 to 768,000 pounds (Fig. 2). The population did not recover and the walleye commercial fishery has been closed since 1970 to protect the remnant broodstock.

The collapse and continued relatively low level of the walleye population is primarily attributed to degradation of the spawning grounds (Schneider 1977). Walleye eggs are very susceptible to siltation, anoxia, and polluted sediments because they lie on the bottom for about 3 weeks. Contributing concurrent factors probably were commercial overharvest, increases in smelt and alewife, and predation by sea lamprey.

Just prior to the collapse spawning occurred in many areas of the inner Bay, but the prime areas were off the mouth of the Saginaw River, along the shore between Quanicassee and Fish Point, and along and on the Coreyon Reef out from Bay Port (Schneider 1977). Some spawning also took place along the west shore between Rifle Bar and Nayanquing Point. Historically, walleyes probably also spawned in the Saginaw River system and the other tributaries which once supported fisheries, but these areas were degraded long ago and their subpopulations were lost.

Attempts to rehabilitate the walleye population by stocking Saginaw Bay and its tributaries began in 1972 (Table 3). (Walleye sac fry were also stocked from 1908 to 1944, but natural reproduction was so good then that stocking was ineffectual—Hile and Buettner 1959). Fry planted directly into the Bay apparently failed to survive, but fry planted into Ross Lake, Gladwin County, in 1977 probably initiated the spawning runs into the Tittabawassee River which began in 1981. Plantings of fingerling walleyes directly into the Bay, which at a length of about 2 inches are too large to be preyed upon by most Bay fishes, have been more successful. Their stocking rate has been increased to about 1 million per year. The fingerlings have been reared in ponds cooperatively by the MDNR and sportsmen's groups, then stocked-out in early summer.

The recent plantings have produced large numbers of adult walleyes and created a walleye sport fishery where essentially none existed before. In earlier years, when native walleyes were abundant, few anglers owned boats safe enough to venture out on the Great Lakes. Good fisheries now occur from September through May in the Tittabawassee and Saginaw rivers and, sporadically, afterwards in the inner and outer bays. The estimated sport harvest from May to November 1986 totaled 73,000—14,000 from rivers, 51,000 from the inner Bay, and 8,000 from the outer Bay (Table 4).

The Tittabawassee River below Dow and Sanford dams has developed into the major spawning ground. Smaller numbers of adults have been running into other tributaries, including the Kawkawlin, Rifle, Au Gres, Pinconning, Pine and Quanicassee rivers, and Saganing Creek. It is not known if spawning is being attempted on traditional spawning reefs in the Bay proper. Studies have been proposed to evaluate spawning on these sites in 1987.

The spring walleye run into the Tittabawassee River, in particular, has been monitored by the MDNR since 1981. Migrants have been (1) captured by electrofishing gear; (2) given serially numbered jaw tags to determine their movements, exploitation rate, and survival rate; and (3) measured and scale sampled to determine their age and growth rate. As of May 1986, 17,623 had been tagged (Table 5).

Tags have been recovered by anglers, commercial fishermen, and biologists conducting surveys. To date, most of the returns have come from the Tittabawassee River. Some walleyes live in the river year-round but most migrate back to the Bay after spawning. Walleyes have been recaptured throughout the Saginaw River system (Saginaw River proper, Flint River, Shiawassee River, and Chippewa River), Saginaw Bay, and Lake Huron. Many have been recaptured by the sport fishery near the Charity Islands in July and August. Some have been caught in the lower reaches of the Au Sable River. Tag returns have come from as far away as Thunder Bay, Manitoulin Island, Sarnia, and Lake St. Clair. In the past, native walleyes roamed widely, migrating into the inner Bay in spring and fall, then back to the outer Bay and beyond in summer (Schneider and Leach 1979).

Exploitation of walleyes by anglers has been low (Table 5). First-year returns of tags have ranged between 1.1 and 2.5%, with an average of 2.1%. This figure is based on voluntary, unrewarded returns so it is a minimal estimate of angler exploitation rate. In a similar study at Lake St. Clair, it was estimated that the minimum rate should be multiplied by a factor of 1.5 to compensate for non-reporting of tags. Thus, the true exploitation rate of walleyes in Saginaw Bay is probably 3% annually. Higher minimum walleye exploitation rates occur in western Lake Erie (2.9%) and Anchor Bay (4.9%) (Bryant 1984).

Adult walleye survival has averaged 62% per year. This estimate was calculated from tag returns to date (Table 5), using a maximum likelihood procedure (Model 1 of Brownie et al. 1985). Since angler exploitation is light, natural mortality must be about 35% per year. Survival rate estimates for other Great Lakes walleye populations are 58% for Lake Erie, 51% for Lake St. Clair, 45% for Nipigon Bay of Lake Superior, and 35% for northern Green Bay (Bryant 1984; Ryder 1968; Schneider and Leech 1979).

Walleyes grow fast in Saginaw Bay. For example, the 1979 year class, which has been sampled at Dow Dam over several years, achieved the following mean lengths (in inches): Age III, 18.1; age IV, 21.1; age V, 22.9; and age VI, 25.1. This growth rate is faster than that for any other walleye population in the midwest. Preliminary results of a diet study started in 1986 show that walleyes are feeding on the abundant populations of alewife, smelt, and gizzard shad (see section on forage fish).

The goal of the walleye rehabilitation effort is to reestablish a population and fishery entirely supported by natural reproduction. Additional study is needed to determine the amount of walleye natural reproduction in the Bay and its tributaries and why walleyes are not spawning more successfully. The broodstock has been reestablished by stocking, but thorough and well-designed surveys of natural reproduction have not been done. Evidence of some natural recruitment was found in 1985 when a few fry were found in the Tittabawassee River and a few fingerlings were captured in trawl samples off the mouths of the Saginaw and

Quanicassee rivers (prior to stocking). No wild fry or fingerlings were captured in a similar amount of sampling in 1986.

Without natural recruitment the walleye population and fishery will be limited by the number of fingerlings which can be reared and stocked. The buildups of the population and fishery were modeled given the rates of exploitation (3%), natural mortality (35%), and stocking (Table 3). We assumed that only the fingerlings stocked since 1978 have contributed significantly and that an average stocking rate of 1 million fingerlings per year will be continued. The simulation results suggest that the walleye population and fishery would stabilize at their peaks in the mid-1990s. However, by 1986 the sport catch would have already reached 75% of its peak. Thus, to make a significant improvement in the fishery, stocking rates would have to be raised to several million fish per year.

The simulations also suggest that the 1986 walleye sport catch should be much lower than the estimated figure of 73,000. The most likely explanations include: (1) natural recruitment has taken place; (2) stocked walleye fry have made a large contribution; (3) fingerling survival has been extremely high; or (4) that there is substantial immigration of adult walleyes from populations in southern Lake Huron, Lake St. Clair or Lake Erie. One or more of these reasons is needed to account for the unexpectedly high sport catch.

Walleyes in Saginaw Bay and its tributaries contract two highly visible diseases known as lymphocystis and dermal sarcoma. The diseases are so similar that we will refer to both as "lymphocystis." These diseases usually appear as a cluster of white- or cream-colored warts or fleshy growths on the skin or fins of the fish. It is possible for a fish to have both diseases at the same time. "Lymphocystis" occurs more frequently in the spring of the year. Although many species of fish are known to contract it, the walleye is the only commonly infected species in the Saginaw Bay area.

"Lymphocystis" is often observed on walleye migrating up the Tittabawassee River during their spring spawning run. Since 1981, records have been kept on its incidence during tagging operations on that river. The infection rate has ranged from 0.0% in 1981 to 15.2% in 1985 to 12.8% in 1986. We have observed that some walleyes which were infected when tagged were healthy when recaptured at a later date; thus it is not usually fatal to fish. The disease agent (a virus) is shed into the water when the external lesions rupture and new infections start when fish come in contact with the viral particles. Thus, the incidence is likely to be greater when the population density of walleyes is greater.

The question most often asked by fishermen is: "Are the infected fish safe to eat?". Although aesthetically unpleasing, the flesh is unharmed by the disease. Neither disease can be transmitted to humans.

Yellow perch

Saginaw Bay yellow perch have been intensely pursued by sport and commercial fisheries for many years. The historical status of the population has been documented by Hile and Jobes (1941) for 1891–1938, El-Zarka (1959) for 1939–55, and Eshenroder (1977) for 1956–76. Weber (1985, 1986) described changes in the population since 1976. Yellow perch growth rate, abundance, harvest, and food habits continue to be monitored by the MDNR. The present management goal is to increase perch growth and yield to a level that was characteristic of the 1950s to early 1960s, when reproduction was stable and yield was large.

Commercial exploitation of perch has varied widely since the first catch records were kept in 1891 (Fig. 2). Landings averaged 1.2 million pounds in 1891–1916. In 1917–63, landings were at a lower level, with an average of 465 thousand pounds. Yield increased in 1964, peaked in 1966, and declined steadily thereafter to a low of 68 thousand pounds in 1986.

A large reduction in commercial trap-net effort began in the mid-1940s when the highly valued, overfished walleye was lost from the multispecies fishery. Trap-net catches historically have accounted for 80% of the yield. However, the most recent peak (1966) in landings was the result of a large increase in small-mesh gill-net effort and the removal of the 8.5-inch minimum size limit. Small-mesh gill nets were subsequently banned in 1972, and the number of trap-net licenses was reduced as part of a zone management plan to reduce total commercial effort.

