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STATUS OF SELECTED FISH STOCKS IN LAKE MICHIGAN AND RECOMMENDATIONS FOR COMMERCIAL HARVEST

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FOREWARD

In 1967 the Michigan Department of Natural Resources established the State's first Great Lakes Fisheries Station at Charlevoix on Lake Michigan. Similar stations were subsequently established at Marquette for Lake Superior, at Alpena for Lake Huron, and at Mount Clemens for lakes St. Clair and Erie. These stations are now fully operative and are staffed and equipped to meet a variety of resource management objectives on the Great Lakes including fisheries surveillance, research, and water quality monitoring.

This report on the Status of Selected Fish Stocks in Lake Michigan, and similar ones for lakes Superior, Huron, and Erie, was prepared to meet a specific requirement, namely, to provide guidelines for management of Michigan's Great Lakes commercial fisheries. Recommendations expressed herein should be viewed as tentative, but largely representative of the direction set for future management of the commercial fisheries.

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OVERVIEW

Lake Michigan, the world's sixth largest freshwater lake, has a surface area of 22,400 square miles and a mean depth of 276 feet. It is approximately 325 miles long with an average width of 65 miles (Koelz, 1926). The watershed and the lake, covers almost 68,000 square miles. It is divided among the four states of Michigan, Wisconsin, Illinois and Indiana, and each has complete jurisdiction over the waters within its borders. Michigan controls about 59% of the lake. Lake Michigan fauna is generally typical of North American oligotrophic lakes. The principal original fish populations included sturgeon, whitefish, lake trout, seven species of chubs, herring, walleye, yellow perch and suckers.

Man's activities have caused great changes in the lake in the past 120 years. Although changes in water quality and in the lower biota have been generally modest except for local areas, those in fish communities have been vast. Commercial exploitation, invasion or introduction of marine species, accelerated eutrophication and inadequate management of the resource have been contributing factors in bringing about the decline in abundance and, in some instances, the extinction of native fish stocks. Commercial exploitation that began around 1843 in Lake Michigan was largely responsible for the changes in the fish populations of high value before the invasion of the sea lamprey in 1936. Later the sea lamprey and alewife, both non-native species, influenced the native stocks greatly, either by direct predation or competition. Until recently the commercial fishery indiscriminately pursued stocks that were abundant and in high demand. The early fishery grew very rapidly. It was conducted mostly along shore with haul seines but gill nets, pound nets and trap nets soon replaced haul seines and have been the most important gears. Trawls were introduced to Lake Michigan in the late 1950's to harvest chubs and alewife.

Annual commercial harvest from Lake Michigan averaged 25 million lb. in 1879-92, 41 million in 1893-1908, 25 million in 1909-65, and 51 million in 1966-71 (Baldwin and Saalfeld, 1962). Michigan's production has averaged 11 million lb. annually from 1933 to 1972 (Fig. 1). Catch of individual species has fluctuated much more widely than total harvest. Stocks that were fished down to uneconomical levels were abandoned and effort was shifted to those that were more abundant. If populations recovered to fishable levels, they were again exploited intensively.

Throughout the history of the commercial fishery, the efficiency of operation increased almost constantly; i.e., changes in gill net material from linen to cotton to nylon to monofilament. It is the opinion of many that the high yield for certain species was only maintained by increases in the efficiency and amount of gear fished. Consequently, the decline of some species has been substantially greater than catch figures would indicate.

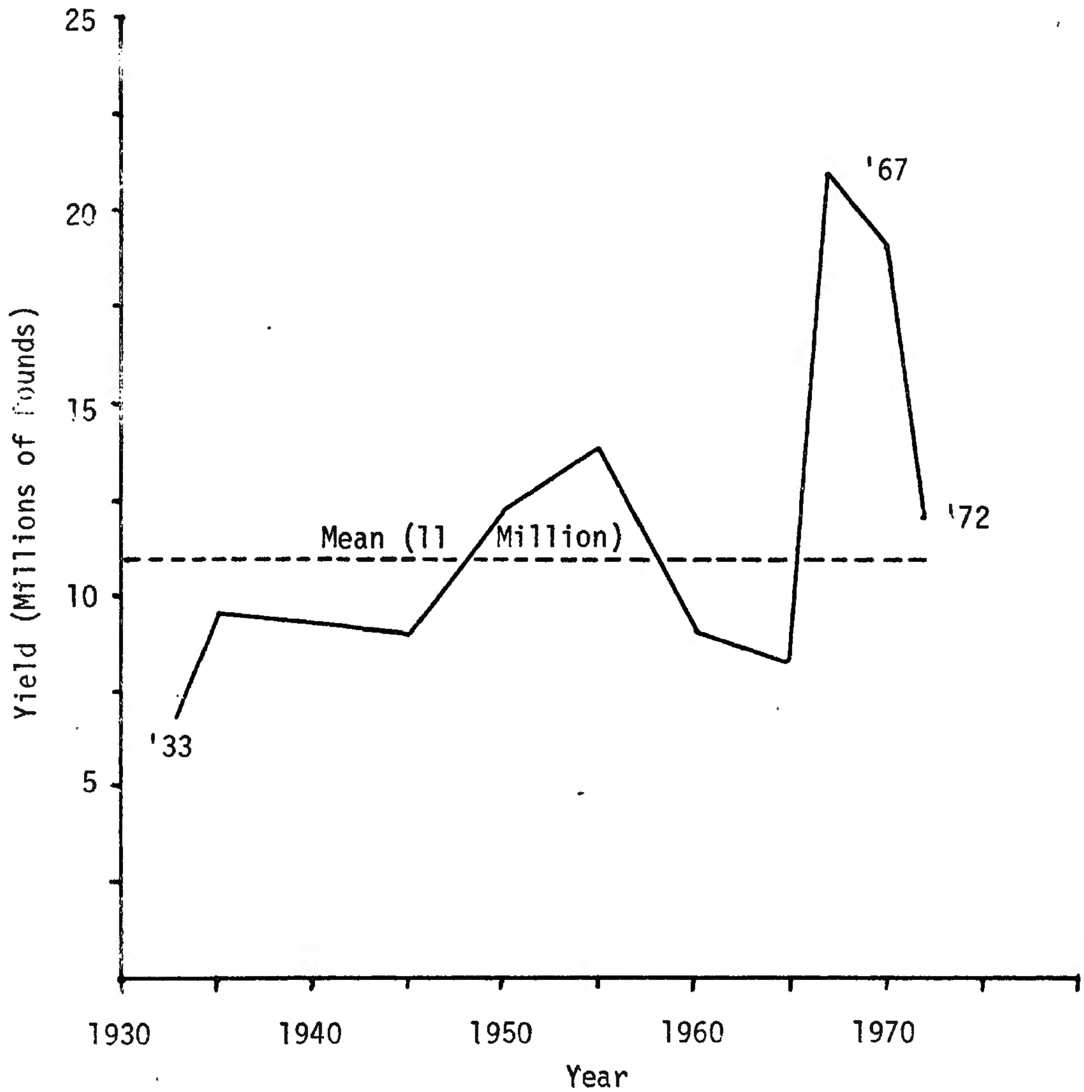

Fig. 1 - Commercial Harvest (all Species) from Michigan Waters of Lake Michigan, 1930-1972.

The Lake Michigan fishery was essentially unregulated until about 1964 because of the absence of biologically meaningful controls. During this period, it was the view of some biologists having influence over fishery management of the lake that intensive exploitation had little effect on a population or group of populations (Regier, Applegate, and Ryder, 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 biologists during this era of abuse. Recently, however, this almost unbelievable degradation of a major resource has attracted more attention than ever before. The interest and concern of management agencies have been rekindled through successful introductions of salmonid species, and the distressing problems of vanishing stocks have drawn the attention of the general public and conservationists.

For the first time in the long history of the Lake Michigan fishery, management measures have been taken to a meliorate conditions that contributed to earlier difficulties. There has been a major shift in emphasis from commercial to recreational fishing. In 1966 the Michigan Department of Natural Resources established a management policy that stated, "The broad goal of our Great Lakes fisheries program is to manage these waters for maximum development of both sport and commercial fishing. There is room for both, and there is no reason to predict at this time that one must be sacrificed for the other. However, in some areas of the Great Lakes and for some species of fish, it is entirely possible that conflicts between sport and commercial fishing interests may arise. In such instances we believe the commercial interest must be subordinated to the recreational interest. In other words, development of the sport fishery must be our primary management goal when there is a choice to be made".

This new philosophy, a drastic change from the previous laissez-faire management policy, has resulted in one of the most spectacular recreational fisheries in all of North America--indeed, throughout the world. Now is the time to incorporate a successful plan for commercial fish management. The development of a food-producing fishery that is an asset and not a liability to the resource and the public is, in fact, very possible. To reestablish a viable fishery of this nature it is necessary to know what species and the minimum size that can be fished, how many should be taken, the location and time of harvest, and the gear to be employed.

Eight species are being considered for commercial exploitation: alewife, burbot, chub (bloater), round whitefish (menominee), yellow perch, rainbow smelt, suckers and lake whitefish. All species that will be utilized fully by the sport fishery (salmon, trout, walleye, northern pike and smallmouth bass) and those that are near extinction (lake sturgeon and lake herring) are not being considered for commercial harvest. A sport fishing capability already exists that can harvest adequate numbers of these species. In fact, in some areas it may be necessary to impose more stringent controls over the recreational fishery to assure desirable levels of abundance for specific species.

The above mentioned species occupy various ecological and geographical niches in the lake. Earlier fisheries investigators recognized this and established statistical districts in 1927 that required reporting of commercial catches on an area basis (Fig. 2). The waters within the boundaries of the State of Michigan were divided into eight statistical districts, starting from the north and ending in the south (Smith, Buettner and Hile, 1961). Commercial catch records over the years have been summarized by these districts, and it is only logical that management of the future fishery conforms to these districts or their subdivisions. Recommendations for the harvest of eight species are summarized in Table 1, together with suggestions on type of gear, depth, season, and minimum size for 1974, 1977 and 1980 for each statistical district. For some species it was necessary to confine recommendations to grids (10 minutes latitude by 10 minutes longitude on a standard lake chart) within a district. Our recommendations include the closure of the Bay deNoc areas to all commercial fishing. Considerable effort and expense is being directed toward the re-establishment of a good sport fishery in these bays.[and it seems unwise to us to permit a commercial fishery to operate in these waters.]

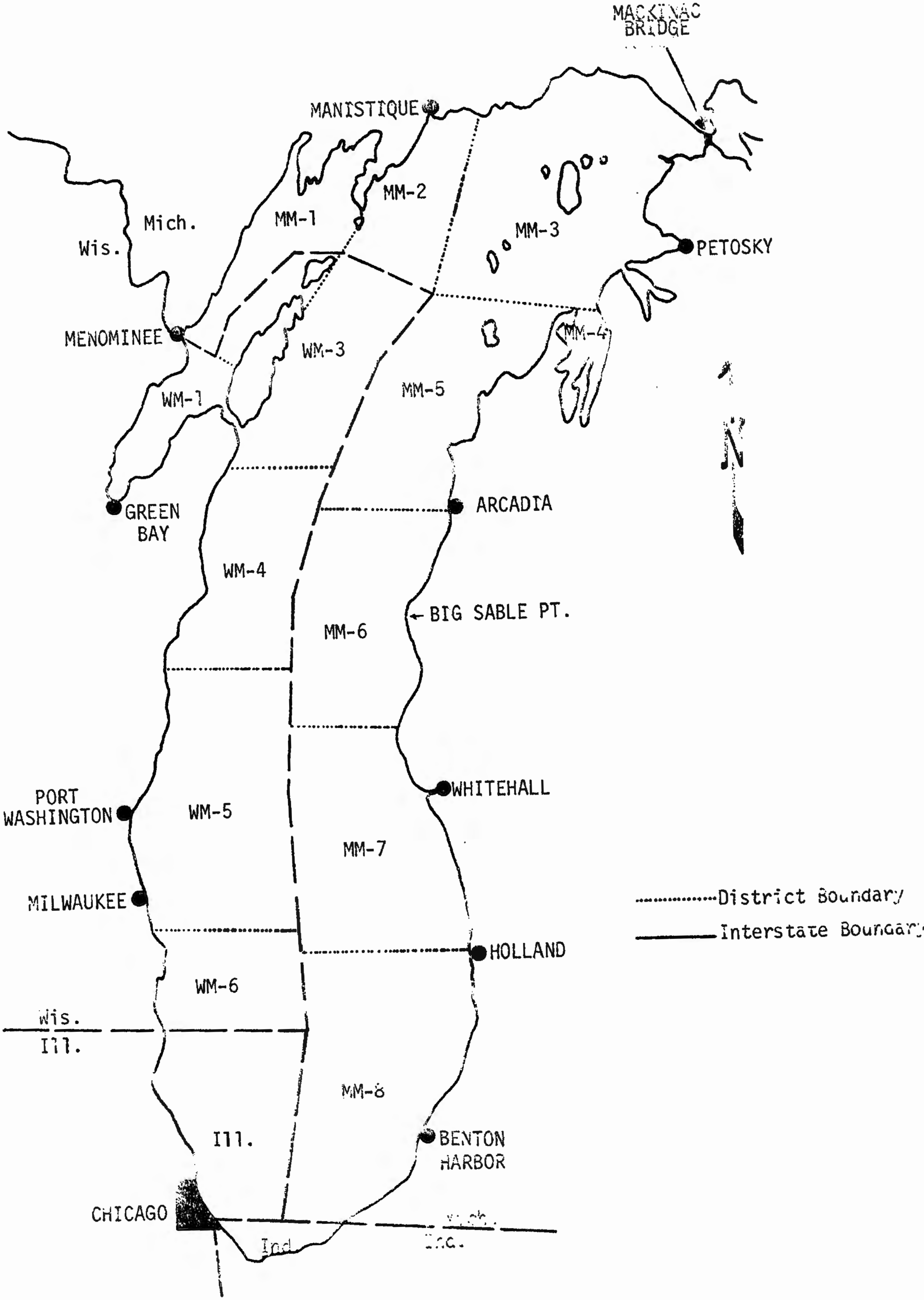

Fig. 2 - Map of Lake Michigan Showing the Statistical Districts used for Reporting Catch Statistics.

TABLE 1. COMMERCIAL FISHERIES RECOMMENDATIONS FOR LAKE MICHIGAN.

(Depths in fathoms; quotas in thousands of pounds)

Item	Statistical District: MM1[1]	MM2	MM3	MM5	MM6	MM7	MM8
ALEWIFE							
Gear[2]	Pound & Trap (small)	--	--	--	--	Pound & Trawl (small)	Pound & Trawl (small)
Depth	≤15	--	--	--	--	≤25	≤25
Quotas:							
1974	3,000	--	--	--	--	1,000	500
1977	2,000	--	--	--	--	500	250
1980	1,000	--	--	--	--	250	100
BURBOT							
Gear	Pound & Trap (large)	Pound & Trap (large)	Pound & Trap (large)	--	--	--	--
Depth	≤15	≤15	≤15	--	--	--	--
Grids	All	All	115-118 213-220 315-320	--	--	--	--
Quotas:							
1974	50	25	50	--	--	--	--
1977	100	50	75	--	--	--	--
1980	150	50	100	--	--	--	--
ROUND WHITEFISH[3]							
Gear	--	Pound & Trap (large & small)	Pound & Trap (large & small)	Pound & Trap (small)	Pound & Trap (large & small)	Pound & Trap (large & small)	--
Depth	--	≤15	≤15	≤15	≤15	≤15	--
Quotas:							
1974	--	25	50	50	25	25	--
1977	--	25	50	50	25	25	--
1980	--	25	50	50	25	25	--

Table 1, continued

Item	Statistical District						
	MM1	MM2	MM3	MM5	MM6	MM7	MM8
RAINBOW SMELT							
Gear	Pound & Trap (small)	--	--	--	--	--	--
Depth	≤15	--	--	--	--	--	--
Quotas:							
1974	2,000	--	--	--	--	--	--
1977	1,500	--	--	--	--	--	--
1980	1,000	--	--	--	--	--	--
SUCKERS							
Gear	Pound and trap nets (small and large mesh)						
Depth	≤15	≤15	≤15	≤15	≤15	≤15	≤15
Grids	All	All	115-118 213-220 315-320	712-714	All	All	All
Quotas:							
1974	500	250	350	100	100	100	100
1977	500	250	350	100	100	100	100
1980	750	250	350	100	100	100	100
LAKE WHITEFISH[3]							
Gear	Pound & Trap (large)	Pound & Trap (large)	Pound & Trap (large)	--	--	Pound & Trap (large)	Pound & Trap (large)
Depth	≤15	≤15	≤15			≤15	≤15
Quotas:							
1974	750	200	600	--	--	--	--
1977	1,000	200	800	--	--	100	100
1980	1,000	200	800	--	--	150	150
Season	--	--	--	--	--	Mar-May Sept-Oct	Mar-May Sept-Oct

Table 1, continued

Item	MM1	MM2	MM3	MM5	MM6	MM7	MM8
	Statistical District						
YELLOW PERCH[3]							
Gear	--	--	--	--	--	Pound & Trap (small)	Pound & Trap (small)
Depth	--	--	--	--	--	≤15	≤15
Quotas:							
1974	--	--	--	--	--	--	--
1977	--	--	--	--	--	100	100
1980	--	--	--	--	--	150	150

[1] Big Bay and Little Bay deNocs excluded

[2] Mesh size in parentheses

[3] Minimum Length:

Round Whitefish = 15.0"
Lake Whitefish = 19.0"
Yellow Perch = 8.5"

ALEWIFE

The alewife has been the only fish in Lake Michigan that has occupied all sections of the lake and its bays in great numbers. It was first recorded in the Great Lakes in Lake Ontario in 1873, having come there from its native habitat along the Atlantic coast. The first alewife recorded in Lake Michigan was taken in the northeastern section in 1949 (Smith, 1970). The species was dispersed throughout the lake by 1953, and the population exploded in the 1960's. Commercial harvest increased from 220,000 lb. in 1957 to 4.7 million lb. in 1967. The catch from the state of Michigan waters averaged 4 million lb. during the period 1957-72 (Fig. 3 and Appendix A). At the present time the alewife has become the most abundant and widely distributed species in the lake, displacing major native planktivorous species.