A seasonal closure on the commercial fishery was in effect from 1927 through 1956. The closed season extended from April 15 through a variety of dates, which included May 10, May 15, June 1, and June 15. During these years 75% of the annual catch was landed in September-November (El-Zarka 1959). There has been no closed season since 1956, and recent seasonal production has been variable and heavily dependent upon weather conditions.

The minimum size of perch that the commercial fishery was permitted to keep also has changed several times over the years. Minimum size limits were 9.0 inches in 1890–1936, 8.5 inches in 1937–65, no size limit in 1966–77, 8.0 inches in 1978–80, none during 1981, and 8.5 inches from 1982 to present.

An active, year-round sport fishery for perch has existed on Saginaw Bay since at least the early 1940s (Eshenroder 1977). It undoubtedly has grown since then because the human population of the Bay area doubled from 1940 to 1970; indeed, the sportfishing effort was an impressive 2.2 million angler hours in May-November 1986 (Table 4). The sport fishery declined severely, especially in the outer Bay, in the mid-1960s. In the mid-1970s, the sport catch was still depressed and heavily dependent upon the abundance of age-3 recruits. A partial creel census on the west side of the Bay (only) indicated the average sport catch during the winters of 1975 and 1976 was 72 thousand pounds (J. R. Ryckman, personal communication). Saginaw Bay accounted for 85% of the perch sport catch from Lake Huron in 1976 (Jamsen 1977), eclipsing the highly successful sport fishery for perch in the Cedarville area of northern Lake Huron. These figures were representative of catches during a period of low abundance.

Yellow perch abundance and sport catches increased in the 1980s. Based on a creel census which covered most of the Bay in 1983–84 (Table 4), we estimate the total annual catch was about 3.6 million perch weighing 742,000 pounds. About 43% of this catch was made during the winter (Ryckman 1986). These perch averaged 7.7 inches long (Ryckman 1986). By contrast, the 1983 commercial fishery took 298,000 perch, weighing 137,000 pounds, and averaging 9.8 inches long. A creel census in 1986, May-November only, estimated perch catch at 1.8 million (Table 4)—a level similar to that in May-November 1983. Only once has the sport fishery been regulated in its quest for perch, that being a 50-perch creel limit during the late 1970s.

Saginaw Bay has undergone several changes in species composition and water quality but few, if any, appear to have had a significant impact on the perch population. Smelt and alewife became well established in the 1940s and 1950s when perch abundance was also very high. On this basis, Eshenroder (1977) tenuously concluded that smelt and alewife did not restrain perch recruitment. Water quality has improved (Bierman et al. 1982); however, the high perch abundance through the early 1960s indicated that poor water quality did not suppress perch recruitment. This is not to say that degraded water quality and smelt and alewives had no adverse impact on the perch stock; rather it may have been that measurement and analytical methods were inadequate to detect subtle, but potentially important, changes in the population. Perch were forced to shift their diet when the burrowing mayfly population collapsed due to poor water quality. The mayfly has not, as yet, recovered and Schneider et al. (1969) noted that it was not fully replaced by other benthic invertebrates which could be utilized by perch. It is suspected that once-abundant walleye stocks preyed on yellow perch and may have influenced perch abundance and growth. Walleye rehabilitation is now well underway due to an extensive fingerling stocking program, and the interaction between the two species is being closely monitored by the MDNR.

Recruitment of yellow perch in Saginaw Bay has varied dramatically over the century. El-Zarka (1959) estimated that seven times as many perch were present during 1949–55 than were present during 1929–30. Growth rate, an indicator of abundance, was relatively slow during 1949–64, suggesting a large standing stock, but increased sharply in 1968–71 in response to intensified commercial exploitation (Table 6). Judging from the relative number of the young-of-the-year perch caught in experimental trawling during 1970–85 (Table 7), the 1975 and 1983 year classes were large and the 1982 year class was exceptionally strong. Overall, recruitment since 1982 has been excellent and is expected to sharply increase adult perch abundance.

Circumstantial evidence suggests that the abundance of the Bay's yellow perch population is now approaching the desired density that existed in the 1950s. Similarities between the perch populations in the two time spans are slow growth rate, the age-size composition of the trap-net catches, and age-at-maturity (Weber 1985). The combined sport and commercial catch in 1986 was a spectacular 434 thousand pounds (excluding the sport ice fishery), of which anglers took 85%. The immediate future of the Saginaw Bay perch fishery appears bright, indeed, and could be improved with a balanced predator-prey relationship.

During the mid-1950s, an increased occurrence of a parasite commonly called "red worm" was noted in yellow perch from Saginaw Bay. This parasite is common in other enriched Great Lakes waters such as Lake Erie. The worm, which resembles a red thread 2 to 3 inches in length, was identified as Eustrongylides tubifex. It occurs in the body cavity of the fish, usually enclosed in a thin-walled cyst. If the fish is not dressed within a short time after capture, the worms may leave the cysts and be found in the body cavity or imbedded in the flesh, often partially protruding from the exterior of the body. Icing the fish immediately will prevent the worms from leaving the body cavity.

As with many parasites, the "red worm" has a long and complicated life cycle. The adult worms are found in fish-eating birds such as mergansers and certain ducks. Eggs from adult worms pass into the water by way of the birds' feces. Fish probably become infected by eating food organisms which have eaten the eggs. At least seven species of fish act as intermediate host to this parasite. By 1959, 30–40% of the yellow perch caught in Saginaw Bay were infected. The current rate of infection is not known but may be lower since fewer complaints or inquiries are received.

The "red worm" does not infect humans but large numbers of the parasite may render the fish aesthetically unpleasing for consumption. The parasite is killed by thorough cooking.

Channel catfish

The channel catfish is the largest species of the catfish family that commonly occurs in Michigan's Great Lakes waters. They are long-lived and often grow to 25 inches in length and 15 pounds in weight. The latest MDNR research study of Saginaw Bay catfish showed that they were growing at an average rate for northern populations (Lorantas 1982). Catfish 12 inches long were 5 years old and 17-inch fish were 7 to 9 years old. Saginaw Bay channel catfish do not become sexually mature until they are at least 17 inches long (Eshenroder and Haas 1974).

The commercial fishery has been the dominant force acting upon the Saginaw Bay catfish population. Commercial production averaged 239,940 pounds in 1919–86, but increased significantly after 1970, and since 1980 has averaged 567,400 pounds (Fig. 3). The annual catfish landings were negatively correlated with the annual landings of yellow perch, indicating that the commercial fishery targeted on catfish as perch harvest declined. Catfish have enjoyed relatively high market demand and value since World War II due, in part, to their desirability for live fish-out ponds in midwestern states. Commercial fishermen have pursued channel catfish with seines, baited set-hooks, and trap nets which can produce live marketable fish. Since 1971, 57% of the production has come from small mesh trap nets, 29% from set hooks, and 13% from seines. Regression analysis showed that small-mesh trap effort did not change dramatically from 1971 to the present; however, there has been a significant increase in set-hook effort and a highly significant decline in seine effort. In contrast, the harvest of catfish per unit of effort has significantly increased in all three gear types, especially in small mesh trap nets. Lorantas (1982) modeled Saginaw Bay channel catfish population dynamics and suggested that yield to both commercial and sport fisheries could be improved by increasing the commercial minimum size limit from 15 inches to 17 or 18 inches and/or by reducing commercial fishing mortality.

The sport fishery for catfish is relatively small; yield to anglers is about 12% of the commercial production. The 1983–84 sport catch of catfish was estimated at 36,600 fish (about 32,000 pounds), and the 1986 catch was estimated at 80,000 fish (about 72,200 pounds) (Table 4). A recent Michigan Public Health Advisory to sportfishermen recommends no consumption of catfish from Saginaw Bay and its major tributaries because of high contaminant levels.

Little is known about food habits and spawning of the Saginaw Bay channel catfish. In the Bay, they spawn in late June when water temperatures reach 75 °F. In other waters, it is known that males guard the nests and young, and that catfish eat a wide variety of benthic invertebrates and fish (Scott and Crossman 1973). Since they feed upon the same kinds of food organisms as yellow perch and walleyes, they are potential competitors. The catch of young catfish in MDNR fall index trawling has declined in recent years. Perhaps increased commercial harvest is reducing the broodstock too severely, thereby reducing the population's reproductive potential. The low minimum commercial size limit allows the harvest of catfish at least 2 years before they have reached sexual maturity. Research on catfish food habits and reproductive success is needed.

Carp

The carp, a large member of the minnow family, originated in Asia, found its way to Europe, and from there was introduced into the Great Lakes in 1874. An omnivorous feeder, the controversial species includes both vegetable and animal matter in its diet. Carp roil the water by grubbing for food in the bottom mud. Those Bay fishes requiring clear water have probably long been driven out of areas of high carp abundance.

Carp did not enter the commercial catch until 1918. From 1943 to 1971 their catch usually exceeded 1 million pounds and peaked at 2.1 million pounds. In the last few years landings have declined as a result of decreased market demand. However, the carp catch still made up to 30–50% of the Bay commercial catch, which in 1986 was 850,000 pounds (Fig. 3). Seines, trap nets, and large-mesh gill nets are used to catch carp.

The sport catch of carp in the Bay is limited to a few shot with bow and arrow and a few caught incidental to fishing for other species. There are no precise figures on the sport catch because in the 1986 creel census the count of carp was grouped with other insignificant species. The eating quality of carp is best when smoked, however, a recent Michigan Public Health Fish Advisory for sport fishermen recommended no consumption of carp from the Saginaw Bay region, including the major tributaries, because of high contaminant levels.

Suckers

Historically, two types of suckers—white and redhorse—were important to the commercial fishery of Saginaw Bay. Longnose suckers were not important because they prefer the deeper and colder waters of Lake Huron. Only the white sucker is still abundant and redhorse suckers, often called mullet, are now rare. Quillback carpsuckers have increased in abundance since the 1970s and are now important; they contributed 56,600 pounds to the commercial catch in 1986.

White sucker commercial production decreased from 1.13 million pounds per year in 1930-34, to 299,000 pounds in 1966, to 133,000 pounds in 1970–86 (Fig. 3). Fishing intensity for suckers also has decreased steadily since 1937. Consequently, the declining harvest probably did not reflect the true abundance of the sucker population because catch-per-unit-effort statistics for the major fishing gear did not undergo a similar decline. Small-mesh trap nets now take more than 90% of the commercial catch of suckers incidentally while fishing for catfish and perch.

The annual sport catch of suckers from the Bay was estimated to be 4,800 fish in 1983–84 and 10,000 fish in 1986 (Table 4). These are minimal estimates because the spring spawning-run fishery, the major sucker fishery, was not included. Although suckers are bony, they are very good to eat and they are a tough fighter on light fishing tackle.

White suckers spawn mainly in tributaries—especially the Rifle River—when spring water temperatures reach about 50 °F. At this time sportsmen harvest them with hook and line, spears, and dip nets. Eggs are scattered over gravel by the spawning fish and adhere to the bottom until hatching in about 2 weeks (Scott and Crossman 1973). Fry remain in the gravel an additional 1 to 2 weeks then drift out of the tributaries into the Great Lakes. Young sucker fry are planktonic feeders but soon they switch to feeding upon benthic invertebrates, the primary food of juveniles and adults. Little is known about growth of suckers in the Great Lakes; they probably reach sexual maturity in Saginaw Bay in about 4 years.

MDNR surveys have not been targeted at assessing suckers. However, the adult sucker population in the Bay is considered to be substantial and, therefore, it may be a major competitor with more desirable species for food and spawning habitat. Research is needed on sucker food habits to determine if they feed on the same types and sizes of benthic organisms that are important to yellow perch and channel catfish. Research to estimate sucker abundance and food consumption rates also would be important.

Freshwater drum (sheepshead)

The freshwater drum is harvested commercially and is often caught incidentally by anglers fishing for other species. The drum is fairly abundant in Saginaw Bay and other shallow areas of the Great Lakes. The species is adapted to bottom feeding and usually eats a wide variety of food including zooplankton and midge larvae (as young), and crayfish, fish, snails, and clams (as adults). The drum spawns during the summer in shallow water. The female may lay from 43,000 to 500,000 eggs. The eggs, which are buoyant and float at the surface, hatch in 25 to 30 hours at 61 °F.

Drum appear to be increasing in the Saginaw Bay area. The commercial catch of drum was 37,840 pounds in 1986. The sports catch was estimated at 4,200 fish from June 1983 to May 1984 and 64,100 from May to November 1986 (Table 4). The bulk of these were caught from the Saginaw River.

Forage species

The term "forage" ordinarily applies to small fish species that rarely grow to a large enough size to be exempt from predation by piscivorous fishes. Note, however, that young (small) stages of larger-growing species—such as perch—may also serve as forage.

The bottom trawl has been used by the MDNR since 1970 to monitor forage fish and other small fish in Saginaw Bay. The catch of each species per unit time is considered to be representative of the fish density that existed in the volume of water swept by the trawl. The mesh size of the trawl is quite small so that fish in the size range of 1 to 12 inches are quite readily captured. Based largely on catches in trawls, but also catches in gill nets and trap nets, the relative abundance indices given in Table 1 were developed.

The following table shows the MDNR average fall survey trawl catch in the Bay for the period 1970 through 1986.

Species	Number/10-min tow
Spottail shiner	431
Smelt	309
Alewife	157
Trout perch	94
Gizzard shad	43
Yellow perch (yearling and older)	396

The catches of yearling and adult yellow perch were included to show their rank in abundance with forage species in the Bay. There were 24 additional species that contributed to the trawl catches in much lower numbers (Table 1).

In Saginaw Bay, as in the shallow bays of the Great Lakes, the primary forage species are alewife, smelt, trout perch, spottail shiner, emerald shiner, and gizzard shad (Table 1). All of these are quite abundant in Saginaw Bay, with the possible exception of the shad. Based on life history characteristics, the forage species belong to two basic types: (1) the pelagic type, such as alewife, smelt, emerald shiner, and gizzard shad, which tend to live high up in the water column and feed predominantly upon planktonic organisms; and (2) the benthic or bottom living forms, such as trout perch and spottail shiners, that feed predominantly upon benthic foods. The pelagic type form more rigid schools and migrate more extensively than the benthic type. Due to these differences in life style, these species may vary in their vulnerability to predators and their catchability in trawls and other types of sampling gear. It appears that the benthic group is buffered or protected against predation relative to the pelagic group.

In 1986 the MDNR began a very intensive research project on Saginaw Bay to investigate the predator-prey and competitive interactions among walleye, yellow perch, and their forage species. A preliminary result is that 40% of the walleye stomachs we sampled contained identifiable prey fish. Alewife (48%), smelt (28%), and gizzard shad (26%) predominated in the walleye stomachs. The abundant spottail and emerald shiners have not been observed in walleye stomach samples as yet and benthic fish such as yellow perch, johnny darter, and trout perch have occurred in low numbers (2% each). Thus the walleye, which is a benthic feeder in many other waters, is feeding primarily on pelagic forage fish in Saginaw Bay—as it is in Lake Erie (Knight et al. 1984).

To date not enough of the yearling and adult yellow perch stomach samples have been analyzed to make reliable estimates of the contributions of the various forage fishes to the perch diet. However, it appears that forage fish made up very little of the diet of yellow perch during June 1986 (Fig. 4). Only 6.5% of the perch stomachs contained forage fish. Trout perch were the major forage species consumed by the few perch we sampled that were large enough to prey upon fish. Trout perch are very abundant in the Bay and live on the bottom where the perch actively search for food. The low contribution of spottail shiners to the perch diet is as yet unexplained and troublesome because Saginaw Bay perch would grow better if they ate more forage fish.

Northern pike

Northern pike occur throughout much of Saginaw Bay but prefer the sheltered, marshy areas. They have been protected from commercial fishing since 1966, in part to prevent the spread of redsore disease by transplanted fish. Prior to then, the largest commercial catch was 176,000 pounds (1961).

Sportfishing for northern pike occurs in summer and winter but the ice fishery is the more productive. Pike are often caught incidental to perch when fishing during the winter. The Au Gres, Sebewaing, and Wildfowl Bay areas have supported good winter spear fishing and several hundred shanties are placed over these fishing grounds each year. The sport catch was 3,200 pike from June 1983 to May 1984 and 700 pike from May to November 1986 (Table 4).

Limited age and growth data suggest northern pike in the Bay are growing well above the State average. Although they grow at a good rate, they do not reach very large sizes. Fish up to 11 pounds (35 inches) are quite common but 15-to 20-pound pike are seldom seen.

In recent years the northern pike population appears to be at low abundance. The reduction in numbers may be due to the loss of habitat which has resulted from record high water levels. Weed beds used for cover and spawning no longer exist and many drainage ditches and cuts have been blocked by dikes and irrigation pump stations. Although pike are still observed in some of the remaining ditches during the spring spawning season, this habitat is probably less than optimum for spawning and nursery purposes. The Kawkawlin River at one time received one of the largest spawning runs of pike in the Bay; however, these runs have been reduced by 50% in recent years.

An infection known as "redsore" has been recorded from northern pike in Saginaw Bay. Early investigators identified the causative agent as the bacterium Proteus hydrophilus, which is known to infect frogs and other species of fish. However, it has recently been determined that the bulk of the incidence is due to lymphosarcoma, a form of tumor caused by a virus (Sonstegard and Hnath 1978). The disease is specific to northern pike and muskellunge. It is known to be fatal to muskellunge, but its affect on northern pike is not fully understood. It is believed that the disease is spread by direct body contact such as occurs during the spawning act. The disease occurs throughout the range of the northern pike in North America and in most Michigan watersheds.

Symptoms of the disease appear as welt-like sores on the flank, fins, or head. The tumor may resemble a cluster of pink blisters which may rupture causing a lamprey-like wound. It may also appear as a series of bluish blisters surrounding a "cream-like" core. There is no evidence that this disease can be transmitted to humans. Heavily infected fish are not considered very palatable.

The incidence level of the disease is not known for Saginaw Bay. Because the disease is considered contagious to other pike, it is recommended that Saginaw Bay northern pike not be transferred to other waters.

The northern pike is an important top predator in the Saginaw Bay fish community, and every effort should be made to protect existing spawning habitat and to enhance populations by constructing rearing marshes.