The nuisance aspect of the alewife in Lake Michigan has attracted wide public attention. During spring periods when they are concentrated along shore areas for spawning, they often cause difficulties by clogging intakes of factories and municipal water filtration plants and accumulate on beaches after dying in huge numbers. Spring mortality of alewife has been occurring since the early 1960's and a massive die-off of several billion fish, or approximately 70% of the population, occurred in 1967.

It is believed that the alewife has a detrimental effect on native fish stocks, probably mostly by competition with their young for planktonic food or by actual predation on the young. On the other hand, the alewife has made possible the successful trout and salmon program in Lake Michigan in recent years because they are the primary food for these predatory species.

The biology of the alewife population in Lake Michigan is well documented (Brown, 1972). Brown estimated that 490 million lb. of alewife were available to bottom trawls in water depths of less than 50 fathoms in the spring of 1964. Estimates of available fish in subsequent years were made in proportion to the previous fall catch rates for experimental and commercial trawling. On this basis there were 2.45 billion lb., or 171 lb. per surface acre of the entire lake, near the population peak in the spring of 1967.

Compared to the high natural mortality and the large changes in recruitment of various year classes to bottom stocks, fishing mortality for alewives over the entire lake was relatively insignificant before 1969 (Brown, 1972). The annual commercial catch through 1970 was no more than 18.6% of the estimated weight of alewife available to trawls. Brown also found that the yield per recruitment to the trawl fishery for the alewife was extremely low because of high natural mortality and an intrinsically low growth rate. Almost 47% of the experimental catch in April 1968-70, for example, was composed of age groups that were not yet available in maximum numbers to bottom trawls.

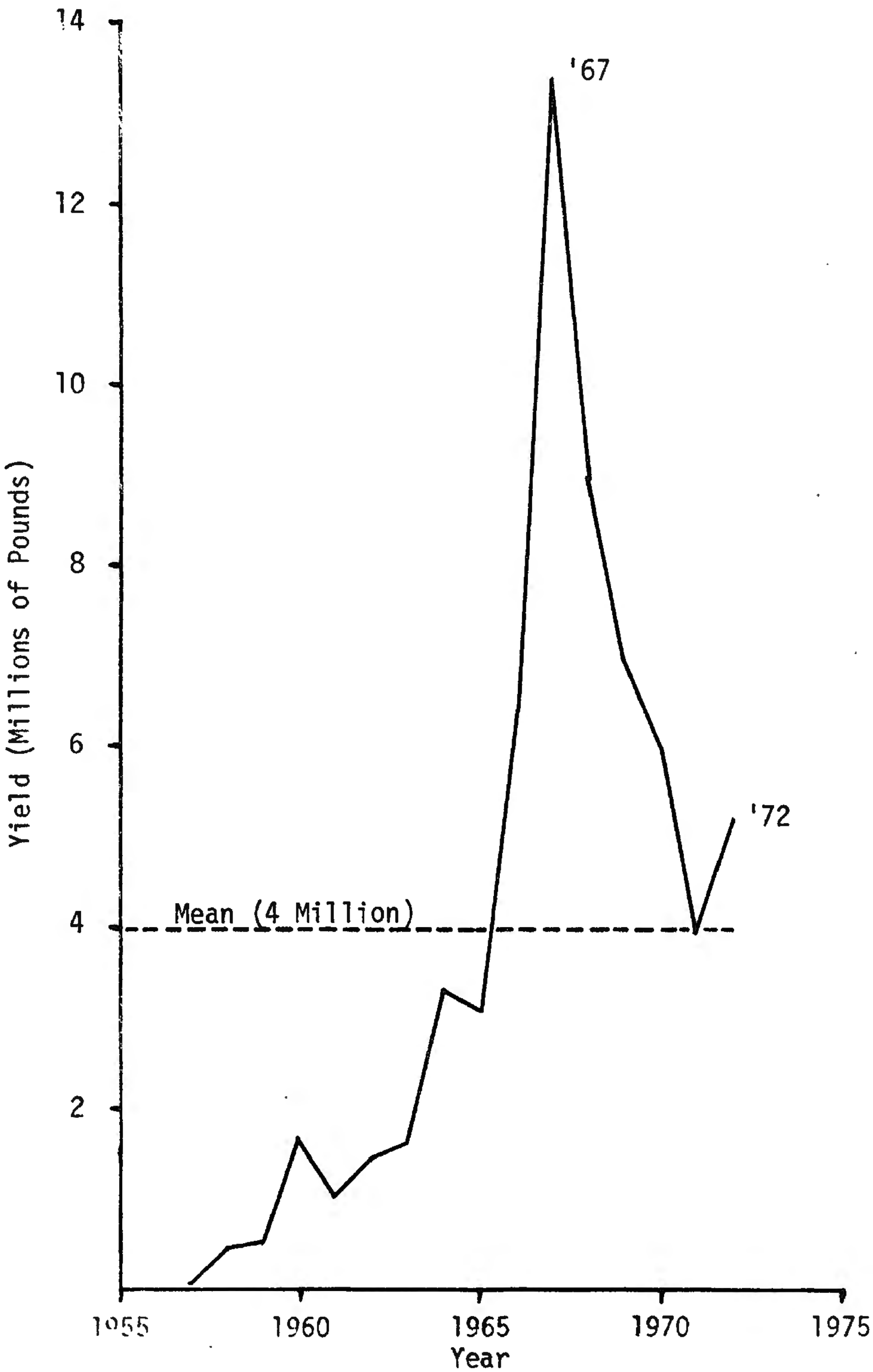

Fig. 3 - Commercial Harvest of Alewife from Michigan Waters of Lake Michigan, 1957-1972.

Brown also noted that future landings by the modest commercial fishery may be greatly affected by the forage requirements of the growing predator populations and the uncertain ability of the short-lived alewife to sustain heavy predation by salmonid species. It should be expected that the alewife population, which is so vulnerable to environmental effects, is in possible danger of collapsing when subjected to an additional unrestrained limiting factor such as predation. This danger may be especially real in the relatively small confines of Lake Michigan.

For this reason, it is recommended that the commercial harvest of alewife be restricted to modest quotas in Green Bay (statistical district MM1) and southern Lake Michigan (statistical districts MM7 and MM8), at least until major population die-offs cease (Table 1). In these areas a commercial fishery presently exists for this species. However, in some cases traditional methods of harvest will need to be changed to reduce the incidental catch of protected species. When the alewife in Lake Michigan is controlled by predatory species, commercial harvest should be terminated.

BURBOT

Literature on the life history of burbot is limited to only a few papers and recent observations from experimental catches at index stations, none of which provides adequate data on the species for management.

Although the burbot has little commercial value and is seldom taken in the sport fishery, it may be very important in the biotic community of Lake Michigan. The burbot and the lake trout inhabit similar depths in Lake Michigan and feed on similar food. Historically, both species in Lake Michigan maintained a stable ecological balance with prey species primarily in the deeper waters of the lake.

In the very early fishery, only a few local markets were available for the burbot and most fish were discarded. The flesh of the burbot is not coarse and tasteless as it has been described but is excellent as food and could be a fish for the future, awaiting only recognition as a desirable food fish.

Annual commercial catch of burbot in Michigan waters of Lake Michigan has averaged less than 10,000 lb. during the period 1930-72 (Fig. 4 and Appendix A). Since burbot have always been caught incidentally to other species, production figures do not provide indices of abundance. From numerous discussions with commercial fishermen and a review of the federal fisheries survey reports of 1930-32, it is evident that burbot were once considerably more abundant than commercial catch records indicate. One of the earlier surveys revealed that 6,000 burbot were taken in small mesh gill nets or about half the number of young lake trout that were caught (VanOosten and Eschmeyer, 1956). Although burbot did not become extinct in the mid 1950's as did lake trout, they were scarce because of sea lamprey predation and exploitation. After both factors were brought under some level of control in the late 1960's burbot populations, particularly in Green Bay and along the northern shore of the lake, showed signs of recovery. In fact, commercial production from these areas increased from 21,000 lb. in 1969 to 99,000 lb. in 1971.

No burbot were captured at index stations south of Frankfort in 1972, but the catch per unit of effort (CPE) was fairly good in the Bay deNoc areas (CPE = 2.2 fish per 1,000' of gill net) and Grand Traverse Bay (CPE = 0.42 fish per 1,000' of gill net). From this information and the catch history of the species, it is recommended that a limited commercial harvest be allowed in Green Bay (statistical district MM1) (Table 1). The catch of burbot in this area should be made with selected gear but will most likely be incidental to other species. We should also consider incidental catches of burbot in statistical districts MM2 and MM3 as part of the catch in the future food fishery. However, stocks in these areas have shown only limited signs of recovery and excessive exploitation could be detrimental.

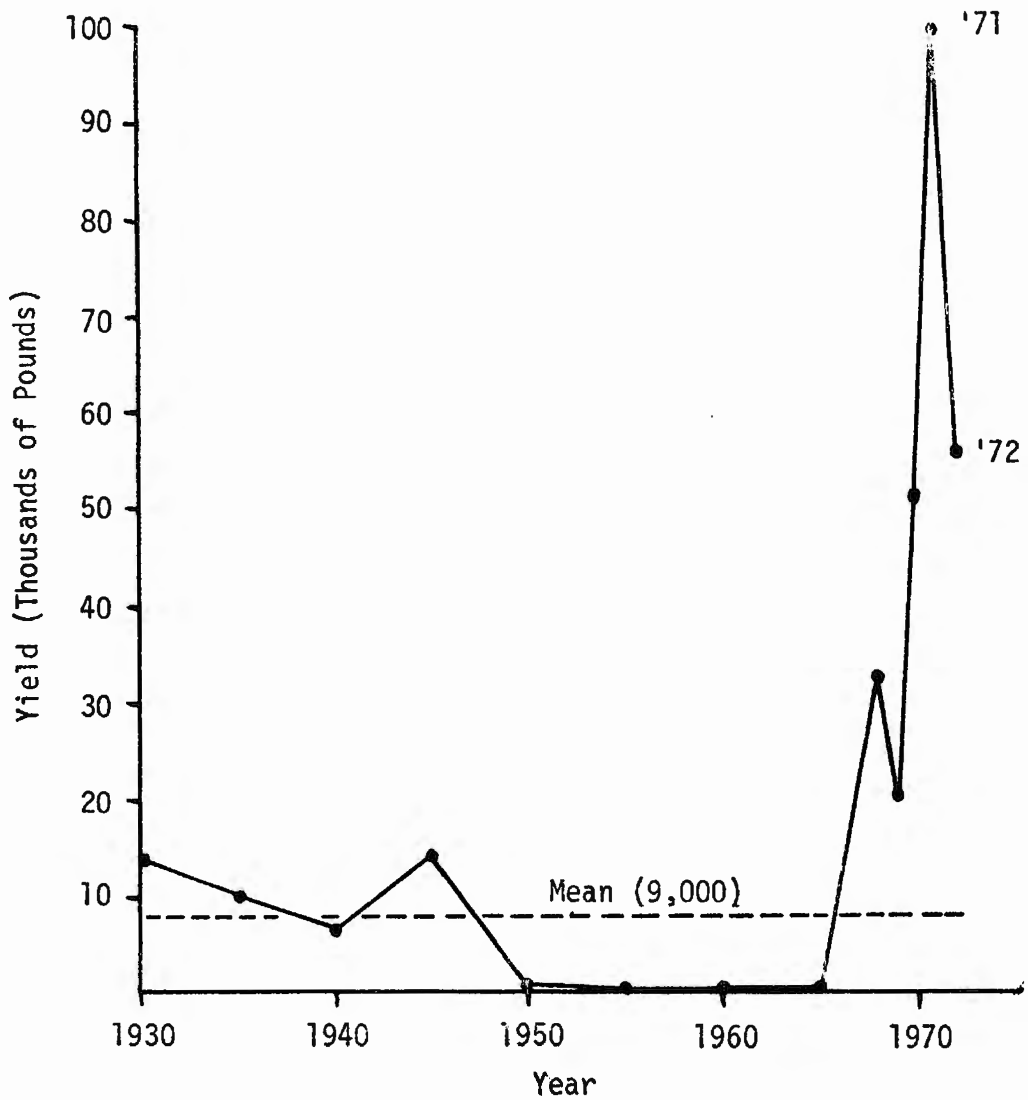

Fig. 4 - Commercial Harvest of Burbot from Michigan Waters of Lake Michigan, 1930-1972.

The only information available on burbot growth and age at first maturity is from a recent study on Lake Superior (Bailey, 1972). Average total lengths and calculated weights were 16.1" and 1.1 lb. at age V and 23.4" and 3.2 lb. at age X. Some were mature at age I at a total length of 9.7" (males) and 10.7" (females); all fish were mature at age V and at lengths greater than 16.4" (males) and 15.9" (females). We can expect these values to be either similar or possibly advanced in Lake Michigan because of higher average water temperatures. Therefore, it is recommended that all burbot held in selective fishing gear be eligible for harvest. Burbot less than 17.0" would not be desirable for sale and a size limit is not necessary.

CISCOES (CHUBS)

SPECIES SUCCESSION: Changes in species composition of chub populations in Lake Michigan have been described in considerable detail by Moffett (1957) and Smith (1964, 1968a). The history of six of the seven chub species in Lake Michigan, as traced by these authors, has been one of severe depletion in abundance and extinction for at least two of the species by 1955--blackfin cisco (C. nigripinnis) and deepwater cisco (C. johannae). Today, the bloater (Coregonus hoyi) is the only known species of chub remaining in Lake Michigan.

Chubs were first taken commercially from Lake Michigan in about 1869. The catch during the early commercial fishery was composed chiefly of the blackfins, some longjaw ciscoes (C. alpenae) and probably deepwater ciscoes. The blackfin and deepwater ciscoes, the two largest species, were only sparsely represented in index catches in the early 1930's and were non-existent in the index catches of 1954-55 and 1960-61 (Table 2). Indeed, the last positive record of C. johannae in Lake Michigan was made in June, 1951 (Moffett, 1957).

With the reduction in abundance of the blackfin and longjaw, the commercial fishery trained its exploitive guns on the intermediate-size ciscoes (C. zenithicus, C. alpenae, C. reighardi, C. kiyi). These species (including the lake herring, C. artedii) constituted about two-thirds of the deepwater chub stocks in the 1930's but declined to 23.9 and 6.4 percent in the 1950's and 1960's (Smith, 1964). These species are now either very rare or absent. Major causes of these changes, according to Smith, were the increased fishing pressure and sea lamprey predation that accompanied the disappearance of the lake trout.

The most diminutive of the chub species, the bloater, was too small to be much affected by the sea lamprey or have much of a market value during the early and mid periods of the fishery. In terms of species composition, the bloater comprised 94% of the catch by 1960-61. Since that time, however, it has declined to disastrously low population levels.

COMMERCIAL FISHERY: As early as 1947, the commercial fishery was marketing the larger bloaters taken incidentally to fishing for the intermediate-size chubs (C. kiyi, C. reighardi and C. zenithicus). By 1960, however, even the heretofore spurned bloater became an attractive source of animal food. Because of their great abundance, they could be taken by trawls cheaply and in large quantities for animal food and even the human food market accepted the small chubs at a lower price.

In Michigan waters, commercial catches of bloaters generally have ranged from 2 to 4 million lb. annually from 1960-72 (Fig. 5). Only in 1964 did the catch drop when the market collapsed due to botulism contamination of smoked chubs (Appendix A). During 1960-63 the trawl fishery accounted for 23% of the commercial catch of bloaters in Michigan waters. However, as shown in Figure 6(A), the pounds produced commercially do not provide an

TABLE 2. CATCH RATES OF CISCOES (CHUBS) TAKEN AT VARIOUS TIMES IN LAKE MICHIGAN IN IDENTICAL GANGS OF GILL NETS.[1] DATA TAKEN FROM SMITH (1964).

Year	Catch per unit of effort								
	C. alpenae	C. artedii	C. hoyi	C. johannae	C. kiyi	C. nigripinnis	C. reighardi	C. zenithicus	Unidentified
North end [2]									
1932	24.3	0.6	26.8	0.4	6.6	0.3	12.0	9.7	4.2
1955	0.8	0.7	54.4	0.0	3.8	0.0	6.5	1.0	0.2
1961	1.3	5.4	209.3	0.0	2.3	2.3	4.5	1.2	0.3
Central and south [3] (25 fathoms)									
1930-31	84.0	4.7	187.1	21.2	8.6	0.3	213.2	32.1	19.5
1954-55	27.7	1.7	562.6	0.0	9.6	0.0	20.4	18.3	10.7
1960-61	3.2	6.1	431.4	0.0	1.5	0.0	6.8	3.3	0.6
(50-60 fathoms)									
1930-31	47.0	0.3	90.3	4.7	73.7	1.8	60.5	8.8	14.7
1954-55	21.8	4.0	430.4	0.0	79.2	0.0	16.1	5.9	5.9
1960-61	3.5	5.2	353.2	0.0	19.2	0.0	4.0	3.6	0.5

[1] Catch rate expressed as number per 1,530-foot gang with equal amounts of 2 1/2, 2 5/8, and 2 3/4-inch mesh used in the north end; 2,550-foot gang in the central and southern areas with equal amounts of 2 3/8, 2 1/2, 2 5/8, 2 3/4, and 3-inch mesh.