Largemouth bass

Largemouth bass are distributed along the entire shoreline of inner Saginaw Bay but are most abundant in the inshore bulrush and cattail areas of the western and southeastern shore. Although once harvested commercially, largemouth are now considered only a sport species. Catch statistics in 1885 showed a commercial catch from the Bay of 152,500 pounds. The sport catch of largemouth bass was estimated to be 2,400 fish in 1983 and 2,900 fish in 1986 (Table 4). Most of the catch occurred from late May through the end of July.

Largemouth bass are quite plentiful and offer excellent angling opportunities. Bass fishing has not yet reached its full potential, but with the tremendous interest nationwide, it may not be long in coming. Recently, several bass fishing tournaments were attracted to the area.

Solid biological data on largemouth bass in Saginaw Bay are lacking. Limited age and growth information indicates bass growth is well above the State average. Management efforts at this time should be directed toward learning more about bass abundance, distribution, growth, and mortality rates.

White bass

White bass are widely distributed throughout the inner Bay but are most abundant in the lower Saginaw River. Although white bass have been present in the Bay for some time, their numbers appear to have increased substantially in recent years. This has been reflected in a growing commercial fishery and a developing sport fishery. Anglers make their best catches in May and June. The open-water sport catch was estimated at 58,950 fish (about 59,000 pounds) in 1986 (Table 4), about three times higher than the 1986 commercial catch (19,763 pounds).

White bass spawn when the water temperature reaches 55–60 °F, which usually occurs in mid-May. White bass ascend tributary streams and lay their demersal eggs among rocks and gravel. Eggs hatch in about 46 hours. The species is fast growing but short-lived. They reach maturity in 3 to 4 years but seldom live beyond 6 years. Adults 8 to 16 inches comprise the bulk of the catch.

Since the mid-1970s an expanding spawning run of white bass has been reported from the Tittabawassee River. The run provides excellent fishing from May to early June in the section from the Sanford Dam downstream to Saginaw. Excellent catches have also been observed in the Saginaw River. The river fishery annually produces several Master Angler fish, and in 1984 the current State record of 3 pounds, 3 ounces was caught below the Dow Dam at Midland. Another location that produces excellent catches of white bass, walleyes, and other fish is the warmwater discharge of the Karn-Weadock Power Plant located at the mouth of the Saginaw River.

Smallmouth bass

Smallmouth bass are rare in the Bay as a whole but commonly occur over rocky bottoms located in the outer Bay and the eastern fringes of the inner Bay. Areas where smallmouth are caught include Au Gres, Pt. Lookout, Charity Islands, North Island, and the shoreline from Caseville to Port Austin. Runs of smallmouth bass have been reported from the Rifle River and the Tittabawassee River during May and June. It has not been determined if these are resident fish or fish moving up from the Bay to spawn.

Most smallmouth are caught from the end of May through the end of July. The annual sport catch from the Bay is 800 to 1,000 fish (Table 4).

Crappies

Both black and white crappies occur in Saginaw Bay, principally along the eastern side. Crappies are harvested by both sport and commercial fishermen. They are caught throughout the summer months, but the best sport catches of 8- to 10-inch fish are made in April and May when the fish are concentrated in the cuts for spawning. Extremely large crappies are caught on "late ice" by fishermen who specialize in fishing them. The 1986 open-water sport catch was 1,400 fish (about 700 pounds), much less than the commercial catch of 11,000 pounds (Table 4). The crappie sport catch from June 1983 to May 1984 was 7,500 fish.

Information concerning age, growth, and seasonal distribution of both black and white crappies should be collected. Also, the relative benefits to the commercial and sport fisheries should be evaluated.

Pumpkinseed

Pumpkinseed sunfish are widely distributed along the weedy inshore perimeter of the Bay. Although they do not occur in large numbers, they provide some locally important sportfishing opportunities. The best fishing for pumpkinseed occurs during the early summer months, but ice fishermen also catch good numbers. The species does not attain large size (average size in the sport catch is 6.0 inches), but they are generally in robust condition. The sport catch is 1,000 to 4,000 fish per year (Table 4).

White perch

The white perch, a member of the marine bass family, was first observed in Saginaw Bay in 1983 when six adults were encountered during commercial catch sampling by the MDNR. The species invaded the Great Lakes system during the 1940s through the Hudson River, which was connected to Lake Ontario by navigational canals (Scott and Christie 1963). White perch became well established in Lake Ontario in the 1950s and eastern Lake Erie by the mid-1970s (Busch et al. 1977). White perch entered Lake St. Clair as early as 1977 and were well established in the system by 1980 (Boileau 1985). A single specimen was collected in Thunder Bay, Lake Huron, from a sportsfisher in 1983, and we can expect further expansion into the upper Great Lakes system by this species where suitable habitat exists.

White perch abundance has remained low in Saginaw Bay thus far. The commercial fishery reported an incidental catch of less than 500 pounds per year in 1983–86. MDNR fall trawling samples caught three young-of-the-year (YOY) white perch in 1984 and six in 1985, for an average of about 0.25 per 10-minute trawl tow. In 1986 the total trawl catch was 253 white perch, mostly YOY, for an average of about six per tow. In comparison, the average catch of YOY yellow perch during this same survey was above 200 per tow.

Little is known about the biology of white perch in Saginaw Bay. They have become abundant in lakes Ontario, Erie, and St. Clair and have been the subject of recent study for the potentially adverse impact they might have on native species. Food of white perch in Lake Erie consists of plankton, invertebrates, and fish that are shared in common with yellow perch; however, it is questionable whether much competition with yellow perch has yet occurred. Fish eggs and detritus made up 100% of the stomach contents of white perch in the Maumee and Sandusky rivers during spring spawning runs (Schaeffer 1984). The eggs were those of walleye, white bass, and white perch; however, there was no evidence of a negative impact on later recruitment of these species. Another concern in Lake Erie is that fertile hybrids are being produced by interbreeding between white perch and white bass.

It is apparent that white perch eventually are likely to interact with walleye, yellow perch, and white bass in Saginaw Bay. Studies should be initiated to evaluate egg predation, food competition, and hybridization.

Burbot

The burbot, a member of the cod family, inhabits deep waters of the outer Bay and is rarely taken from the inner Bay. In the past, they were often caught incidentally by ice fishermen who were fishing for lake trout north of Pt. Lookout. (In recent years, the lake trout season was reduced to May 1 through August 15.) The commercial catch of burbot from the Bay was reported to be only 88 pounds in 1986. Although the catch is low, other indicators suggest the abundance of burbot has been increasing in the deep-water niche of the outer Bay during the 1980s.

Although ugly in appearance and difficult to handle, the flesh of the burbot is white, flaky, and mild. It is preferred by some to lake trout or salmon when prepared in a fish boil. It could be a fish for the future, awaiting only recognition as a desirable food fish.

The burbot is one of a few fishes that spawn in midwinter. It is a voracious predator and could prey heavily on newly stocked lake trout.

Lake trout

The lake trout was once an important commercial species in the outer Bay. The largest catch recorded in this century, in 1931, was 325,000 pounds. By the late-1940s their numbers had been reduced to insignificance by overharvest and sea lamprey predation. Lake trout now provide a valuable sport fishery maintained by stocking. Since 1973 fall fingerlings or yearlings have been stocked annually at Oscoda, Tawas, Pt. Lookout, and Port Austin. A total of 230,000 fall fingerlings and 151,000 yearlings were stocked in the outer Bay during 1986. These fish are provided primarily by federal hatcheries. Discovery of several naturally reproduced fingerlings in Thunder Bay during 1986 kindled hope that a self-sufficient trout population may be restored someday.

Good to excellent sportfishing for lake trout occurs during the summer months along the tip of the "thumb" from Sand Point to Port Austin and along the western shore of the Bay from Pt. Lookout to Oscoda. The sport catch in 1986 was in excess of 19,000 fish (Table 4). Lake trout occasionally wander into the inner Bay during the winter, but that area is too warm and shallow in the summer for this species.

Brown trout

Brown trout are stocked in the outer Bay at Oscoda, Tawas, Whitney Drain, Pt. Lookout, Caseville, and Port Austin. A total of 50,050 yearlings and 375,000 fall fingerlings were stocked in 1986. Brown trout provide excellent sportfishing, especially in the early spring when smelt are in the shallows spawning. They can be caught in the shallows until the water temperature reaches about 60 °F. Browns provide good fishing again in the fall when they concentrate off some of the river mouths during the spawning season. The brown trout sport catch in 1986 was 7,500 fish (Table 4).

Steelhead

Steelhead are the migratory strain of rainbow trout that spend their adult lives in the Great Lakes and ascend suitable tributary streams to spawn. Yearlings or fall fingerlings are stocked in streams where they may spend from a few days to a couple of years before migrating down to the Great Lakes. As with other members of the salmonid family, they often return to the same stream to spawn. Steelhead are able to reproduce successfully in waters such as the Rifle River and the east branch of the Au Gres River. Most other rivers tributary to Saginaw Bay are too warm to provide proper habitat. Attempts are presently underway to develop steelhead runs in the Chippewa and Tittabawassee rivers. Although summer water temperatures in the Bay would probably be lethal to steelhead, they can move through the inner Bay during fall, winter, and spring to ascend these streams.

Streams tributary to Saginaw Bay presently stocked with steelhead include the Au Sable River, Whitney Drain, Rifle River, Chippewa River, Pigeon River, and Pinnebog River. Approximately 234,000 yearlings and 100,000 fall fingerlings were stocked in these river systems.

The Au Sable River and the east branch of the Au Gres both provide good to excellent steelhead fishing. The Rifle River has also been producing good catches for the past few years and should reach its potential in the near future as more fishermen are attracted to it. The Pigeon River, although small in size, produces fair catches to local anglers.

Pacific salmon

In 1966 the MDNR made a major policy decision to promote development of a new sport fishery in its Great Lakes waters while attempting to control excessive alewife abundance. Michigan introduced coho and chinook salmon from the Pacific Ocean in 1966 and 1967, respectively. In 1968 Lake Huron was included in the program with plantings of both coho and chinook. Plants have continued on an annual basis at various locations, including outer Saginaw Bay. In 1986 chinook were planted in the Au Sable River (652,000), Au Gres River (74,000), Tawas River (75,000), and at Port Austin (151,000).

The sport fishery is dependent on stocked fish, although some natural reproduction probably occurs in the Au Sable, Au Gres, and Rifle rivers. Chinook catches in the Bay are not as good as in northern Lake Huron or Lake Michigan because it has warmer water and it lacks steep drop-offs which concentrate fish. The best fishing occurs in the area from Sand Point to Port Austin during spring and early summer. The fishery at Au Gres is usually of short duration from late August to mid-September. The 1986 sport catch of chinook was estimated at 10,800 fish (Table 4).

The only Bay site regularly stocked with coho salmon is Tawas (99,000 in 1986). These plantings have provided poor returns to anglers—a disappointment shared by the coho program throughout the Lake Huron basin. The 1986 sport catch of coho from the Bay was only 1,700 fish (Table 4).

Chinook salmon, sampled from the sport catch in Lake Huron during 1983, averaged 31 inches in total length and 13 pounds in total weight. The age composition of the chinook catch was 16% age-group II, 22% age III and 62% age IV. The mean total length and weight of coho in the Lake Huron sport catch was 21.4 inches and 4.0 pounds, respectively.

Salmon research should include delineation of individual stocks, determination of survival and growth rates for each stock, and integration of data collected by various means for use in stock assessment and management. Marked (fin clipped) chinook salmon were planted in Lake Huron in 1983, and marked coho in 1986, as part of this research.

DISCUSSION

The ecosystem of Saginaw Bay has been unbalanced for at least 30 years. We perceive that:

1. Piscivorous fish (top predators) are too sparse.
2. Prey fish (primarily planktivors) are too abundant.
3. The zooplankton has probably shifted to unfavorably small organisms due to intensive grazing by prey fish.
4. Pollution and degraded habitat still limit adequate natural reproduction by walleye and the recovery of the burrowing mayfly population.
5. Bottom-feeding fish are too abundant and may be competing with the young of walleye and yellow perch.

Points 1 through 3 are closely interrelated and are best attacked at point 1, a lack of predators. By enhancing piscivors, we expect prey fish to be reduced and zooplankton to shift to larger size. Expected benefits are improved sportfishing because overabundant prey fish will have been converted to useful sport fish and improved growth of zooplankton-eating yellow perch. Other conceivable benefits are improved growth of yellow perch due to thinning out by walleye predation, and improved survival of fry and fingerling walleyes due to reductions in competitive and predacious alewife, smelt, and fingerling perch. The basic features of this scenario have been documented for Lake Michigan: salmon and trout have controlled the alewife, zooplankton has shifted in response to the intensity of alewife grazing, and yellow perch have rebounded (Stewart et al. 1981; Evans 1986).

For Saginaw Bay, the walleye should be restored as the predominant piscivor because the habitat is suitable, it has a history of success, and it is popular with anglers. The phenomenal growth and survival of walleyes (and other piscivors) already present in the Bay demonstrate that much potential exists. Serious consideration should also be given to establishing the Great

Lakes musky in the Bay to provide a secondary, high-quality fishery. However, the success of the musky may be limited by the high turbidity in some areas, the low amount of submergent vegetation, and gilling mortality in commercial trap nets. The northern pike population could be increased by stocking pike fingerlings, but this increase may be restricted to limited near-shore marshy habitat.

The initial step in walleye restoration, the buildup of an adult broodstock, has been accomplished by stocking. Now the environmental factors that still limit successful spawning need to be identified by additional research. A new cooperative study with The University of Michigan on walleye reproduction in the Bay is scheduled to begin in 1987. The remarkable recovery of the Lake Erie walleye, which was entirely accomplished by a period of limited commercial fishing mortality, pollution control, and natural reproduction, demonstrates the potential for the Saginaw Bay walleye.

As an alternative to natural reproduction, the walleye population and fishery could be built to higher levels by additional stocking on a put-grow-and-take basis. Earlier we projected that at the current stocking rate of about 1 million fingerlings per year, the current fishery (73,000 sport-caught walleye per year) was already within 25% of its peak (100,000 per year by the mid-1990s). Currently it costs about 4 cents to rear and stock each fingerling, a total cost of about $40,000 per year per million fingerlings. The stocking rate would have to be increased several fold to produce a good all-round walleye fishery and have a significant effect on the ecosystem. Clearly, walleye natural reproduction is the preferred alternative.

Saginaw Bay has the potential to produce 600,000 walleyes (1 million pounds, if they average 17 inches and 1.7 pounds apiece) annually to the sport fishery. This prediction is based on (1) the fact that historically the Bay often produced in excess of one million pounds annually to the commercial fishery and (2) that the Bay's productive capacity per acre is equivalent to western Lake Erie (peak total commercial yields of 7 and 8 lb/acre, respectively), where 605,000 walleyes were sport-caught from Michigan waters in 1986 (G. Rakoczy, personal communication). Since the Bay is ten times the size of Michigan's share of Lake Erie (1,143 vs 110 square miles), we consider this estimate to be conservative.

The value to the Bay region of a recreational fishery which produces 600,000 walleyes is estimated at 100 million dollars annually. This would be a net increase of 72 million dollars over the current (1986) estimated value of the Bay fishery. These figures are based on the assumption that (1) catch per angler trip would be 0.32, which is one-half the catch rate of the Lake Erie fishery; (2) fishing effort would increase threefold, from 500,000 to 1.8 million fishing trips (G. Rakoczy, personal communication); and (3) an angler trip would have a value of $55, the same as for Great Lakes salmon fishing (D. Jester, personal communication).

Although the quality of water and sediments in the Bay seem to be improving, we suspect that they remain poor enough to limit walleye reproduction, and the recovery of burrowing mayflies and submergent vegetation. From our perspective, pollution reached a critical level during the 1950s when walleye reproduction collapsed and the population of burrowing mayflies was reduced. Both are sensitive to dissolved oxygen and chemicals at the water-mud interface. The walleyes importance as a top predator has already been discussed; the mayfly was an important link in the food chain. Tharratt (1959) observed that mayflies were important to the diet of medium- to large-sized yellow perch as late as 1956; by contrast, almost none were found in recent perch stomach samples due to the mayflies' scarcity in the Bay (Fig. 4). High turbidity probably also limits the production of submergent vegetation in the Bay. Once-abundant weed beds disappeared over 20 years ago. In optimal amounts, vegetation would improve the habitat for yellow perch, northern pike, musky, and largemouth bass.

Another consequence of poor water quality and an indicator of ecosystem imbalance is the relatively high proportions of bottom feeders, such as suckers and carp, in the fish community. These species prosper in enriched waters and have benefited from pollution of the Bay. While not numerically predominant (about 5%—Table 1) they likely make up a substantial portion of the total fish biomass because of their large average size. They may significantly compete with yellow perch, walleye, and other species if they comprise more than 50% of the community biomass (Schneider and Crowe 1980). These species could be reduced by improving water quality and by encouraging selective commercial harvest.

The yellow perch "problem" (too many small fish) in Saginaw Bay is not fully understood. At present, it is attributed to imbalance in the fish community, deterioration of food chains, and perhaps overfishing before perch grow to an optimal size. Small yellow perch seem to predominate due to a combination of poor growth in the inner Bay, and/or high natural mortality, and/or high exploitation by sportsmen. Based on data gathered thus far (mainly in 1983–84), it appears that:

a. Yellow perch total mortality is moderate, about 64% per year.
b. Natural mortality is rather low.
c. Exploitation is rather high before the optimal size is reached.
d. Most (92% by number) of the yellow perch harvested each year are taken by anglers rather than commercial fishermen.
e. Perch growth varies by location and type of collecting gear; consequently, it is difficult to obtain a representative sample.

These data and others were fed into a computer model which simulated the characteristics of the yellow perch population, the sport fishery, and the commercial fishery. The model predicted that:

1. Even complete elimination of the yellow perch commercial fishery would have little beneficial effect on the yellow perch population or fishery because, at present, sport fishermen take the bulk (92%) of the total perch harvest. However, if the commercial fishery would target for perch and utilized all the legal licensed gear allowed, it could impact on the fishery by cropping off the larger perch.

2. If growth is relatively good and exploitation is relatively high, then a minimum size limit of 7.0 to 7.5 inches on sport-caught fish should be instated to cure "growth overfishing"—the condition in which fish are harvested at too small a size, before they have realized their growth potential. We also believe that a shift in the perch population to increased numbers of larger fish will stimulate further growth because perch are cannibalistic on their own kind.