[2] Manistique, Charlevoix and Beaver Island

[3] Grand Haven and Ludington

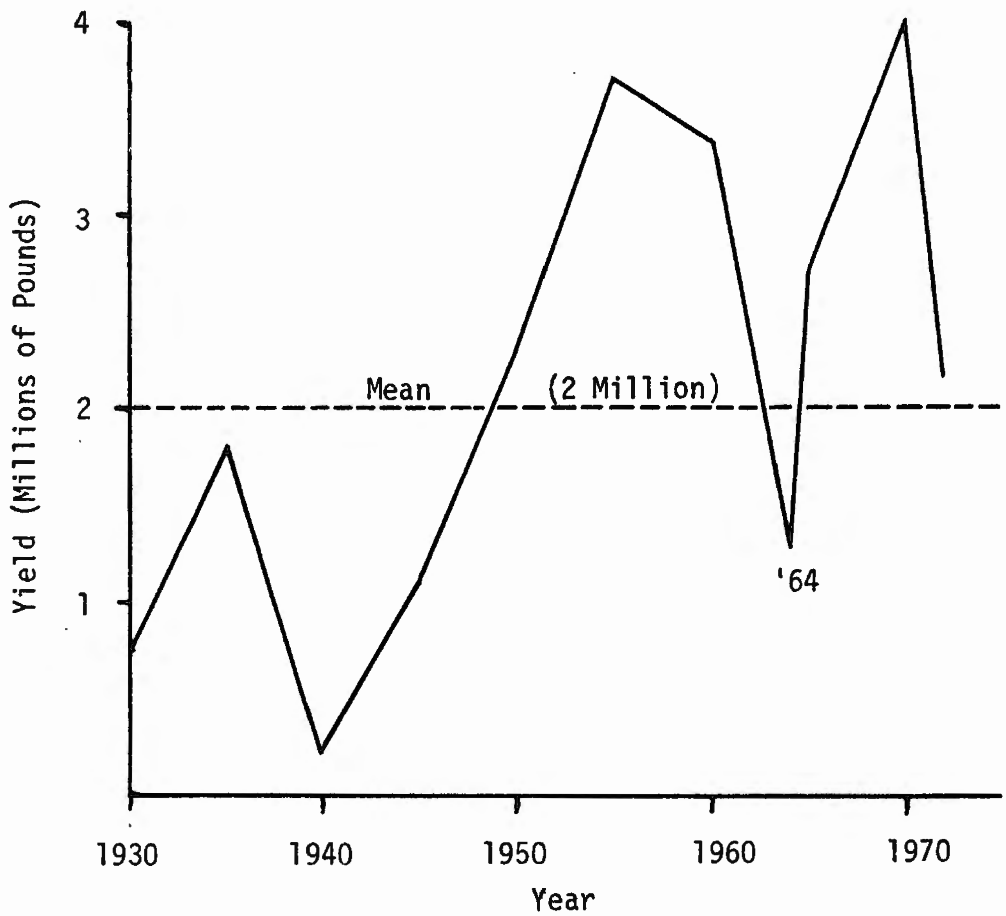

Fig. 5 - Commercial Harvest of Chubs from Michigan Waters of Lake Michigan, 1930-1972. Entire Catch after 1960 Consisted of <u>C. Hoyi</u>.

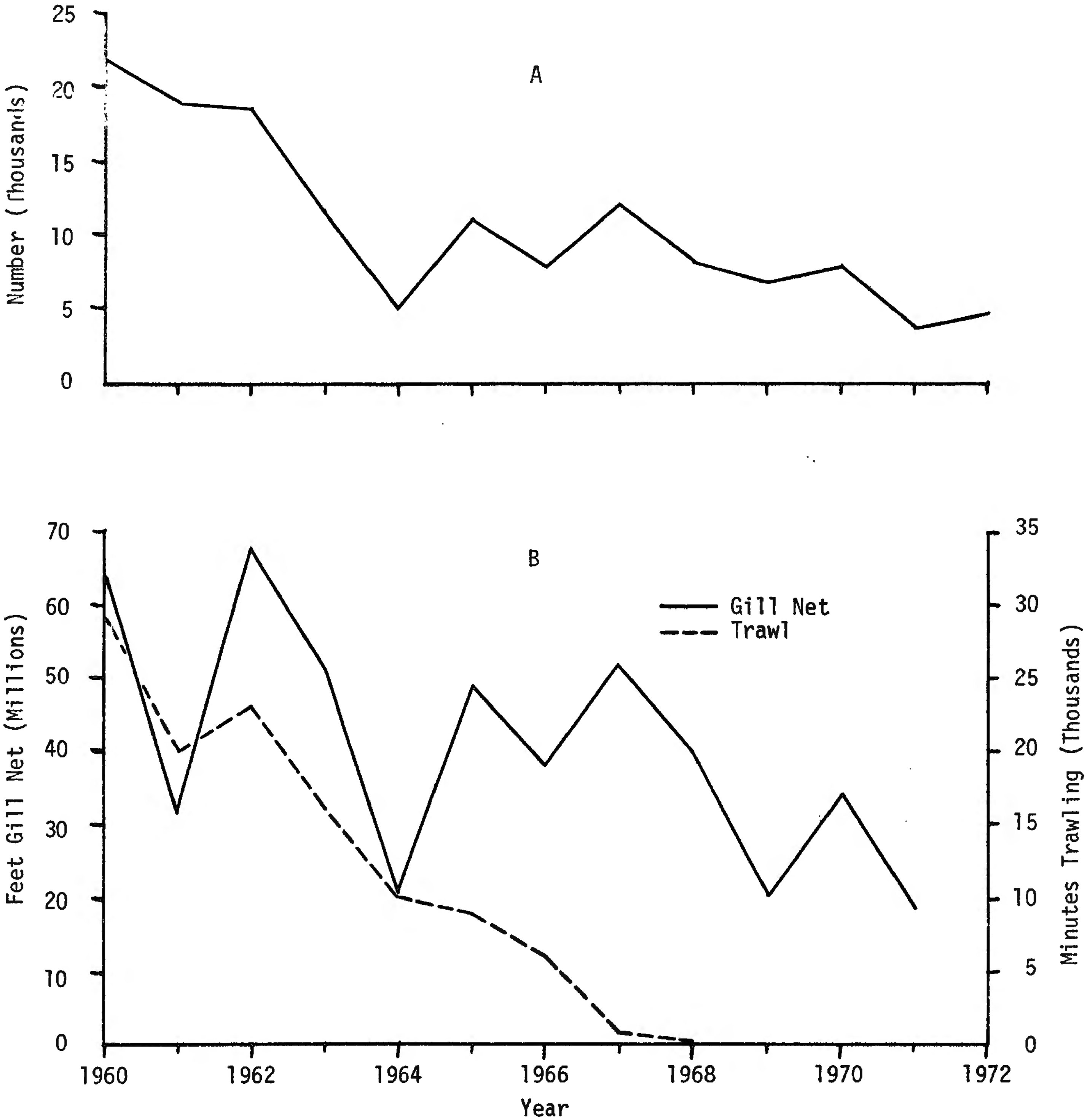

Fig. 6 - (A) Estimated Number of Bloaters Caught Commercially in Michigan Waters of Lake Michigan, 1960-1972.
(B) Commercial Fishing Effort in Michigan Waters with Small-Mesh Gill Nets and Trawls, 1960-1971.

accurate trend of the status of the bloater stocks because the size of the chub in the catch increased while the numbers caught declined. These numbers were derived by dividing the annual commercial catch (pounds) by mean weight per fish. Since no field data were available prior to 1971 on the average weight of the bloater in the commercial trawl and gill-net catches, the following best estimates were used:

	Mean weight (lb.)
1960-61	0.15
1962-63	0.20
1964-65	0.25
1966-67	0.30
1968-69	0.40
1970-72	0.50

The trend in fishing effort is shown in Fig. 6(B). Small-mesh gill net (2 1/2 - 2 3/4 inches, extension measure) effort was erratic but shows a declining trend. The trawling effort was in districts MM7 and MM8 and steadily dropped from 1960 through 1967. Catch trends in the northern (MM1-MM5) and southern (MM6-MM8) areas of Lake Michigan also were examined. The catches, particularly in numbers, corresponded rather closely to the effort which raised the question of whether or not declining numerical catches were a function of decreasing effort. On the average, effort in areas MM1-MM5 has been dropping at 7.0% per year (Fig. 7), and the catch at 11.0% per year. In the southern half of Lake Michigan (MM6-MM8), the trend in effort for the small-mesh gill nets (Fig. 8) has a slightly larger negative slope (-0.029, a decrease of 6.6% per year) than does the catch (-0.020, or 4.6% per year). These data analyses do not consider the greater efficiency of increasing the mesh size of gill nets from 2 1/2 to 2 3/4 inches to take the larger chubs. This use of larger mesh began about 1967. Greater gear efficiency would result in smaller slopes for the effort curves. Since the catch slopes would then decrease at an even greater rate than the corresponding effort slopes, the declining numerical catches must be the result of decreasing abundance rather than effort. Recent commercial catch data indicate that the fishery in northern Lake Michigan is shifting to new fishing grounds further away from the home ports. This suggests that historical fishing grounds are becoming depleted, requiring pursuit of offshore stocks.

DISTRIBUTION: Wells (1966, 1968) reported that larval bloaters were found in the hypolimnion (40-60 fathoms) and that bloaters live in mid levels in southern Lake Michigan until their third year (or about 7.0" long). The greatest proportion of adult fish are taken near the bottom.

Wells (1968) has shown that bloaters in southern Lake Michigan have a distinct seasonal depth distribution. From February through March, they occupy strata at a mean depth of 36-38 fathoms. Shoreward migration begins in May (30 fathoms) and continues into July (17 fathoms). Offshore migration is evident in August (23 fathoms) and continues through November when they are found down to 35 fathoms. Jobes (1947) determined the bathymetric distribution of bloaters in northern Lake Michigan to be 30-49 fathoms in June; 40-59 fathoms in July and September. They have been taken at depths

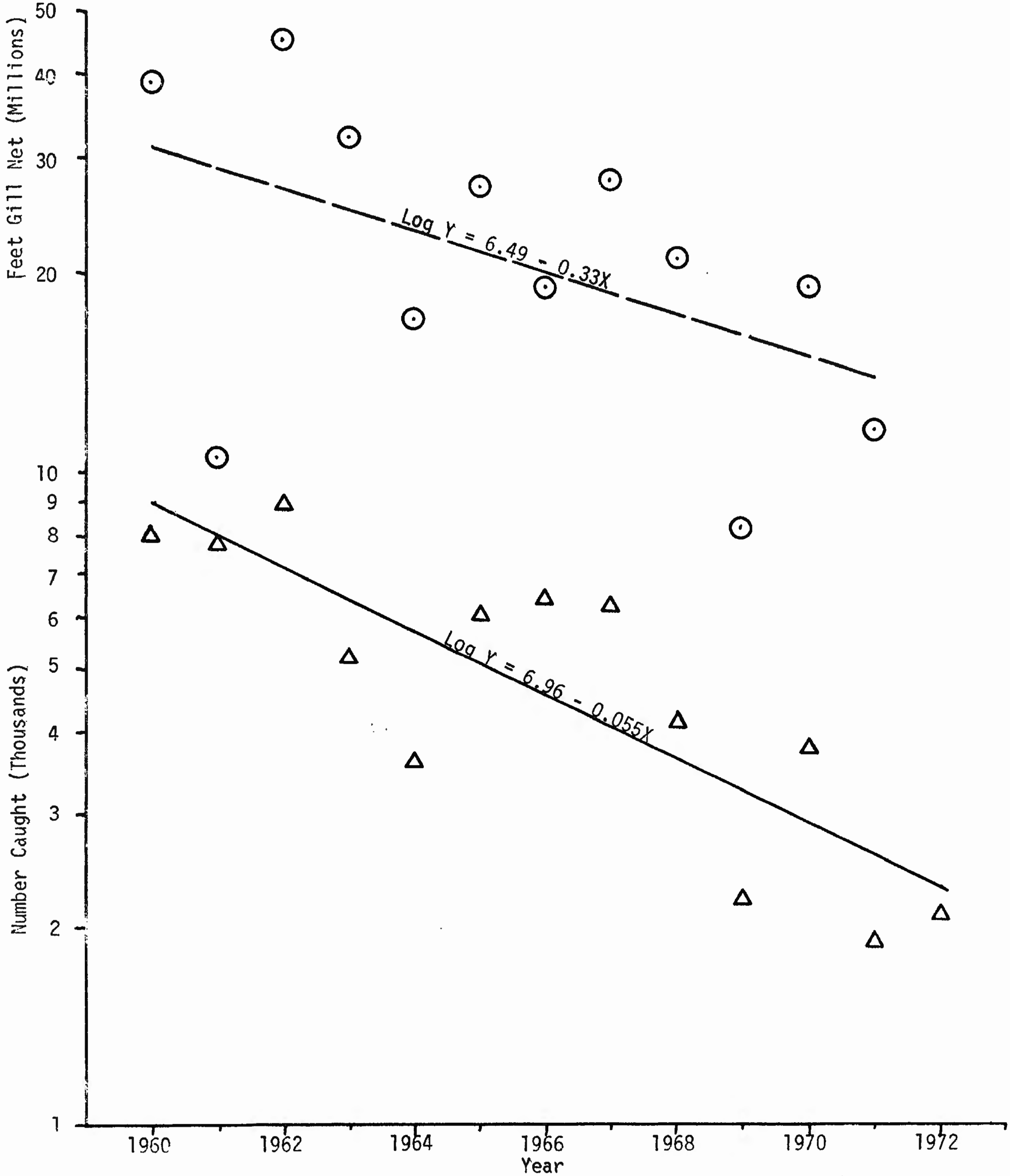

Fig. 7 - Calculated Trends in Feet of Small-Mesh Gill Net Lifted (---) and Numbers of Bloaters Caught (—) in Statistical Districts MM1-MM5, 1960-1972.

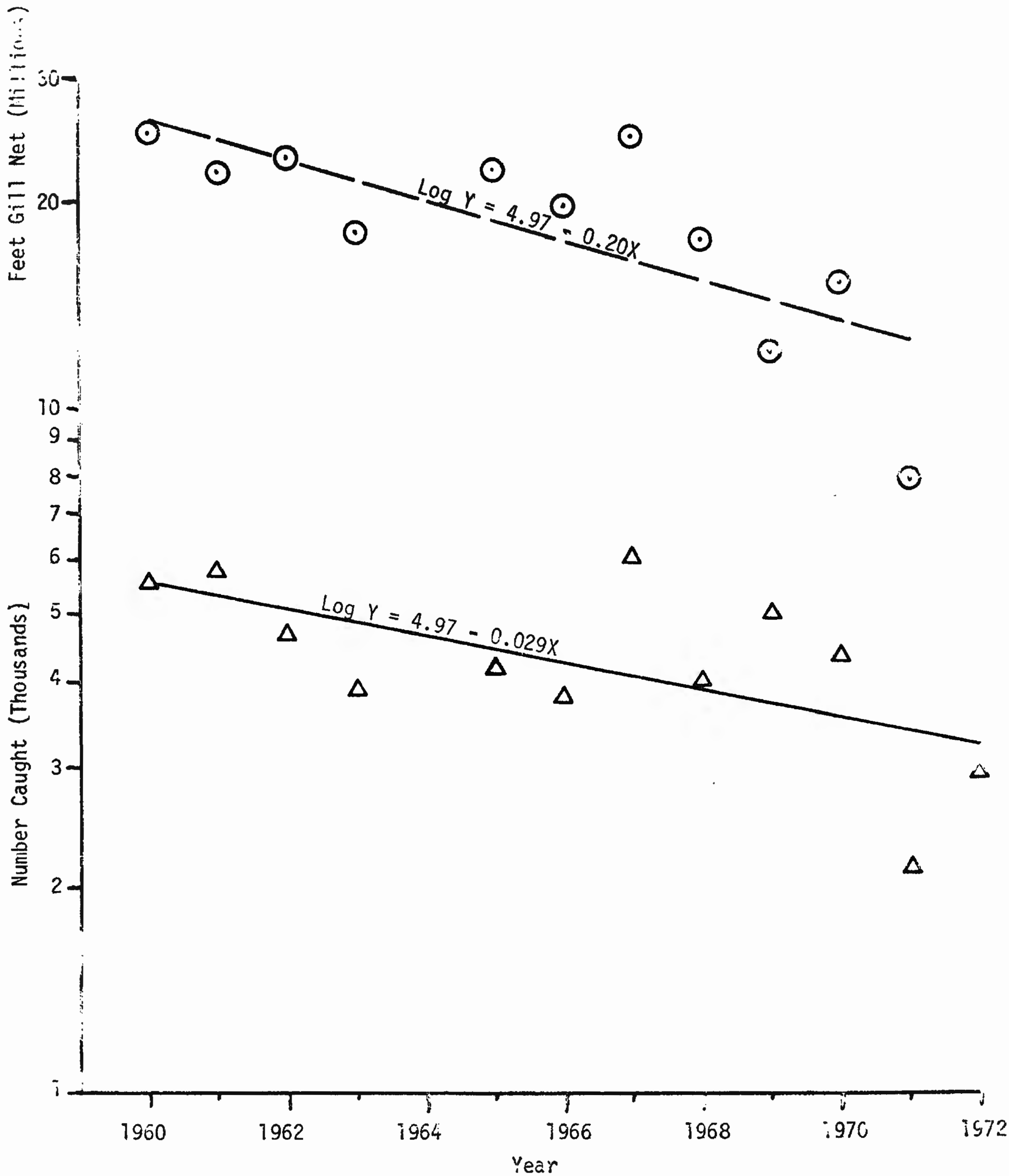

Fig. 8 - Calculated Trends in Feet of Small-Mesh Gill Net Lifted (---) and Number of Bloaters Caught (——) in Statistical Districts MM6-MM8, 1960-1972.

ranging from 3 to 140 fathoms, but, with the exception of July, the greatest abundance is between 15 and 60 fathoms.

The geographical distribution of discrete bloater stocks is not known. However, the commercial fishing areas for chubs may roughly define the boundaries of major bloater populations. In Michigan waters of Lake Michigan, there appeared to be at least four principal chub areas in 1972 (Fig. 9). The majority of grids where fishing for chubs occurred were at or inside of the 60-fathom contour; only in Area C did significant fishing occur in grids well outside of 60 fathoms.

Jobes (1947) postulated that there was very little, if any, intermingling between bloaters along the east and west shores of lower Lake Michigan. He reasoned that the deeper water between the two shores would act as a barrier because the bloaters tended to be distributed at 60 fathoms or less. This may be true for the area north of Little Sable Point, but south of this Point there is very little water of depths greater than 60 fathoms; thus, there is no effective depth barrier in the southern one-third of the lake.

AGE AND GROWTH: The average age composition of bloaters from southern Lake Michigan taken by index trawling showed a pronounced increase of from 3.2 years in 1954 to 6.0 years in 1969 (Table 3). This is also a clear indication of declining recruitment. The average age dropped to 3.1 years in 1972, indicating recruitment for ages II and III was on the upswing. This was also reflected in the catches of young-of-the-year bloaters of 7 per tow in 1969 and 8 per tow taken in 1970 (Brown and Wells, 1973). However, young-of-the-year bloater catches promptly fell to 3 per tow and 1 per tow in 1971 and 1972. The average age of bloaters captured in the Frankfort area in 1972 was 4.0 years. Presumably recruitment of bloaters in northern Lake Michigan was also improved by the somewhat stronger 1969 and 1970 year classes.

The average age of bloaters in the commercial catches sampled at Frankfort and Charlevoix in 1971 was 4.3 years (Table 4). Age-groups II-IV dominated the catch at Frankfort, while age-groups IV and V comprised 77.0% of the catch at Charlevoix.

The growth rate of bloaters in southern Lake Michigan has changed considerably since 1928 (Table 5). Most age groups in the 1954 sample were of a smaller size than the same age groups in 1928. A drop in average size would be expected to accompany the drastic increase in abundance which occurred when the number of bloaters in the southern part of the lake peaked in 1954-55. All of the age groups in the 1963-69 period showed increases in average length, ranging from 2.0 to 8.5 percent over the mean lengths in 1928.

The greatest change in growth, if the data are unbiased, occurred in 1972. Age-groups IV, V, and VI were 20, 24, and 22 percent larger, than the respective age groups in 1928. The 1972 population would have to be at an extremely low density to produce that much of a change.

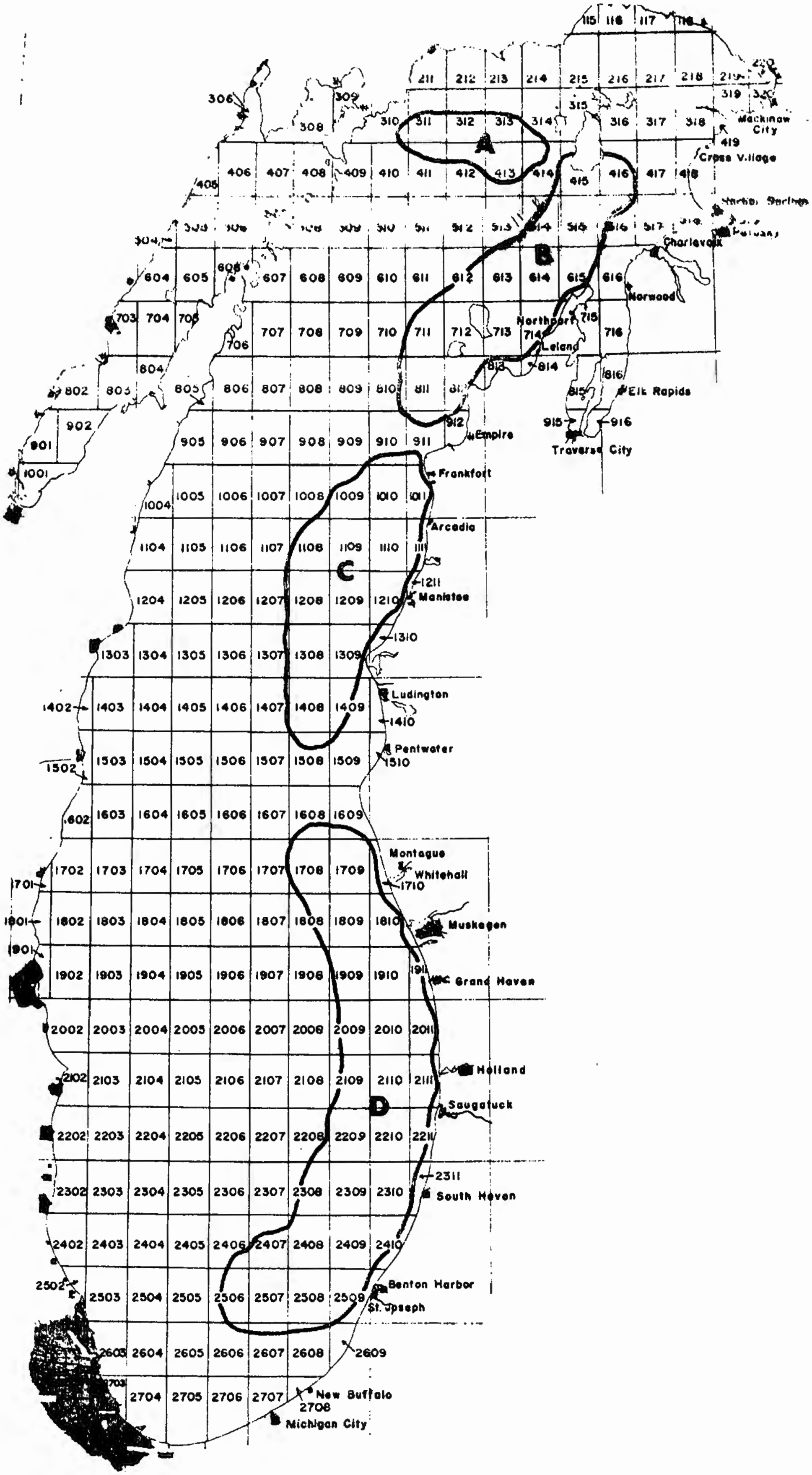

Fig. 9 - Distribution of Major Bloater Populations in Michigan Waters of Lake Michigan as Inferred from Locations of Commercial Catches in 1972.

TABLE 3. PERCENTAGE AGE COMPOSITION OF BLOATERS IN CATCHES AT INDEX TRAWLING STATIONS IN SOUTHERN LAKE MICHIGAN, 1954-1972[1]

Year	Sample Size	Age Group II	III	IV	V	VI	VII	VIII	Mean Age
1954[2]	553	21.2	45.4	18.4	9.0	2.9	0.4	0.2	3.2
1963	204	2.5	57.8	26.5	7.8	4.9	0.5	--	3.6
1964	908	2.9	62.4	20.6	9.0	4.1	0.8	0.2	3.5
1965	297	1.0	50.2	27.3	15.5	4.0	1.7	--	3.8
1966[3]	272	0.4	30.5	31.2	19.9	11.4	4.4	1.8	4.3
1967	201	--	12.9	39.3	23.9	14.4	8.5	1.0	4.7
1968	178	--	10.1	20.2	33.7	23.1	9.0	3.9	5.1
1969[4]	202	3.0	2.5	5.9	29.7	26.2	20.3	6.9	6.0
1972[2]	845	21.4	53.0	17.9	5.3	0.7	--	--	3.1
1972[5]	294	11.3	22.9	31.7	22.2	10.2	1.0	0.7	4.0

1 1954-1969 data from Brown, 1970

2 1954 age-group I--2.5%
1972 age-group I--1.7%

3 age-group IX--0.4%

4 age-group IX--5.0%; age-group X--0.5%

5 Frankfort area

TABLE 4. PERCENTAGE AGE COMPOSITION OF BLOATERS SAMPLED IN THE COMMERCIAL CATCH AT FRANKFORT AND CHARLEVOIX IN OCTOBER, 1971. CATCHES WERE FROM 2 3/4-INCH MESH GILL NETS.

Age Group	% Age Composition	
	Frankfort	Charlevoix
I	1.9	--
II	17.6	5.1
III	22.2	7.7
IV	18.5	43.6
V	14.8	33.3
VI	9.3	7.7
VII	12.0	2.6
VIII	3.7	--
Mean Age	4.2	4.4
Sample Size	108	39

TABLE 5. MEAN LENGTH (INCHES) OF AGE-GROUPS I-IX FOR BLOATERS IN SOUTHERN LAKE MICHIGAN, 1928-1972. PERCENTAGE CHANGES FROM THAT OF 1928 SHOWN IN PARENTHESES.

Age Group	Year			
	1928	1954	1963-69	1972
I	3.6	3.4 (-5.6)	3.9 (8.3)	--
II	5.8	5.7 (-1.7)	6.2 (6.9)	6.5 (12.1)
III	7.1	7.0 (-1.4)	7.7 (8.5)	7.8 (9.9)
IV	7.9	7.9 (0.0)	8.5 (7.8)	9.5 (20.3)
V	8.9	8.7 (-2.2)	9.2 (3.4)	11.1 (24.7)
VI	9.5	9.3 (-2.1)	9.7 (2.1)	11.6 (22.1)
VII	10.2	9.7 (-4.9)	10.1 (3.9)	--
VIII	--	10.3	10.6	--
IX	--	--	11.0	--

SPAWNING TIME, AGE AT MATURITY AND SEX RATIOS: Koelz (1929) reported that bloaters spawn mostly during February and March, although some spawning may occur in nearly all months of the year. There are no other published observations on the spawning habits of this species. However, it is reasonable to infer that the bloaters spawn at depths where they are most commonly found during February and March which is 30-50 fathoms. Wells (1966) reported that 83% of the bloater larvae were taken at depths of 40-60 fathoms and that the depth of greatest abundance appeared to be between 50 and 60 fathoms.

Ages at maturity for male and female bloaters are given in Table 6. Note that the bloaters sampled in September are nearing the end of the growing season and each age group, therefore, should be considered as age t + 1; e.g., age 2 + 1 = 3. With that adjustment, 77% of age III and all age-IV females at South Haven-Holland (September) were mature as compared to 70% and 90% for the respective age groups of female bloaters at Frankfort (June).

Brown (1970) discussed in detail the extreme predominance of females in the Lake Michigan bloater population and this is the source of much of the following information. The percentage of female bloaters in index trawling catches from southern Lake Michigan increased from 77% in 1954-55 to 95% in 1969 and dropped to 65% in 1972 (Table 7); female bloaters in northern Lake Michigan comprised 69% of the catch in 1954-55, 97% in 1969, and 79% in 1972. There is some evidence that sexual imbalance is the result of extreme environmental stresses. Svardson (1945) reported a dominance of males in *Betta splendens* when food, space and water conditions were poor. Clady's study (1967) showed that unusually large percentages of females (93-99%) appeared as the lake herring population declined in Birch Lake, Michigan, a phenomenon not unlike that for the Lake Michigan bloater. Sexual imbalance in Lake Huron bloater stocks preceded the demise of that species during the early to mid 1960's (Eshenroder, personal communication). The reduction of female dominance in 1972 may indicate some stability of bloaters at low population densities but the status of the species is still critical (Brown and Wells, 1973).

Other species of Lake Michigan chubs have also exhibited a preponderance of females even during 1930-32 when these species were relatively abundant --C. *reighardi*, 67% (Jobes, 1942); C. *alpenae*, 76%, (Jobes, 1946); and C. *kiyi*, 88%, (Deason and Hile, 1947). Apparently female dominance is characteristic of the chubs, but extreme female preponderance implies a population under severe stress.

ABUNDANCE: The bloater population in central and southern Lake Michigan probably attained maximum density about 1955. The index of relative abundance (CPE) tripled between 1930-32 and 1954-55 in southern Lake Michigan--187 in 1930-31; 562 in 1954-55 (Table 2). In the northern portion of the lake, the bloater abundance index increased from 26.8 in 1930-32 to 54.4 in 1955; 209.3 in 1961. In terms of species composition, they made up 31% of the index chub catch in 1930-32 and increased to 76 and 94 percent in 1954-55 and 1960-61, respectively (Smith, 1964). Smith believed that disappearance of the predaceous lake trout and burbot coupled with the intensive fishery for the larger ciscoes explained the rising dominance of the bloater. Selective destruction of lake trout and burbot

TABLE 6. AGE AT SEXUAL MATURITY FOR BLOATERS SAMPLED BY INDEX TRAWLING AT FRANKFORT IN JUNE AND IN SOUTH HAVEN-HOLLAND AREA IN SEPTEMBER, 1972

	June				September				
Age	% Mature Males	% Mature Females	Sample Size Males	Sample Size Females	Age t+1	% Mature Males	% Mature Females	Sample Size Males	Sample Size Females
2	50	20	2	10	2	100	0	1	2
3	100	70	6	10	3	97	77	29	22
4	100	90	4	10	4	100	100	11	27
5	--	100	0	11	5	100	100	2	17
6	100	100	2	8	6	--	100	0	8
7	--	100	0	1	7	--	100	0	1
8	--	100	0	2	8	--	--	--	--

TABLE 7. PERCENTAGE OF FEMALE BLOATERS IN INDEX TRAWLING CATCHES IN LAKE MICHIGAN[1]

Year	South	North
1954-55	75	69
1960-61	92	88
1963	95	--
1964	94	--
1965	97	--
1966	97	98
1967	97	96
1968	97	97
1969	95	97
1972a	65	--
1972b[2]	64	79

[1] Data for 1954-1972a from Brown (1970) and Brown and Wells (1973)

[2] Data from index trawling by S/V Steelhead

was increased greatly as the sea lamprey invaded Lake Michigan and increased in abundance. By the early 1950's, lake trout were extremely scarce. Because both the lake trout and burbot preyed heavily on the small bloater, a decrease in abundance of these predators eased the pressure and allowed the bloater population to increase. As the lake trout decreased, the commercial fisheries directed their effort to the larger chub species. This, combined with lamprey depredation on large chubs, reduced those populations to their lowest levels. The small chubs (C. hoyi) took advantage of its much improved competitive position and expanded. However, the high population levels for the bloater were short-lived. Index trawling by the R/V Cisco from 1960 to 1972 has shown that the bloater population in the southern one-half of Lake Michigan has declined at a rate of 20% per year (Fig. 10). The average catch per 10-minute trawl tow in 1972 had dropped 94% from the "normal" population level of 1930-32, 98% from peak abundance in 1954-55, and 92% from 1960 (Table 8). Thus the bloater abundance presently is only 6% of what it was during the stable period of 1930-32! Ricker (1963) demonstrated the adverse effects of extremely low spawning-stock density on recruitment. We believe that the bloater stock in southern Lake Michigan is at the low end of the spawner-recruitment curve and, if not already over the edge, is at least on the brink of disaster.

Little effort has been made to follow the chubs in northern Lake Michigan in recent years. The only reliable data available has been in the Frankfort area and even that indicates a 50% reduction from 1971 (74 per tow) to 1972 (37 per tow). However, the trend in the estimated catch in numbers in MM1-MM5 is one of continuous recession (Fig. 7). In all probability, the bloater populations in northern Lake Michigan are no better off than those in the southern area of the lake.

There was no evidence of a massive and spectacular die-off after reaching peak abundance in 1955-56 such as the alewife exhibited in 1967. Indeed, extrapolation of the abundance trend shown by Brown and Wells (1973) back to 1954 agrees perfectly with the converted 1954-55 index CPE of 1,100 bloaters per trawl tow (Table 8), indicating that the average rate of decline from 1955 to 1960 must also have been on the order of 20% per year. Two favored explanations for the bloater demise are competition with the alewife and over-fishing.

ALEWIFE COMPETITION: The build-up of the alewife population in Lake Michigan coincided with the decline of the bloater population in the same water. Both species simultaneously inhabit the same areas and depths of the lake at least part of the time (Smith, 1968b), and both rely heavily on the zooplankters Mysis and Pontoporeia (Wells and Beeton, 1963).