This model incorporates numerous assumptions which need to be refined with additional data before management action is taken on the yellow perch problem. A tagging study has been proposed by the MDNR for 1988 to obtain better estimates of exploitation and mortality, track perch migrations, and determine if there are discrete subpopulations. However, we are optimistic that the yellow perch population will improve after a dominant piscivor, like walleye, is reestablished in the Bay.

We are pessimistic about the future of the white perch in Saginaw Bay. It will likely become a troublesome species, as it was in the Bay of Quinte, Lake Ontario. We expect it to become a strong competitor with yellow perch, interbreed with white bass, and hinder walleye reproduction. There is no practical way of preventing its establishment in the Bay; however, it is encouraging that in the Bay of Quinte the population explosion was short-lived and that their abundance declined as water quality improved (Frances et al. 1979).

To review thoroughly the Saginaw Bay fishery, and not mention the conflict between user groups over the rich fishery resource, would ignore an important aspect of the fishery. The conflict arises when concentrations of commercial fishing gear physically obstruct the sport fishery. Although nets legally must be marked with flags, most anglers do not understand how the nets are deployed. Consequently, the angler's propeller and tackle often become entangled in the nets. Trollers, especially those equipped with downriggers, are particularly vulnerable to entanglement in commercial gear.

Commercial fisheries presently are licensed to fish a number of species with fixed gear such as trap nets, hooks, and large-mesh gill nets. Seines are not fixed to the bottom and are retrieved from the water after each day's use. The Bay's commercial fishery is licensed to fish 358 trap nets (approximately 68 miles if placed end-to-end), 179 thousand million feet of hooks (trotlines; approximately 34 miles), and 146 thousand feet (38 miles) of large-mesh gill nets. However, not all of this gear is likely to be fished at the same time, although legal. The licensed amount of trap-net effort is far in excess of that required to harvest target species; potential effort could be reduced by almost half, to 3,300 net lifts annually, to achieve projected total allowable catches (TACs). This estimate is predicated upon the assumptions that six full-time trap-net fishermen would each lift 550 nets/season, the catch/net would be 30 pounds, and the TAC on yellow perch would be 100 thousand pounds. Any reduction of trap nets would benefit the resource by lessening gilling and handling mortality of sport species caught in the nets. Additionally, reduction of commercial gear in key sportfishing areas would be a positive step toward alleviating tensions and conflicts for space and fish between sport and commercial fishermen. We suggest a buy-back program to purchase commercial licenses on a willing seller/willing buyer basis to reduce excess fishing power.

The management of channel catfish, presently a key piscivor in the ecological system, needs further review. Simulation models predicted that catfish yield to both the commercial and sport fisheries could be increased by increasing the minimum commercial size limit and/or reducing mortality induced by commercial fishing (Lorantas 1982). The present commercial minimum size limit of 15 inches on catfish allows harvest at least 2 years before they have reached sexual maturity. This may be reducing the adult stock too severely. An 18-inch size limit and/or reduced set-hook effort (set hooks are the major commercial gear for catfish) should be imposed on the commercial fishery. That regulation should enlarge the piscivor stocks and, in turn, shrink an overabundant forage fish population and ease tensions between the sport and commercial interests. These suggested regulations might seem too severe to the Bay's commercial fishermen. However, we have kept in mind the management tenet that "what is best for the fish is best for the fishers, whomever they might be". Moreover, the MDNR's policy is to manage the fishery resource for maximum public benefit.

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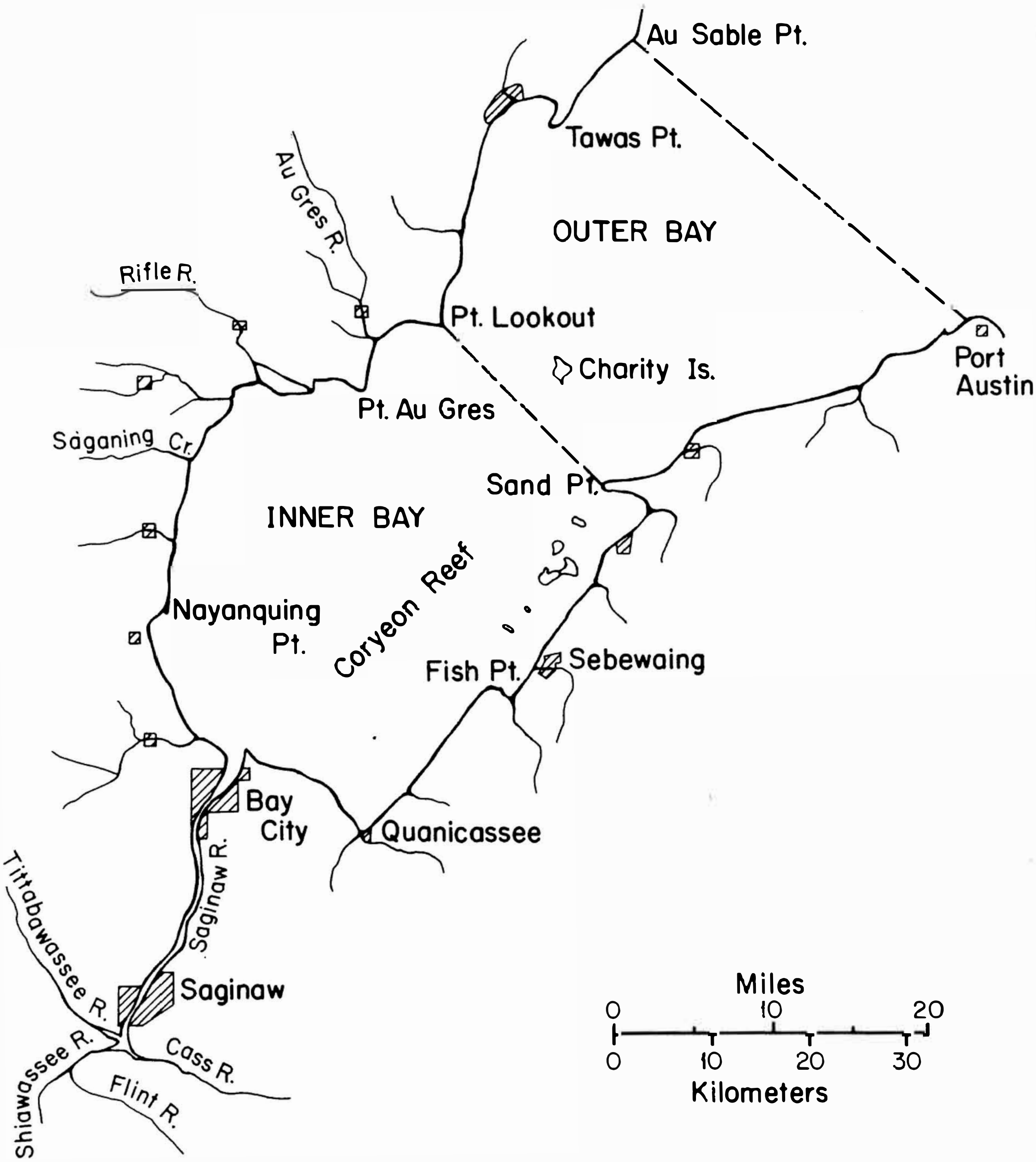

Figure 1. The Saginaw Bay region of Lake Huron.