Brown and Wells (1973) stated that "...there is no real evidence anywhere that bloaters and other deep water ciscoes can sustain themselves in the presence of large populations of alewives (and possibly smelt). Drastic changes in the fish stocks of lakes Huron and Ontario suggest that ciscoes are incompatible with, and are eventually replaced by, the

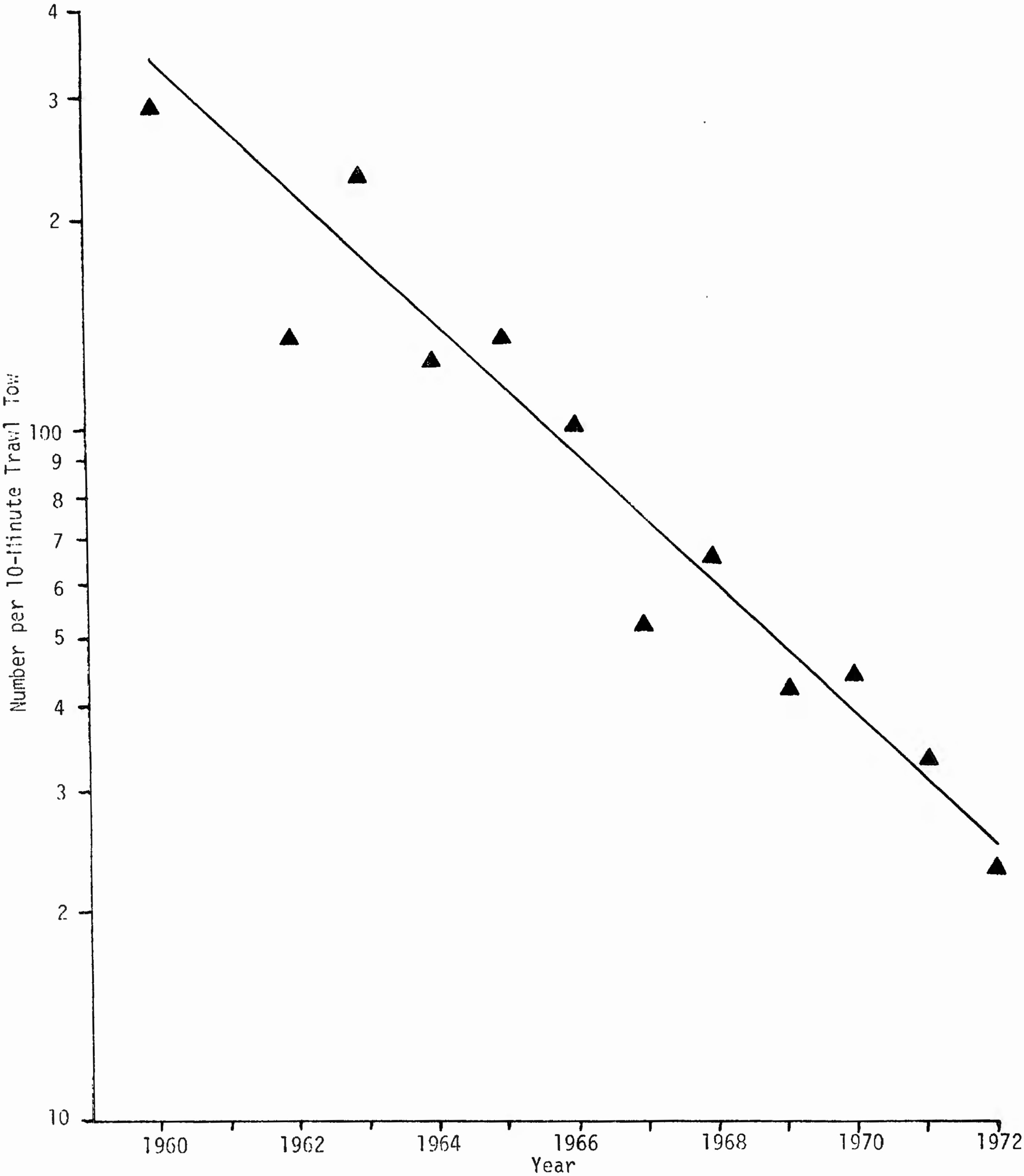

Fig. 10 - Mean Catch of Adult Bloaters Taken at Trawling Index Stations in Southern Lake Michigan (Ludington, Saugatuck, Benton Harbor and Waukegan), 1960-1972. Data from Brown and Wells, 1973.

TABLE 8. CATCH OF BLOATERS PER 10-MINUTE TRAWL TOW AT INDEX STATIONS IN SOUTHERN LAKE MICHIGAN[1] AND THE PERCENTAGE CHANGE FROM PREVIOUS YEARS

Year(s)	% Change from Year(s)	CPE and % Change West Shore	East Shore	Combined
1930-32	--	183*	534*	359*
1954-55	--	466*	1733*	1100*
	1930-32	+ 155%	+ 225%	+ 206%
1960	--	--	--	290
	1930-32	--	--	- 19%
	1954-55	--	--	- 74%
1965	--	--	--	137
	1930-32	--	--	- 62%
	1954-55	--	--	- 87%
1972	--	5	29	23
	1930-32	- 97%	- 95%	- 94%
	1954-55	- 99%	- 98%	- 98%
	1960	--	--	- 92%

1 Ludington, Saugatuck, Benton Harbor, and Waukegon 1960-1972. Manitowoc, Ludington, Racine and Grand Haven, 1930-55.

* Converted from gill net catch to catch/10-minute trawl tow by regression $\hat{y} = 3.25x - 2.08$, where x is the catch/1,000' of gill net multiplied by a factor of 3.0 (efficiency of nylon net over cotton net).

non-native competitor species". However, Christie (1972) stated that "...the resurgence of the premium fish stocks (in Lake Ontario) in the 1920's in the face of heavy alewife densities, argues in favor of a harmless role for the alewife. The resurgence of the deepwater ciscoes (in Lake Ontario) in the 1930's was also seemingly unaffected by the alewife. Equally important, the collapse of the ciscoes was not followed by a surge of alewife abundance as might have been expected if competition pressure had been a major consideration." It should also be noted that six of the seven species of chubs in Lake Michigan had practically or totally disappeared before the advent of the alewife, and that the bloater population apparently began its decline before alewife abundance peaked in 1965-66.

We believe that alewife have had less of a debilitating effect on the chubs than has exploitation.

<u>MORTALITY RATES</u>: Natural mortality rates of bloaters in Lake Michigan were estimated from data obtained from experimental gill net fishing during 1930-32. The chub populations probably were quite stable during this period and subject only to natural mortality.

Jobe's (1947) 1930-32 data did not contain age composition, and length frequencies were used to plot catch curves (Fig. 11). The calculated regression of the descending leg of each catch curve is shown as the dotted line, and the slope approximates the rate of natural mortality. The annual natural mortality rate of bloaters in lower (MM6-MM8) and upper (MM2-MM5) Lake vichigan during 1930-32 was 65% and 63%, respectively.

Brown (personal communication) has estimated annual natural mortality rates of 56% for bloaters taken in index trawling in lower Lake Michigan during 1963-65 and 1967-69 (Table 9, Fig. 12). The discrepancy between the 1930-32 and 1963-69 estimates may be due partly to the tendency of mortality rates obtained from gill-net samples to be over-estimated (Cucin and Regier, 1966), whereas the trawl tends to provide a more representative sample. However, a good size range of gill nets was employed to take the 1930-32 samples (see footnote 1, Table 2) so that the estimate should have had at most only a slight positive bias. Alternatively, the larger natural mortality rates during 1930-32 might merely have reflected intensive predation upon the bloater by lake trout and burbot. Once the lake trout and burbot disappeared, natural mortality dropped to 56%. It could be argued that commercial fishing also reduced natural mortality and, at the same time, increased total mortality. While the latter probably is true, Brown's calculations indicated a constant natural mortality rate (0.56) during 1963-65 and 1967-69 while the fishing rates averaged 0.64 and 0.34, respectively (Table 9). Even with the rehabilitation of predatory salmonid populations, it is improbable that the bloater population will again face such intensive predatory pressures because the alewife and smelt almost certainly will serve as a buffer. Examination of some 5,000 lake trout stomachs during 1969-72 revealed no chubs in the diet; however, alewife, smelt and sculpin were found. Thus the annual natural mortality rate should remain at approximately 56%.

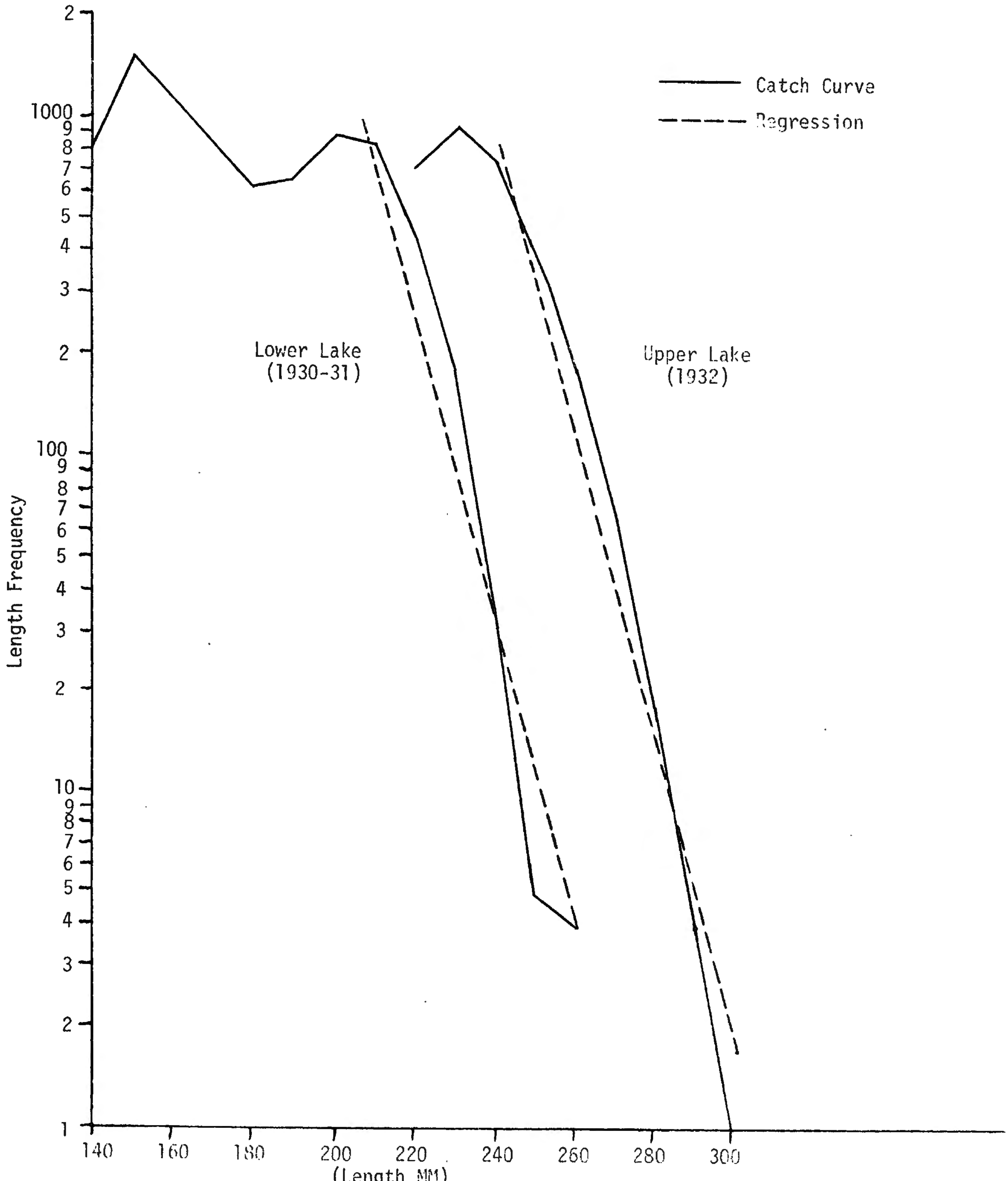

Fig. 11 - Catch Curves for Lake Michigan Bloaters Based on Length Frequencies in Gill Nets. See Note 1, Table 2, for Net Specifications. (Data from Jobes, 1947).

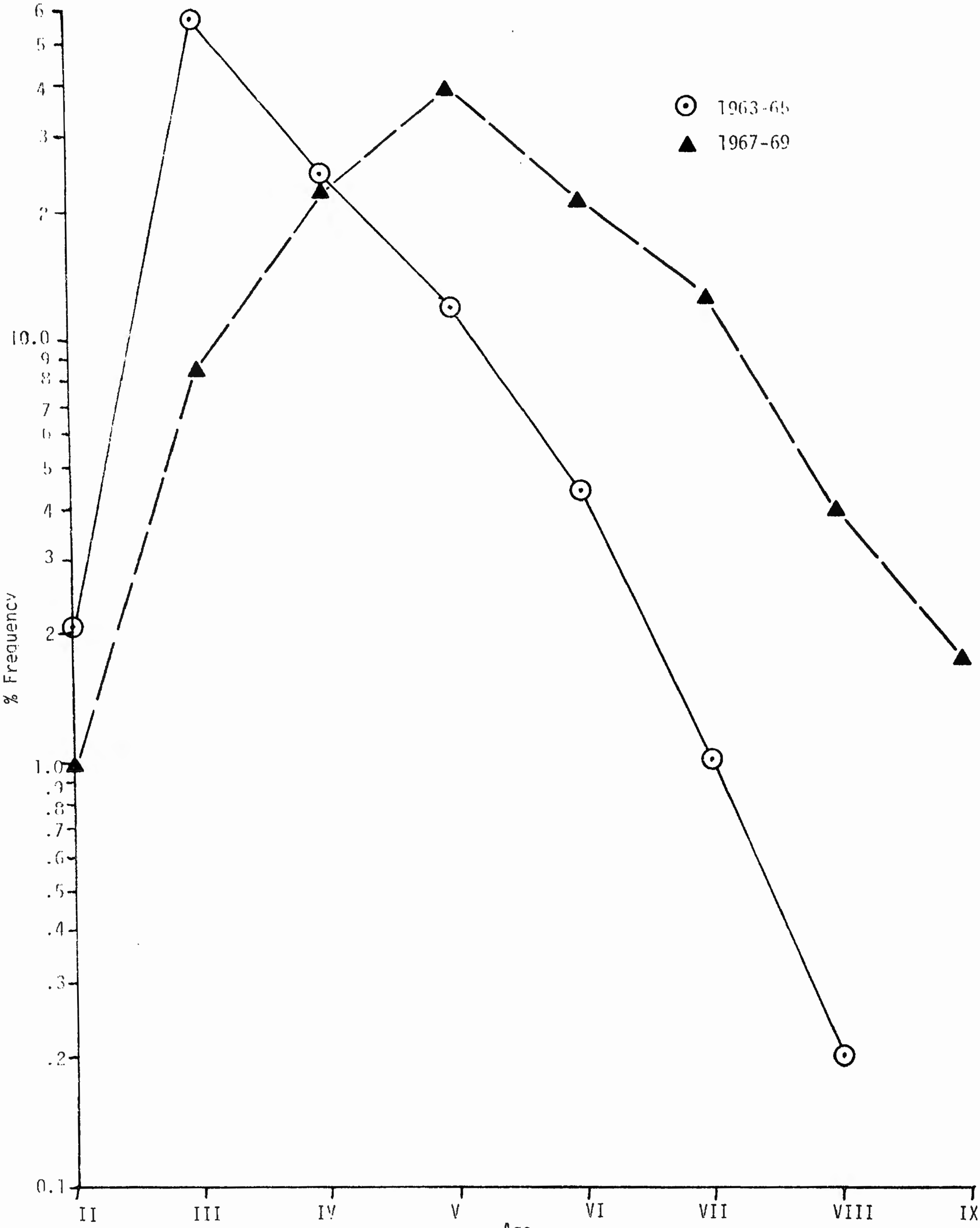

Fig. 12 - Average Catch Curves for Bloaters taken in Southern Lake Michigan by Index Trawling, 1963-65 and 1967-69. (Data from Brown by Personal Communication).

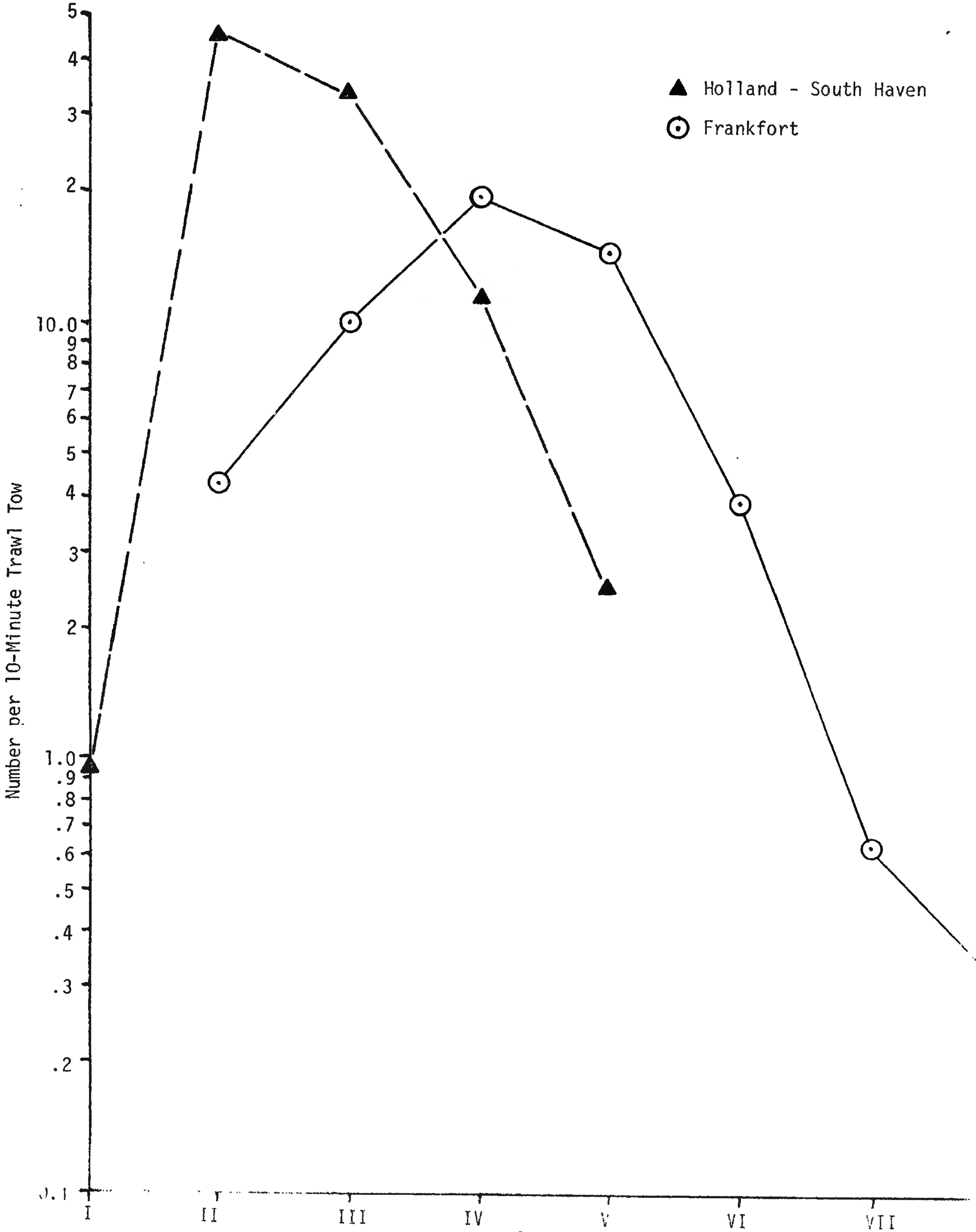

Fig. 13 - Catch Curves for Bloaters from Index Trawling at Frankfort, June 1971-72, and Holland-South Haven area, September 1972.

TABLE 9. ESTIMATED ANNUAL MORTALITY RATES FOR LAKE MICHIGAN BLOATERS (INSTANTANEOUS RATES IN PARENTHESES).

Lake Area	Years	Ages or Lengths	Survival	Mortality Total	Mortality Natural	Mortality Fishing
Lower (MM6-8)	1930-31[1]	200 mm+	.35	.65 (1.05)	.65 (1.05)	.00 --
	1963-65[2]	VI-VII	.23	.77 (1.47)	.56 (0.83)	.47 (0.64)
	1967-69[2]	VII-VIII	.31	.69 (1.17)	.56 (0.83)	.30 (0.34)
	1972	IV-V	.22	.78 (1.51)	.56 (0.83)	.49 (0.68)
Upper (MM2-5)	1930-31[1]	240 mm+	.37	.63 (0.99)	.63 (0.99)	.00 --
	1971-72	V-VII	.21	.79 (1.56)	.56 (0.83)	.52 (0.73)

[1] Data from Jobes (1947, Table 12)

[2] Data from Brown (pers. comm.)

Index trawling data from the South Haven-Holland area in 1972 and Frankfort in 1971-72 indicated an average annual total mortality rate of 79% (Table 9, Fig. 13), the instantaneous rate of which is 1.54 subtracting the instantaneous natural mortality rate of 0.83, we arrive at an average instantaneous fishing rate of 0.71, or an annual fishing mortality of 51%.

Historically, the bloater apparently was able to maintain a stable population level at a mortality rate of 65%. Ideally, then, the present instantaneous rates of natural mortality (0.83) plus fishing mortality should equal the instantaneous total mortality rate of 1.05 (equivalent to the annual total mortality of 65%). Thus the instantaneous rate of fishing should be: 1.05 - 0.83 = 0.22,or an annual fishing mortality of 20% rather than the present 51% noted above. Ricker (1963) pointed out that an increase of only 14% over the optimum rate of fishing could result in a swift and drastic decline in both stock and catch. If 0.22 is the optimum instantaneous rate of fishing, then the current average fishing rate of 0.71 exceeds 0.22 by 3.2-fold, or 223%. Even if 0.50 were the ideal fishing rate, the optimum would still be exceeded by 42%. If fishing is not solely responsible for the decline in bloater stocks, surely it must at least play a significant role.

MANAGEMENT OPTIONS AND RECOMMENDATIONS: The bloater population in Lake Michigan is in serious difficulty as evidenced by the following facts:

(1) Since 1960, the population abundance has been declining at 20% per year. The population level in southern Lake Michigan is only 8% as abundant in 1972 as in 1960.

(2) Although the bloater catch has remained fairly large at between 2 to 4 million lb., the catches in numbers show a declining trend of 5% per year in southern Lake Michigan and 11% per year in the northern area of the lake.

(3) The average age composition of bloaters from southern Lake Michigan gradually increased from 3.2 years in 1954 to 6.0 years in 1969. This is a clear indication of decreasing recruitment. Age groups in the 1963-69 period showed increases in average lengths ranging from 2.0-8.5 percent over the mean lengths for the same age groups in 1928. The greatest change in growth was in 1972 when age groups IV, V and VI were 20, 24 and 22 percent larger than were the same age groups in 1928. Accelerated growth rates are also an indicator of decreasing abundance.

(4) The percentage of female bloaters in index trawling catches from southern Lake Michigan increased from 77% in 1954-55 to 95% in 1969. In northern Lake Michigan, female bloaters comprised 69% of the index catch in 1954-55 and 97% in 1969. Extreme female dominance is believed to result from severe population stresses and accompanies a declining abundance.

Only by swift and drastic action is there a chance to salvage the bloaters. This means curtailment of the commercial fishery. It is estimated that the present instantaneous fishing rate of 0.71 exceeds the optimum fishing rate of 0.22 by 220% so that fishing is a significant cause of mortality and must share the blame for the current poor condition of the bloater population. Therefore, the following options and recommendations pertain to curtailment of the fishery and are given in order of our preference:

Option A -- Lake-wide closure.

A lake-wide ban, including Wisconsin, Illinois and Indiana, is proposed, particularly in the lower one-third of the lake because there is no deep-water barrier to limit migration. A ban by one state might very well be ineffective if the same population continues to be exploited by the others.

A total closure is recommended because the bloater population must be at a very low point on the spawner-recruitment curve, and it needs all available spawning potential. With the cessation of commercial exploitation, the survival rate of the spawning stocks would be expected to increase from the present 21% to 44%--a doubling of the spawning potential that now exists.

If and when the chubs do respond to closure and exploitation is again desirable, the fishing rate initially should not exceed 0.22. Also, the population should not be permitted to drop below the abundance index of 1930-32 of 500 bloaters per trawl tow (Table 8) in the lower lake (MM6-MM8) and 170 bloaters per trawl tow in the upper lake (MM2-MM5).

The minimum size at which chubs should be harvested will depend upon the changes in growth rates and maturity which an increase in abundance might cause. This can best be determined when the time for exploitation arrives.

The disadvantage of total closure is that there is no guarantee that the bloater populations will respond as planned. In that case, much of our time and effort will have been wasted and some economic loss to the fishery will result before total collapse.

Option B -- Refuge.

A refuge would establish an area free from commercial exploitation. Such an area would have to be very large to insure adequate protection. It is recommended that the area south of Ludington be declared a refuge. The bloater population in Area D (Fig. 9) is subject to intensive exploitation and faces most of the severe competition from the alewife. It is here that the bloaters need all of the help they can get.

It will also be necessary for Indiana, Illinois and Wisconsin (south of Manitowoc) to suspend chub fishing in southern Lake Michigan because the fish populations may very well intermingle. Fishing would then be permitted north of Ludington (chub population centers A, B, and C) but under the harvest quotas set in Table 10. These quotas were derived by reducing the 1972 catch from each of the chub population centers by 70%. This reduction in catch reduces the fishing rate from 0.71 to 0.22, assuming that stock abundance in 1974 will be similar to that in 1972. Survival of the exploited spawning stock would increase from 21 to 35 percent. An open area without a quota would doom the chubs for certain.

TABLE 10. RECOMMENDED HARVEST QUOTAS FOR LAKE MICHIGAN BLOATERS UNDER OPTIONS "B" AND "C" (see text)

Population Area[1]	1972 Commercial Harvest (Lbs.)	1974 Quotas (Lbs.)
A	258,459	76,000
B	747,296	224,000
C	357,153	107,000
D	1,185,594	356,000
Totals	2,548,502	763,000

[1] See Figure 9 for area delineations.

If cooperation from the other states does not materialize, then the area north of Ludington (chub population centers A, B, and C) should be declared a refuge. There is sufficiently deep water that would act as an effective barrier to migration into Wisconsin waters. The remaining states, hopefully, would at least adopt a quota similar to ours (70% catch reduction) for the fishery in the southern part of the lake.

Option C -- Harvest quotas only.

The harvest quotas given in Table 10 also apply to this option. Quotas have the advantage of being somewhat more palatable to the fishing industry than a complete ban and do have humanitarian considerations. However, they have the disadvantage of being difficult to administer and, even if effective, would delay the biological recovery processes. If the bloater population does not recover, there will always be the pangs of conscience that the populations might have survived had they been given complete protection. If quotas were reduced below the recommended levels, economic returns probably would not justify the cost of enforcement.

Option D -- Restrictions on gear, depth, seasons.

Restrictions are useful only when used in conjunction with quotas. These types of restrictions were used in past chub fisheries but did not prevent over-exploitation.

Option E -- Do nothing.

The position that the bloater population is "doomed to extinction anyway why do anything" is both irresponsible and indefensible. As long as there is still a chance that the bloater population can be salvaged, every effort should be made to do so. In sum, this option is a short-term gain for a potentially long-term loss.

ROUND WHITEFISH

The round whitefish, commonly called menominee or pilot fish, is found in all the Great Lakes except Lake Erie. The species ranges north of the Great Lakes to the Arctic, is present in the streams and lakes of eastern Canada, and occurs in both the St. Lawrence and Hudson River drainages. Although both fresh and smoked menominee are excellent food, they are only a minor part of the sport and commercial fishery.

Information on the life history of the menominee is limited to three studies on the Great Lakes and recent data from index fishing, none of which provides suitable information on the species for management. In fact, we found that menominee have been studied the least of any of the coregonines in the Great Lakes.

The menominee probably never has been abundant in Lake Michigan except locally (Mraz, 1964). They are more numerous, however, than commercial harvest figures indicate because this fish is usually sought only when either the price is well above normal or the fishing for more desirable species is poor. At other times, much of the harvest results from incidental catches in nets fished for other species. Only at Leland and in the Brevort area are specific catches taken for the local market.

Annual catches of menominee in Michigan waters of Lake Michigan averaged 70,000 lb. during the period 1930-72 (Fig. 14 and Appendix A). The bulk of the Lake Michigan commercial catch always came from Michigan waters. Earlier records indicated that yields were much higher in the late 1800's (519,000 lb. in 1899) than after 1900 and included catches of menominee weighing 4-6 lb. each. Few approach that size today. Recent catch records indicate menominee production has increased from an average of 10,000 lb. per year in the mid 1950's and 1960's to 170,000 lb. in 1971; 244,000 lb. in 1972. This increase in catch is believed to be influenced both by a change in fishing effort on the north shore of the lake (probably due to a higher price) and increased local market demand.

Menominee were taken at 13 of the 15 index stations fished in 1972. None were obtained in the sampling gear in the Green Bay area and south of Holland. They were not abundant at most other locations. The north shore stations had a CPE of 1.8 fish per 1,000 feet of net; Northport-Leland area, 3.0 fish; and Portage Lake, 4.5 fish. Catches at the remaining stations amounted to less than 1.0 fish per unit of effort. These low catches, however, could be attributed to both seasonal abundance and limited sampling with specific mesh sizes at some locations.

Selectivity by index nets (smallest mesh, 2 1/2" stretched) undoubtedly accounted for the absence of any menominee of age-group I, and no doubt only the larger fish of age-group II were captured. The average lengths of the well-represented, succeeding age groups suggests that they were reasonably well sampled--12.1" for age-group III, 13.2" for age-group IV, 14.7" for age-group V, 15.8" for age-group VI, and 16.4" for age-group VII.

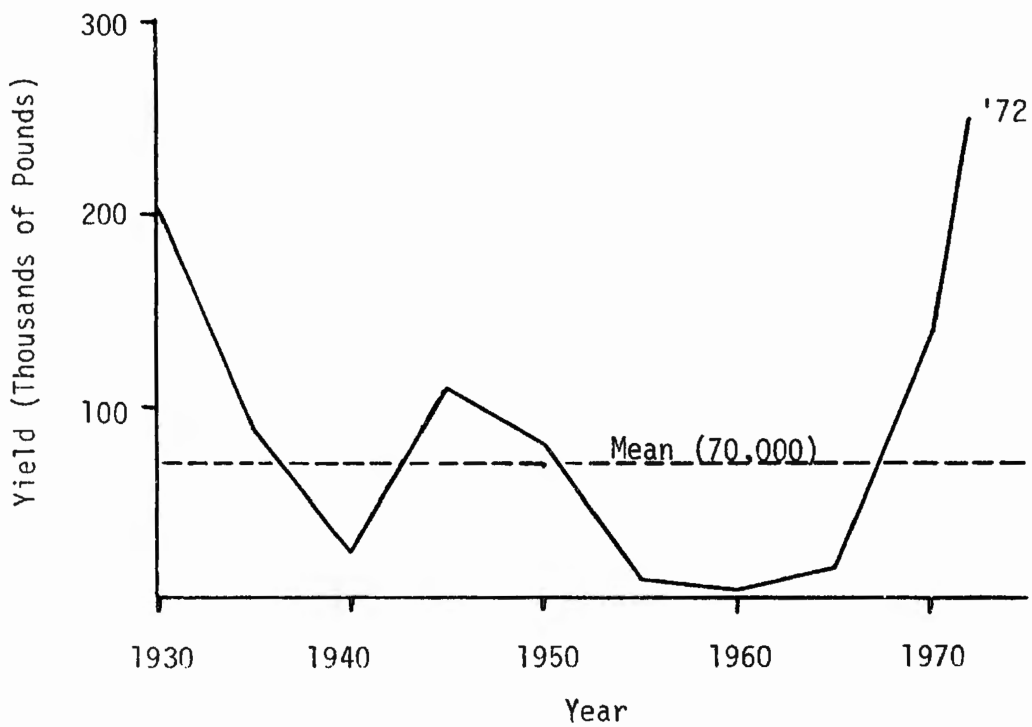

Fig. 14 - Commercial Harvest of Round Whitefish in Michigan Waters of Lake Michigan, 1930-1972.

Age-groups III-VI comprised the bulk of the samples. Sex ratios for menominee approximate a 1 : 1 ratio. No fish smaller than 12.0" was mature, and all those 15.0" long or longer were mature.

A recent study in the vicinity of the pump-storage power plant near Ludington by Armstrong (1973) showed that the growth rate of round whitefish is somewhat faster here than elsewhere in the lake (Table 11). These fish were caught in graded-mesh gill nets in the fall near the end of the 1972 growing season. The empirical lengths and weights shown in the table agree approximately with his back-calculated data which are shown below:

	Year at annulus formation						
	1	2	3	4	5	6	7
Length (in.)	5.5	10.0	13.6	15.6	17.2	18.1	18.9
Weight (oz.)	0.5	4.5	9.7	16.0	22.0	28.0	34.5

About 50% of the 2-year-olds and 90% of the 3-year-olds were mature in the fall. Armstrong also reported that a chi-square test revealed no significant differences between the percentages of mature males and females.

If a minimum desirable weight of 1.0 lb. in the commercial catch is assumed for Lake Michigan menominee, the corresponding length is about 15.5". On the average, the fish attains 1.5 lb. at about 17.5" and 2.0 lb. near 19.0". Since the highly palatable flesh of menominee is often accepted as a substitute for lake whitefish, a marketing weight of 1.0-2.0 lb. would be desirable. The exception would be the smoked product which, in the past, has been a smaller fish. From a biological standpoint, menominee of lengths more than 15.0" (85% sexually mature for both sexes) would be the most appropriate sizes to be harvested commercially.

Therefore, it is recommended that a limited number of round whitefish be harvested commercially with selective gear in statistical districts MM2, 3, 5, 6 and 7 (Table 1). Grand Traverse Bay (MM4) has some potential but it should remain a sport fishing area.

TABLE 11. MEAN LENGTH AND WEIGHT AT CAPTURE NEAR LUDINGTON (SEPT.-NOV. 1972) BY AGE GROUP FOR 233 ROUND WHITEFISH. DATA FROM ARMSTRONG (1973)[1]

Age Group	Number of Growing Seasons	Length (in.)	Weight (oz.)
I	2	10.6	4.5
II	3	13.0	9.0
III	4	15.1	16.0
IV	5	16.5	22.0
V	6	17.7	28.0
VI	7	18.7	35.0
VII	8	19.5	41.0

[1] Original data in metric units

RAINBOW SMELT

Rainbow smelt originated in Lake Michigan from a planting in Crystal Lake, Benzie County, in 1912 (Van Oosten, 1937). It is believed that the Crystal Lake population, which originated from 16.4 million eggs obtained from Green Lake, Maine, is the source of the smelt now found throughout all of the Great Lakes (except Lake Ontario) and their tributaries. The first smelt reported in Lake Michigan were caught in a commercial net in 1923 off Frankfort at the mouth of the stream through which Crystal Lake drains into Lake Michigan. By 1936 smelt had occupied the entire lake.

As smelt first spread throughout Lake Michigan and multiplied rapidly, it was considered a nuisance and potential menace to stocks of native fish. Some predicted the destruction of all fisheries and many urged that measures be taken to control or, if possible, exterminate this newcomer. Fortunately, the gloomy predictions concerning the destruction by smelt did not materialize although there was some evidence that suggests smelt might have competed with lake herring, whitefish and walleye in Green Bay. In these waters, smelt reached a very high level of abundance--higher than in any other section of the lake. It was reported that young of the three native species reappeared in Green Bay in considerable quantities following the catastrophic mortality of smelt during the winter of 1943. Since then walleye and herring have become almost extinct in this area but whitefish are present in fair numbers. The reduction in abundance of these species was not caused by smelt but by over-exploitation.