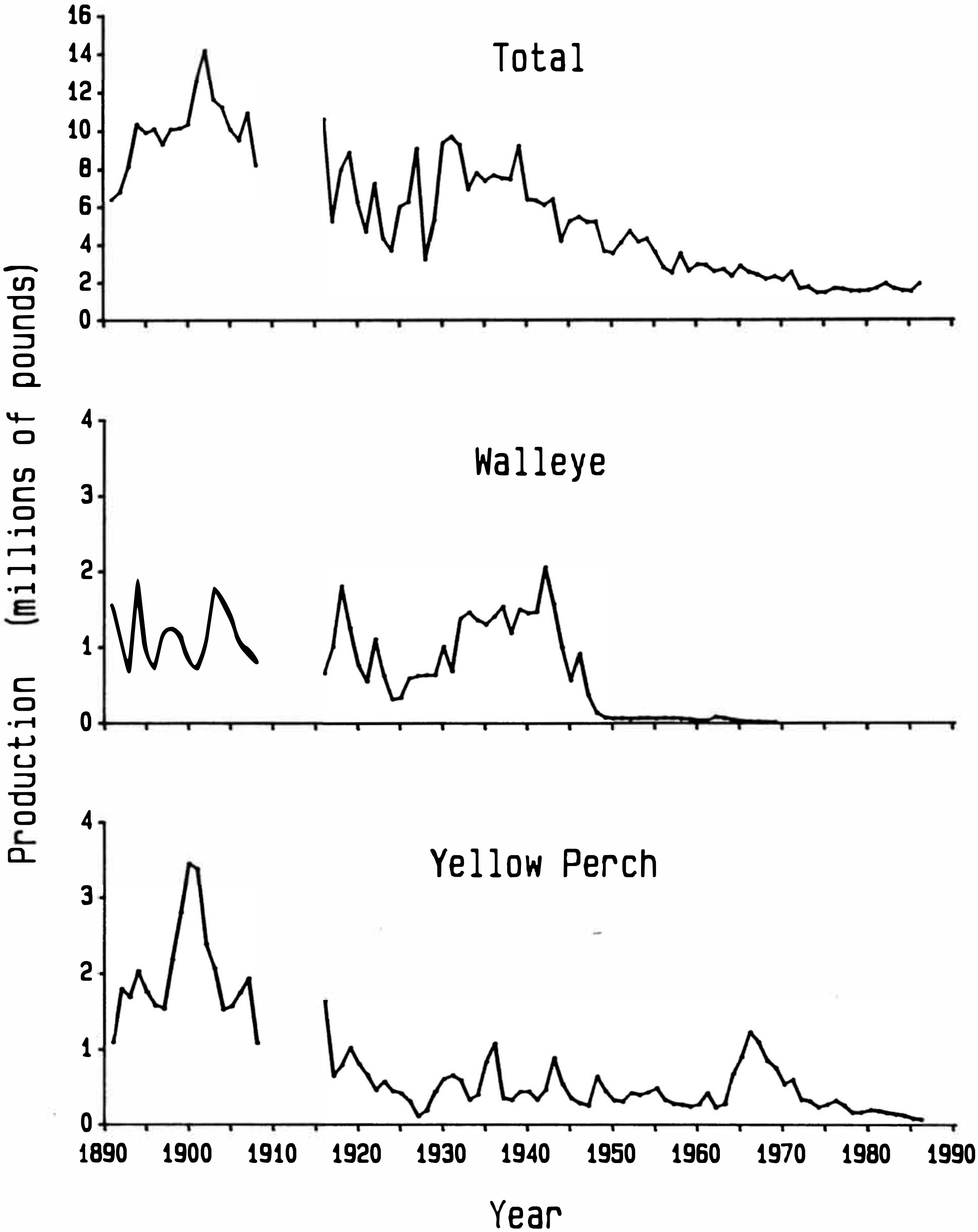

Figure 2. Commercial production for all species (total), walleye, and yellow perch in Saginaw Bay, 1891–1986.

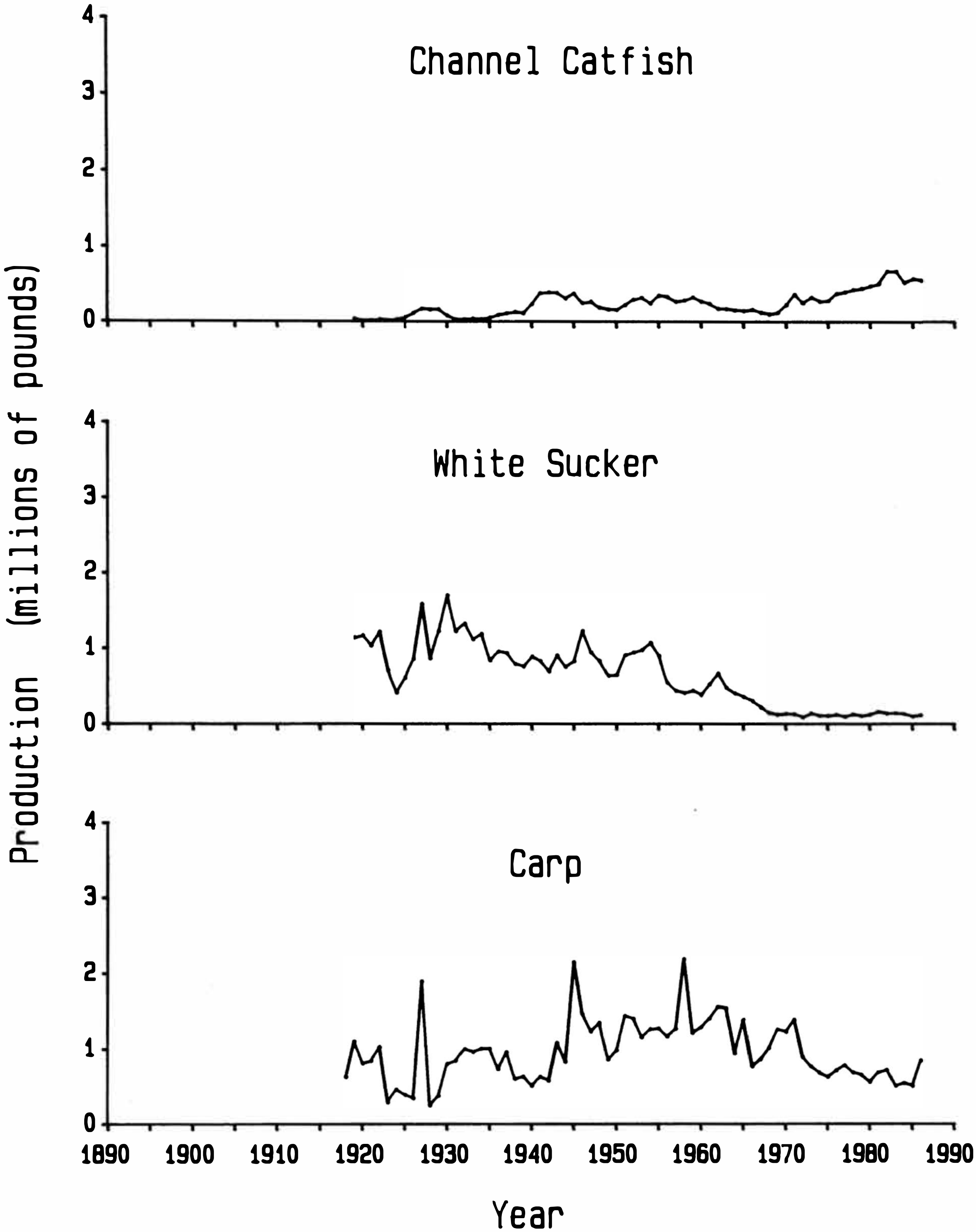

Figure 3. Commercial production for channel catfish, white sucker, and carp in Saginaw Bay, 1918–1986.

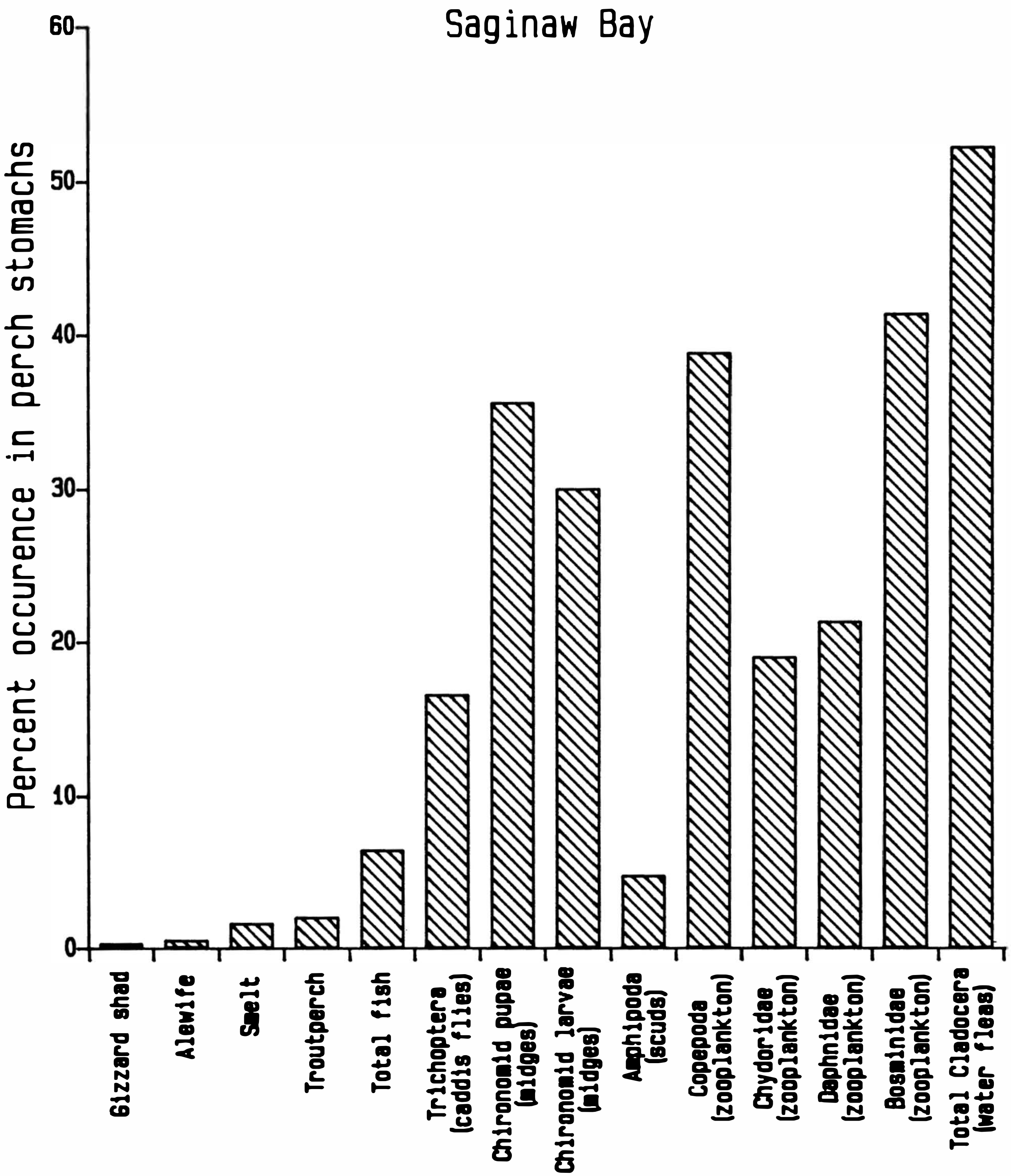

Figure 4. Frequency of occurrence (percent) of food types in 704 yellow perch stomachs from Saginaw Bay during early June 1986.