Commercial harvest of smelt in Lake Michigan increased from 86,000 lb. in 1931 (the first year of record) to 4.8 million lb. in 1941. The catch then dropped abruptly to 2.2 million lb. in 1943, 5,000 lb. in 1944, recovered rapidly to 1.1 million lb. in 1948 and reached a record high of 9.1 million lb. in 1958. The catch has been much lower since 1958. Commercial production in Michigan waters of Lake Michigan has centered around the Green Bay area (72-98% of the catch), averaging 1.8 million lb. from 1932 to 1972 (Fig. 15). Peak catches were reached in 1958 at 6.2 million lb., declined steadily to a low of 700,000 lb. in 1965, then rose to 2 million pounds in 1969, but has since dropped to a low of 600,000 lb. in 1972 (Appendix A). This reduced catch does not reflect the abundance of smelt. It is more a reflection of the available market because the species is abundant, especially in the northern portion of the lake.

Index fishing in 1972 indicated smelt were present at all sampling stations throughout Michigan waters of Lake Michigan. They were most abundant in Green Bay (CPE = 1,958 fish per hour of trawling) and Grand Traverse Bay (CPE = 3,087 fish per hour of trawling). At all other stations, the catch was less than 1,000 fish per unit of effort. Recruitment appears to be strong but, with only one year's data and knowing the selectivity of the gear, no predictions on strength of oncoming year classes can be made at this time.

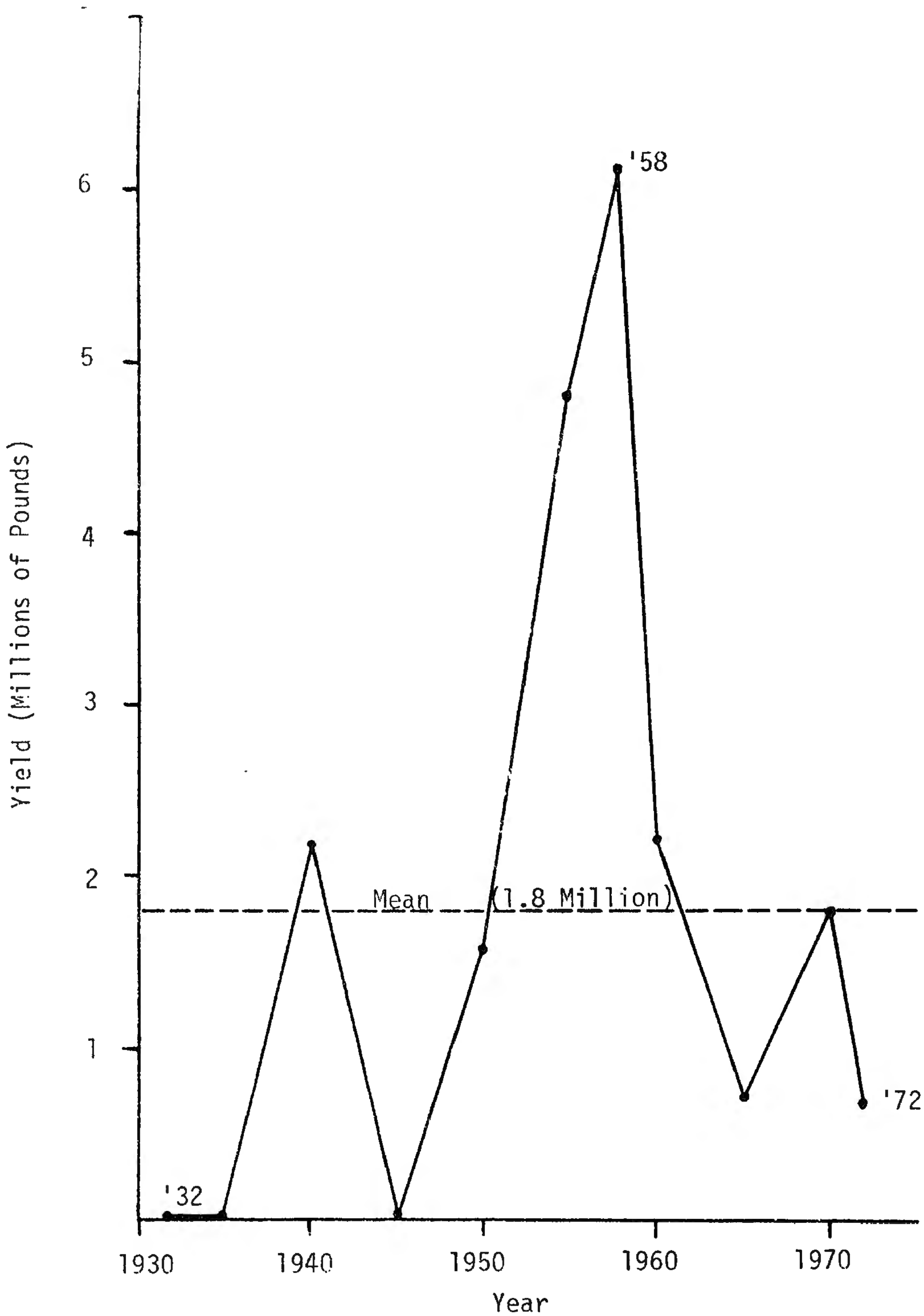

Fig. 15 - Commercial Harvest of Smelt from Michigan Waters of Lake Michigan, 1932-1972.

The length frequencies of smelt at index stations ranged from 2.0-9.0" with the dominant inch groups at 4 and 5 (78%). No smelt were aged. However, if we apply our length-frequency data to age data from other studies (Baldwin, 1950; Bailey, 1964) on smelt in the Great Lakes, the age composition of our 1972 catch approximates the following: age-group I--36%; II--48%; III--11%; IV--4%; and V--1%. All smelt of both sexes were mature at age II ($\geq$5.5"). Sex ratio of fish examined at a few stations approximated the 1:1 level.

From an economical standpoint, smelt have been beneficial to the Lake Michigan fishery and its users, being not only tasty but also a sport fish. It was estimated that the sport dip-net catch in 1942 was 5.5 million lb. in the state of Michigan waters and was probably nearly that high in Wisconsin (Van Oosten, 1947). In recent years, estimates of the sport catch from Michigan's mail creel survey were somewhat less but nevertheless significant; i.e., in 1970, 1.5 million lb.; in 1971, 1.1 million lb.; and in 1972, 2.4 million lb.

Smelt also have provided excellent forage for both trout and salmon species and, to a lesser degree, other predatory fish. The value of smelt as forage for predatory species and sport for the recreational fishermen justifies restricted production by commercial fishermen as most of their present-day catches are utilized by meal plants for pet-food processing with low return to the supplier. Therefore, it is recommended that the commercial harvest of smelt be confined to Green Bay ($\geq$90% recent catches were from this area) with selective gear (Table 1). The majority of the catch will be made during the months of February through May although some will be taken incidental to fishing for other species. A size limit on smelt is not necessary. Few fish survive the present method of harvest and bulk handling but the selectivity of the gear employed normally catches fish of a size that is mature. The quota on the commercial catch should be liberal, at least in 1974, because of present smelt abundance. As salmonid populations and their forage requirements increase in the future, it may be necessary to cut back on production allocations.

SUCKERS

Three species of suckers have been moderately abundant in the Lake Michigan commercial fishery. White suckers (C. commersoni) make up most of the catch and longnose suckers (C. catostomus) are also important. Redhorse suckers (Moxostoma spp.) which are often called mullet were common during the early period but are now rare. Green Bay has been the center of production, but the northern portion of the main body of the lake yielded substantial catches several decades ago. They are taken chiefly in impoundment gear although large catches are landed incidentally in gill nets.

The commercial catch of suckers in Lake Michigan ranged from 1.5 to 4 million lb. and averaged 2.1 million lb. in 1889-1949. In fact, suckers ranked fourth among the fish in Lake Michigan in 1922 (Koelz, 1926). After 1949, total catches declined to an average of only 766,000 lb. in 1950-60; 337,000 lb. in 1961-68. However, nearly 1 million lb. were taken in 1970. In Michigan waters the catch has averaged 750,000 lb. from 1930-72 (Fig. 16). Yields declined steadily from the late 1940's to the late 1960's, as described for the entire lake, but increased to a 19-year high of 500,000 lb. in 1970 (Appendix A).

In more recent times, suckers have played only a very modest role, primarily because the catch is strongly dependent on market demand. Probably the severe drop in production which began in the 1940's was partly due to decreased abundance resulting from sea lamprey predation. The sea lamprey has been shown to attack large suckers heavily in Lake Huron (Hall and Elliott, 1954), although it may not do so if more highly favored prey such as lake trout are abundant. The increase in catch of suckers the last few years can be attributed partly to lamprey control.

Information on biology of suckers in the Great Lakes is limited to two studies, neither of which are on Lake Michigan populations. Suckers appear to be fairly discrete and occupy the inshore waters. Growth of longnose suckers is very slow in Lake Superior, reaching only 3.6" the first year, 12.0" in the sixth year, and 18.0" in the eleventh year (Bailey, 1969). The annual length increment of adult white suckers in South Bay, Lake Huron, was about 0.3" (Coble, 1967). Annulus formation on suckers occurs between mid-May and September. Over 6 years are required for suckers to weight 1.0 lb. and nearly 10 years to reach 2.0 lb. Growth could be faster in shallow, warm waters such as Green Bay. All suckers are mature at lengths greater than 15.0".

Suckers could be an excellent commercial species for food if processing techniques and markets were established. The species is abundant enough to allow a substantial catch over most of the lake except Grand Traverse Bay and the Bay deNocs. It is recommended that a fishery for suckers with selective gear be pursued (Table 1). This fishery should be restricted to white and longnose suckers. If possible, redhorse should be protected as they are scarce. The consumer demand for large suckers of filleting size

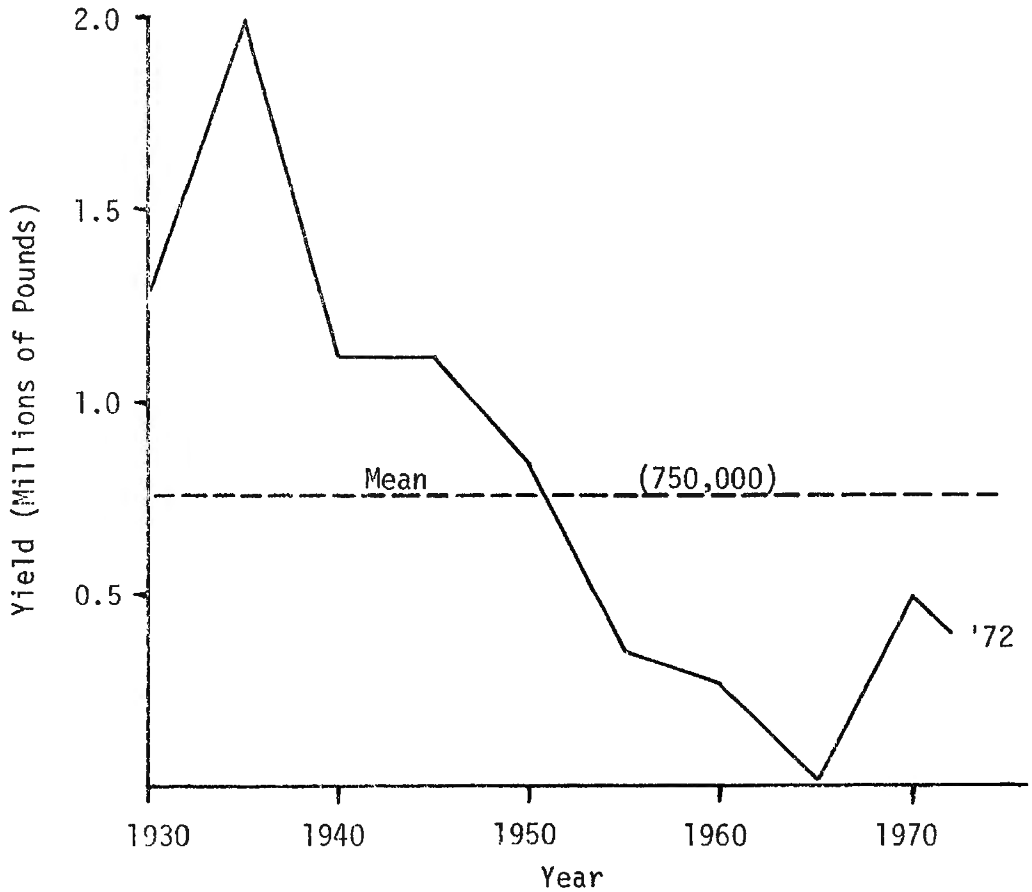

Fig. 16 - Commercial Harvest of Suckers in Michigan Waters of Lake Michigan, 1930-1972.

should automatically restrict the catch to mature fish so that a size limit is not needed. A seasonal restriction on catch is also unnecessary providing selective gear is employed and those taken incidental to other species may be sold. The operation of pound nets and trap nets for suckers should be conducted at depths less than 15 fathoms. Both small and large mesh may be used.

LAKE WHITEFISH

With the demise of the commercial fishery for lake trout and yellow perch in Lake Michigan, the lake whitefish has regained its status as the most valuable food resource supplied by the commercial fishery. The bloater is the only other species of commercial importance.

Judging by comprehensive reviews of the commercial fishery by Smith (1968a) and Wells and McLain (1973), whitefish were the backbone of the early fishery before 1900 with reported catches of over 10 million lb. However, by 1900 commercial production had dropped to around 1.6 million lb. and since then has reached peaks of approximately 4-5 million lb. only in 1929-31. Over-exploitation was the cause of the erratic production and gradual decline. Between 1956 and 1960, less than 100,000 lb. were caught in Michigan waters (Fig. 17 and Appendix A). Wells and McLain attribute this latter population decline to sea lamprey predation. Substantiating this supposition is the gradual recovery of the fishery (on the north shore at least) following successful control of the lamprey and implementation of the Zone Management Plan which restricted the fishery to specific zones. There are signs that the population is rebounding in parts of the lake further south, especially around the Holland-Grand Haven area. Eighty adults were captured in 1972 in nets set at the index station at Holland by the crew of the S/V Steelhead. Further evidence comes from reports by the federal vessel R/V Cisco and the brief flurry of Indian commercial fishing success in 1971 near Grand Haven.

The recent rise in commercial production of whitefish in the Bay deNoc area (Zones 12 and 13) and along the north shore (Zone 16) is illustrated in Table 12 in which total pounds, effort, CPE, and the dominant age group(s) are presented. Despite this recent upward trend, there is a persistent worry that the population is actually being over-fished. Evidence to support this concern lies chiefly in the age composition of these commercially-fished stocks, as compared to the age composition of the unfished population in Grand Traverse Bay, together with changes in growth rate and age at maturity (Keller, 1969-71).

Considerable attention has been given to these whitefish populations in the northern part of the lake from which a number of publications, theses, and reports have been generated (Van Oosten et al, 1946; Roelofs, 1957; Mraz, 1964; Piehler, 1967; R. J. Brown, 1968; DeMuth, 1969; Tyra, 1971; and Patriarche, 1971). Keller also has reported on these stocks in annual reports to the Great Lakes Fishery Commission. Nearly all of these papers have presented growth data, age composition of commercial catches and some information on total mortality. There seems to be little point in a detailed review of previous growth calculations in this report, except to state that pronounced differences in growth have been observed for the stocks in different parts of northern Lake Michigan (Table 13). Brown showed differences between Seul Choix, Naubinway and Brevort populations. Mraz found better growth for Green Bay populations than in nearby Lake Michigan while Roelofs reported a slower growth rate for whitefish taken

Fig. 17 - Commercial Harvest of Lake Whitefish in Michigan Waters of Lake Michigan, 1930-1972.

TABLE 12. COMMERCIAL CATCH (LB) AND EFFORT FOR WHITEFISH IN THE FISHING ZONES OF LAKE MICHIGAN, 1963-1972

	Gill Net			Dominant	Pound & trap net[1]			Dominant	Total
	Catch	Effort	CPE	age group	Catch	Effort	CPE	age group	catch
Zones 12 & 13									
1968	77,095	5,882	13.11	II,III	30,943	619	50.00	II,III	108,038
1969	133,291	7,533	17.69	II,III,IV	82,806	834	99.29	II,III,IV	216,097
1970	129,328	5,489	23.56	--	127,795	1,083	118.00	--	257,123
1971	645,588	15,925	40.54	III	215,929	975	221.46	III	861,517
1972	919,123	19,277	47.68	--	315,759	791	399.19	III	1,234,882
Zone 16									
1968	251,396	14,785	17.00	III	211,516	1,465	144.38	III	462,912
1969	473,872	21,512	22.03	III,IV	314,038	1,916	163.90	III,IV	787,910
1970	324,704	14,675	22.13	III	444,240	2,015	220.47	II,III	768,944
1971	605,976	20,417	29.68	III	655,946	2,384	275.15	III	1,261,922
1972	679,194	18,772	36.18	III	743,532	2,236	332.53	III	1,422,726

[1] Mostly pound nets in Bay deNoc; mostly trap nets in Zone 16

TABLE 13. AVERAGE, CALCULATED TOTAL LENGTHS (INCHES) FOR SEVERAL AGES OF LAKE WHITEFISH TAKEN IN VARIOUS AREAS OF NORTHERN LAKE MICHIGAN

Area	Year of Life					Source	
	1	2	3	4	5		
Big Bay DeNoc	5.9	10.5	15.0	18.0	--	Roelofs	(1958)
Green Bay	6.6	11.8	15.8	18.2	20.0	Mraz	(1964)
Wisconsin	5.6	9.8	13.8	17.1	19.5	"	"
Green Bay	7.1	13.5	17.9	20.1	22.2	DeMuth	(1970)
Green Bay	6.7	12.5	16.3	17.3	19.7	Tyra	(1971)
Seul Choix	9.5	13.6	18.2	20.6	--	Brown	(1968)
Naubinway	8.7	12.1	16.7	19.6	--	"	"
Brevort	8.9	12.6	16.7	19.8	--	"	"

around South Fox Island than those from Bay deNoc. These facts point towards the possibility there are a number of discrete populations. However, the slower growth implied for the South Fox Island waters may be artificial. These calculations were made from age VI-VIII fish whereas only 3- and 4-year olds were used for Bay deNoc.