Table 1. Fish species in Saginaw Bay, listed in decreasing order of relative abundance (expressed as percent, by number, of fish community).

Species	Scientific name	Index of abundance (percent)
Yellow perch	Perca flavescens	26.8729
Alewife*	Alosa pseudoharengus	17.9843
Spottail shiner	Notropis hudsonius	15.6595
Smelt*	Osmerus mordax	13.4139
Trout perch	Percopsis omiscomaycus	6.6481
Black crappie	Pomoxis nigromaculatus	4.4545
Channel catfish	Ictalurus punctatus	3.5423
White sucker	Catostomus commersoni	3.3779
Emerald shiner*	Notropis atherinoides	2.4708
Gizzard shad*	Dorosoma cepedianum	2.4583
Walleye	Stizostedion vitreum	0.6390
Pumpkinseed	Lepomis gibbosus	0.4694
Common carp	Cyprinus carpio	0.4284
Freshwater drum	Aplodinotus grunniens	0.3271
Brown bullhead	Ictalurus nebulosus	0.2708
Stonecat	Noturus flavus	0.1616
White bass	Morone chrysops	0.1463
White perch	Morone americana	0.1041
Johnny darter	Etheostoma nigrum	0.0998
Quillback	Carpiodes cyprinus	0.0675
Lake trout	Salvelinus namaycush	0.0552
Longnose gar	Lepisosteus osseus	0.0528
Golden shiner	Notemigonus crysoleucas	0.0439
White crappie	Pomoxis annularis	0.0370
Northern pike	Esox lucius	0.0333
Round whitefish	Prosopium cylindraceum	0.0234
Lake whitefish	Coregonus clupeaformis	0.0222
Smallmouth bass	Micropterus dolomieui	0.0203
Redhorse spp.	Moxostoma spp.	0.0181
Coho salmon	Oncorhynchus kisutch	0.0171
Bowfin	Amia calva	0.0149

Table 1. Continued:

Species	Scientific name	Index of abundance (percent)
Black bullhead	Ictalurus melas	0.0144
Brown trout	Salmo trutta	0.0113
Chinook salmon	Oncorhynchus tshawytscha	0.0084
Splake	Salvelinus namaycush x S. fontinalis	0.0084
Longnose sucker	Catostomus catostomus	0.0067
Logperch	Percina caprodes	0.0059
Goldfish	Carassius auratus	0.0032
Rock bass	Ambloplites rupestris	0.0028
Rainbow trout	Salmo gairdneri	0.0024
Lake sturgeon	Acipenser fulvescens	0.0004
Bluegill	Lepomis macrochirus	0.0004
Largemouth bass**	Micropterus salmoides	0.0004
Ninespine stickleback	Pungitius pungitius	0.0003
Slimy sculpin	Cottus cognatus	0.0003
Bluntnose minnow	Pimephales notatus	0.0003

* Probably underrepresented due to pelagic distribution.

** Probably underrepresented due to high net avoidance.

Table 2. Additional fish species in Saginaw Bay (most species were reported by Carr 1962).

Species	Scientific name
Sea lamprey	Petromyzon marinus
Silvery lamprey	Ichthyomyzon unicuspis
Yellow bullhead	Ictalurus natalis
Tadpole madtom	Noturus gyrinus
Mudminnow	Umbra limi
Banded killifish	Fundulus diaphanus
American eel	Anguilla rostrata
Burbot	Lota lota
Longjaw cisco	Coregonus alpenae
Lake herring	Coregonus artedii
Bloater	Coregonus hoyi
Hogsucker	Hypentelium nigricans
Stoneroller	Campostoma anomalum
Longnose dace	Rhinichthys cataractae
Common shiner	Notropis cornutus
Sand shiner	Notropis stramineus
Spotfin shiner	Notropis spilopterus
Fathead minnow	Pimephales promelas
Sauger	Stizostedion canadense
Iowa darter	Etheostoma exile
Blackside darter	Percina maculata
Mottled sculpin	Cottus bairdi

Table 3. Recent plantings of walleyes into Saginaw Bay, its lower tributaries, and (marked with an *) its upper tributaries.

Year	Fry	Fingerlings
1972	50,000,000	—
1973	50,000,000	—
1974	—	5,500
1975	300,000	—
1976	300,000	—
1977	400,000 4,175,000*	— 4,070*
1978	300,000	25,000
1979	300,000 900,000*	334,427 —
1980	600,000*	9,898
1981	800,000 500,000*	294,656 —
1982	—	269,540
1983	845,735 900,000*	869,141 23,406*
1984	2,000,000* —	947,796 39,382*
1985	— —	954,218 87,921*
1986	— —	871,267 67,600*

Table 4. Estimated sport catch and effort in the Saginaw Bay area, June 1983-May 1984 and May-November 1986.[1]

Species	June 1983-May 1984	May-November 1986			
		Inner Bay	Rivers[2]	Outer Bay	Total
Yellow perch	3,626,400	1,380,700	8,700	438,200	1,827,600
Walleye	6,700	50,800	13,900	8,500	73,000
Channel catfish	36,600	63,000	2,000	14,700	80,000
Chinook salmon	8,633	—	—	10,800	10,800
Coho salmon	30	300	—	1,400	1,700
Lake trout	2,700	10	—	19,600	19,600
Rainbow trout	3,100	—	—	3,900	3,900
Brown trout	400	—	—	7,500	7,500
Northern pike	3,200	300	100	300	700
Largemouth bass	2,400	2,900	—	—	2,900
Smallmouth bass	800	1,000	—	50	1,050
White bass	1,200	43,300	15,600	50	58,950
Crappie spp.	7,500	1,400	—	—	1,400
Pumpkinseed	3,400	1,100	200	—	1,300
Sucker spp.	4,800	8,700	—	1,300	10,000
Drum	4,200	10,900	53,100	100	64,100
Angler hours	1,671,800	1,164,200	282,800	794,200	2,241,300
Angler trips	516,400	284,500	42,400	188,400	515,400

[1]Estimates for June 1983-May 1984 were derived from a creel census conducted March 1983-May 1984 (Ryckman 1986). The census area included the counties of Tuscola, Bay, Arenac, and Huron (west of Port Austin) but not Iosco County or the tributary rivers. Estimates for May-November 1986 were provided by G. Rakoczy (personal communication).

[2]"Rivers" includes the spring fishery for the Tittabawassee and lower Saginaw rivers only.

Table 5. Number of adult walleyes tagged (nearly all at Dow Dam on the Tittabawassee River) and number recaptured by anglers, 1981–86.

Tagging year	Number tagged	Number reported					
		1981	1982	1983	1984	1985	1986
1981	441	10	3	2	0	1	0
1982	727	—	8	13	6	2	4
1983	3,566	—	—	72	54	29	30
1984	4,152	—	—	—	76	78	52
1985	4,106	—	—	—	—	115	82
1986	4,631	—	—	—	—	—	96

Table 6. Back-calculated average lengths (inches) at end of year for Saginaw Bay yellow perch sampled from the commercial trap-net fishery during various periods.

	Age										
Period	1	2	3	4	5	6	7	8	9	10	Number sampled
Males											
1929–30[1]	3.0	5.3	7.7	9.3	10.6	11.5	12.8	—	—	—	203
1949–55[2]	2.6	4.2	5.6	6.7	7.6	8.5	9.3	—	—	—	2,096
1960–64[3]	2.7	4.7	5.8	6.4	7.4	8.0	8.7	—	—	—	126
1968–71[3]	3.4	5.8	7.1	7.9	8.7	9.3	9.9	—	—	—	159
1983	3.0	5.5	6.3	6.9	7.4	8.2	9.1	10.2	11.9	—	671
Females											
1929–30[1]	3.9	5.3	8.1	9.6	10.7	11.5	12.1	—	—	—	600
1949–55[2]	2.7	4.3	5.9	7.5	8.8	10.1	11.1	—	—	—	1,305
1960–64[3]	2.9	5.1	6.4	7.5	8.2	9.1	—	—	—	—	151
1968–71[3]	3.5	6.1	7.8	9.0	10.0	—	—	—	—	—	37
1983	3.0	5.8	6.8	7.6	8.5	9.5	10.7	11.8	12.8	13.0	724

Sources: [1]Hile and Jobes; [2]El-Zarka 1959; [3]Eshenroder 1977.

Table 7. Number of young-of-the-year yellow perch caught per 10-minute tow (CPE) from Saginaw Bay, fall 1970–85.

Year	CPE
1970	29.5
1971	20.3
1972	13.9
1973	30.6
1974	27.9
1975	247.9
1976	11.1
1977	52.9
1978	99.8
1979	166.7
1980	39.0
1981	71.3
1982	686.7
1983	251.9
1984	171.0
1985	147.8

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