Age at maturity has been reported by Brown, Mraz, DeMuth and Tyra. Brown stated that at the end of 4 seasons of growth (age-III fish), more than 50% of whitefish of both sexes were mature. Ninety % of the 17" males were mature; 60% of the 17" females were mature. Likewise, Mraz observed that Green Bay whitefish had similar characteristics in 1952. Most of the males (87%) were mature at age III (16.5" and over) as were 61% of the 17" females. Examination of recent (1969, 1970) gill net catches near St. Martins Island in MM1 by DeMuth and Tyra showed a somewhat different picture of maturity. DeMuth reported that among age-II fish, 46% of the females were mature as well as virtually all the age-III females (98.2%). All males age II and older were believed to be mature. Tyra observed that the smallest mature male was 15.2" and the smallest mature female was 17.2" long. From his data, Tyra stated that all females 18.7" and longer were mature. Ninety-seven percent of these whitefish were mature at age III. In 1972 biologists who examined the commercial trap and pound net catches reported that in the spring samples virtually all age-III females were mature (124 out of 125 fish). In the fall, 90% of the 62 females examined were deemed mature.

Of interest, too, is the fact that the age of full recruitment to the fishery is usually age III under the 17.0" minimum size limit and the use of 4 1/2" mesh in both gill nets and impoundment gear. The latter, however, frequently retain many sublegal whitefish. There have been times when age-II fish have comprised a substantial portion of the commercial catch (Table 12).

Estimates of total mortality can be obtained rather easily from a good sampling of the age distribution in a population, or from comparisons of CPE by age group in non-selective gear (or nearly so) between one year and the next. However, sub-dividing total mortality into the two major components--natural and fishing--can be difficult. Fortunately, for whitefish populations in northern Lake Michigan, there is a valuable reservoir of natural mortality data for older age groups within the unfished populations of Grand Traverse Bay. For age-group III, we presently have to assume that the average natural mortality rate of 34% determined by Cucin and Regier (1966) for whitefish in Georgian Bay approximates that of northern Lake Michigan. A summary of estimated mortality rates is presented in Table 14.

QUOTA RECOMMENDATIONS: The present commercial fishery for whitefish is centered in MM1 and MM3 with some fishing also being carried on in MM2. The very few whitefish caught and reported elsewhere are taken incidental to the target species. The following discussion on quota recommendations for 1974 will deal with Zone 16 (MM3) and Zones 12 and 13 in the Bay deNoc area (MM1). We used a portion of Ricker's (1958) yield model to calculate a quota recommendation, using the most recent data available (1971 and 1972) for growth, mortality, and age composition of the commercial catch samples. The procedure was outlined in some detail by Patriarche (1971).

TABLE 14. SUMMARY OF ESTIMATED MORTALITY RATES FOR WHITEFISH IN NORTHERN LAKE MICHIGAN.

Locality	Year	Source of fish	Age Groups	Total (%)	Natural	Fishing	Total	Method	Source
					(Instantaneous rates)				
Michigan									
Seul Choix	1967	Pound & trap nets	II-III	53	--	--	.75	age structure	Brown
			III-IV	61	--	--	.94		
			IV-V	94	--	--	2.81		
Zone 16 (North Shore)	1968	Trap	III-IV	59	.41	.48	.89	CPE	Patriarche
			IV-V	42	.24	.30	.54		
			V-VI	32	.13	.26	.39		
Zone 12 & 13 (Bay deNoc)	1968	Pound net	II-III	33	--	--	--	CPE	
			III-IV	57	.41	.44	.89		
			IV-V	93	.24	2.42	2.66		
Gd. Traverse Bay	1968	Exp.gill nets	IV-V	21	.24	--	.24	age structure	Keller
			V-VI	12	.13	--	.13		
			VI-VII	50	.70	--	.70		
			VII-VIII	33	.40	--	.40		
Zone 16	1971	Trap net	III-IV	71	.42	.82	1.24	CPE	Patriarche
			IV-V	86	.24	1.72	1.96		
Zone 12 & 13	1971	Pound net	III-IV	56	.41	.40	.81	CPE	Patriarche
Gd.Traverse Bay	1971	Exp.gill nets	VI-VII	59	.89	--	.89	age structure	Keller
			VII-VIII	69	1.17	--	1.17		
			VIII-IX	75	1.39	--	1.39		

Zones 12 and 13--From catch statistics supplied by the Bureau of Sport Fisheries and Wildlife and the Charlevoix Great Lakes Fisheries Station, together with monitoring data supplied by the Charlevoix staff, the estimated age composition of the commercial catches in impoundment gear for 1971 and 1972 were computed and are presented in Table 15. These data were used for the mortality calculations because this gear was deemed to be less selective than gill nets. The total catch from all gear was 861,517 lb. in 1971; 1,234,882 lb. in 1972. Since monitoring was done both in spring and fall, separate tabulations were made by season, and the data were then combined for the final estimates. In both years, age-group III completely dominated the catches both in the pound and trap nets and the gill nets. Total mortality rates were derived from the comparison of CPE by year class in consecutive years (Ricker, 1958) and were subdivided into instantaneous rates using previously calculated natural rates "borrowed" from either Grand Traverse Bay or Georgian Bay.

Instantaneous growth rates were computed from a series of mean lengths and weights obtained from index sampling in 1972 in Green Bay, as shown in Table 16.

Calculations of yield and production (of new growth) per 1,000 recruits were limited to the dominant age-group III because no mortality value could be assigned to any other of the older age groups for this 1971-1972 period. Only age-groups III and IV were caught in 1971 and the CPE for age-group V in 1972 was larger than that for age-group IV in 1971.

The following calculated instantaneous rates for age-group III were used in Ricker's yield model:

g - .52 (growth)
p = .40 (fishing mortality)
q = .41 (natural mortality)

The computations show that, under the rates extant in 1971, production per 1,000 (1,650 lb.) recruits was greater than the harvest. The desired point where yield approximately matched production would have been realized if the fishing mortality rate were increased by 30%, as shown below ($\bar{w}$ = mean weight of 1,000 recruits available during the year):

	g	p	$\bar{w}$ (lb)	g $\bar{w}$ (production)	p $\bar{w}$ (yield)
1971 rates	.52	.40	1,427	742 lb	570 lb
"adjusted" p	.52	.52	1,361	712 "	712 "

The corresponding increase in harvest was 25%. Therefore the 1971 catch of 861,517 lb. theoretically could have been as high as 1,076,896 lb. without exceeding the production of new growth by the population in 1971.

In 1971, 90.5% of the total catch by all gear (974,590 lb) consisted of 3-year-olds (Table 17). In 1972 there was in increase in recruitment of 44% (428,820 lb), as judged by the comparison of CPE for age-group III in 1971 and 1972. Since 713 lb. were produced and could be harvested for each 1,650 lb of recruits, an additional 185,120 lb. $(\frac{428,820}{1,650} \times 712)$ could be

TABLE 15. ESTIMATED AGE COMPOSITION OF THE WHITEFISH CATCH IN IMPOUNDMENT GEAR IN 1971 and 1972

Age Group	1971		1972	
	Number	CPE	Number	CPE
Zone 12 & 13				
II	--	--	3,197	4.0
III	92,384	94.8	109,637	138.6
IV	1,501	1.5	33,106	41.7
V	--	--	3,424	4.3
Total Number	93,885		149,364	
Number lifts	975		791	
Zone 16				
II	5,152	2.2	1,064	0.5
III	226,928	95.2	341,817	152.9
IV	50,188	21.0	60,865	27.2
V	1,944	0.8	6,458	2.9
VI	978	0.4	2,868	1.3
Total Number	285,190		413,072	
Number lifts	2,384		2,236	

TABLE 16. MEAN LENGTHS AND WEIGHTS AT CAPTURE FOR SEVERAL AGE GROUPS OF WHITEFISH CAUGHT BY TRAWL AND GILL NET IN MAY 1972

Age Group	Number of Fish	Length (inches)	Weight (Pounds)
I	65	7.9	0.20
II	119	12.5	0.71
III	89	15.8	1.52
IV	51	18.6	2.57
V	5	20.6	2.94
VI	2	23.5	4.65
VII	1	24.7	5.70

TABLE 17. PERCENTAGE OF THE TOTAL WHITEFISH CATCH IN MM1 (ZONES 12 and 13) AND MM3 (ZONE 16) COMPRISED OF AGE-GROUPS II AND III, 1968-1972

Year	Zones 12 and 13			Zone 16		
	II	III	II & III	II	III	II & III
1968	38	38	76	9	77	86
1969	28	31	59	6	53	59
1970	--	--	--	28	63	91
1971	--	91	91	3	81	84
1972*	2	73	75	**	83	83

* Based only on impoundment gear catches. No gill net catch monitored in 1972.

** 0.3%

allotted to the 1971 allowable yield, thus arriving at a permissible catch of 1,262,016 lb. for 1972. Therefore, both in 1971 and 1972 a commercial harvest of at least 1 million lb. could have been tolerated without endangering the stock. If recruitment holds up, a quota of this magnitude could be feasible in 1974.

Zone 16--The total catch for all gear in 1972 was 1,422,726 lb.; 1,261,922 lb. in 1971. However, only the data for impoundment gear (Table 15) were used for the mortality calculations. As described above, separate estimates were made for the age composition of spring and fall catches and the data combined to show the over-all age structure. Age-group III completely dominated the catch both years, the same as in Zones 12 and 13. Instantaneous rates used for these computations, in which production and yield per 1,000 (2,500 lb.) recruits were computed for age groups III and IV, were as follows:

Age III	Age IV
g = .52	.22
p = .82	1.72
2 = .42	.24

At the above rates of fishing which occurred in 1971, a calculated yield of 1,600 lb. per 1,000 recruits greatly exceeded the production of 1,014 lb. When the fishing rate was cut to 1/3 of the same rate, production and yield were matched (1,554 vs. 1,549 lb.), or a difference of 55% between these two theoretical yields. Thus the total harvest in 1971 should have been only about 694,057 lb. Although only two age groups could be used in these calculations, they comprised 97% of the catch.

In 1972 there was an increase in recruitment (age-III fish) of 58% (334,119 lb.) over that in 1971, on the basis of comparative CPE's for this age group. The equillibrium harvest per 1,000 fish (2,500 lb.) was 621 lb. so that an additional 83,214 lb. could have been taken in 1972, or 777,271 lb. (694,057 + 83,214) - some 645,000 lb. less than actually was harvested. A quota of 800,000 lb. would appear to be a reasonable one for 1974 if these high rates of recruitment of the past 2 years are sustained.

These suggested quotas of 1 million lb. for MM1 (Zones 12 and 13) and 800,000 lb. for MM3 (Zone 16) seem to be conservative in view of the phenomenal recruitment that is occurring. There is some evidence that the peak has not yet been reached. The proportion of sublegal fish in monitored trap-net catches was 39% in 1971; 55% in 1972 (Keller, 1973). One must keep in mind, however, that the fishery is dependent upon these young fish and there is only a comparatively small reservoir of older fish. As R. J. Brown (1968) pointed out, an increase in the minimum size limit to the point where 4-year-olds would be at the age at entry into the fishery would accomplish two things--protect more age-III fish until they had spawned and, in the long run, provide a greater yield in which the mean weight would be greater and command a better price. The probability of a sustained and stabilized fishery would be greatly enhanced. However, to effectively raise the minimum size limit to age IV would reduce the catches by 75-90%, judging by the age distributions of the past 2 years (Table 15). In 1972, 17" fish alone comprised 40% of the catch in Zone 16; 43% of the catch in Zones 12 and 13.

On the basis of the calculations described previously, the above quotas could be proposed for 1974. To hedge against a pronounced drop in recruitment (which doesn't seem likely in 1973), and as an aid in stabilizing the fishery, a reduction of 25% in the above recommendations is suggested, making the recommended quotas 750,000 lb. for MM1 and 600,000 lb. for MM3 in 1974 (Table 1). By 1977, if an increase in survival of older (and heavier) fish is noted and recruitment has stabilized, this cut could be restored. There is a large population of whitefish in MM2 that has been closed to gill nets to protect lake trout. One trapnetter has been operating here and markets around 100,000 lb. a year. To provide for the probability another fishermen will fish in this district with trap nets (after the gill net ban takes effect on the lake), a quota of 200,000 lb. is recommended for MM2. It is entirely possible that by 1980 a sizable whitefish population will have become re-established in MM7 and MM8, at which time a moderate fishery with impoundment gear could be instituted. There is one encouraging factor to remember. The failure of a year class to reproduce would, under present conditions, collapse the fishery for awhile, but the phenomenal capability for this species to recover has already been demonstrated. The large catches in recent years have not resulted from one strong year class but a succession of good ones.

YELLOW PERCH

Perch have been an important component of both the commercial and sport catches in Lake Michigan over the years. While documentation of the sport fishery has been poor, commercial catch summaries since 1898 are available from several sources (Baldwin and Saalfeld, 1962; Smith, 1968a; and others).

These catches have ranged from 247,000 lb. in 1969 to 5 million lb. in 1964. Prior to 1966, more than 1 million lb. were taken annually. Michigan's production has averaged 600,000 lb. annually from 1930 to 1970 (Fig. 18 and Appendix A). However, between 1966 and 1969, there was a drastic decline in the perch catch and the fishery was closed in Michigan in 1970 with the advent of a zone management plan.

As an index to the relative abundance of perch stocks in Michigan waters, catch data from gill nets are presented in Table 18 by statistical district for the period 1960-69. Two of the formerly most productive areas for perch were in Green Bay (MM1) and southeastern Lake Michigan (MM7 and MM8). During the 10-year period, perch catches in MM1 were highest in 1960 and declined steadily thereafter. The perch harvest in MM7 and MM8 peaked in 1964 at what were probably record highs, following which there was a pronounced decline. Commercial catches in the rest of the lake were relatively small, but a downward trend is apparent for all districts. Smith (1968a) associated this decline with the presence and/or competition of the dense schools of alewives that dominated the lake in the 1960's. Presumably the displacement of perch in the shallows at spawning time by the inshore invasion of alewives could have a marked effect on perch recruitment. It is also believed that intensive commercial exploitation reduced perch abundance.

Coincidental with the cancellation of the commercial perch fishery, the pier fishery revived from a long period of the doldrums. A postcard census for all sport fishing in the state was instituted in 1970 (Jamsen and Ellefson, 1970, 1971). Catch estimates from the censuses of 1970 and 1971 amounted to 1,678,010 perch from Lake Michigan in 1970; 1,913,720 perch in 1971. On the assumption these fish weighed, on the average, 3.0 oz. apiece (about a 7.5" perch), anglers harvested over 300,000 lb. each year--314,627 lb. in 1970 and 358,822 lb. in 1971. These catches approximate or exceed the annual commercial catch each year from 1966-69.

Information on perch biology for Lake Michigan stocks is somewhat limited, and most published studies relate to Green Bay (Hile and Jobes, 1942; Joeris, 1957; Dodge, 1968; Mraz, 1952). Current work near South Haven at the Palisades Nuclear Power Plant by Patriarche and recent collections made at index stations by biologists on the S/V Steelhead will provide updated information on the age structure and growth rates of these fish populations. In addition, biologists for the Bureau of Sport Fisheries and Wildlife in Ann Arbor are analyzing growth data from collections made at Benton Harbor, South Haven, Saugatuck, Grand Haven, Ludington, and Frankfort. An indication of growth rate in southeastern Lake Michigan is

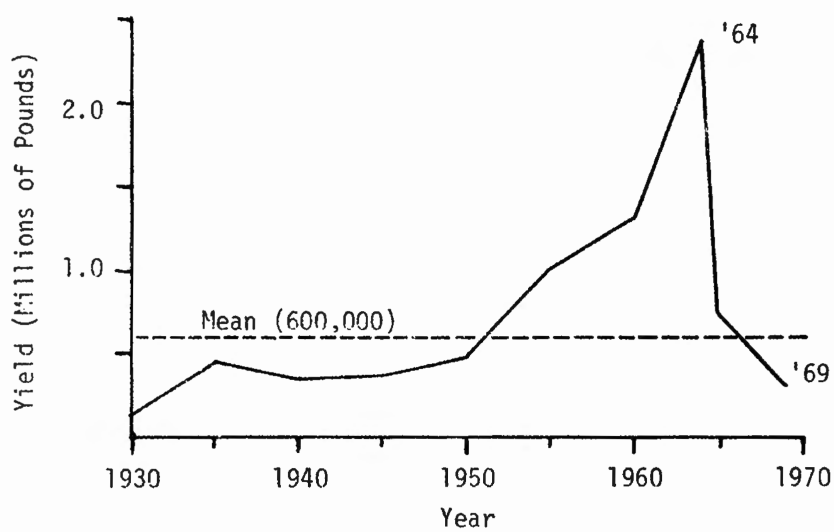

Fig. 18 - Commercial Harvest of Yellow Perch in Michigan Waters of Lake Michigan, 1930-1969.

TABLE 18. COMMERCIAL GILL-NET CATCH OF PERCH (THOUSANDS OF POUNDS) IN THE MICHIGAN STATISTICAL DISTRICTS OF LAKE MICHIGAN, 1960-1969. CPE IN PARENTHESES

Year	Statistical District							
	1	2	3	4	5	6	7	8
1960	733 (60.5)	24 (27.3)	97 (60.8)	30 (34.6)	58 (54.9)	38 (80.0)	88 (44.1)	157 (40.2)
1961	707 (48.4)	16 (29.0)	85 (31.2)	18 (22.8)	128 (31.6)	34 (84.1)	134 (58.7)	369 (55.9)
1962	430 (62.6)	...	15 (18.6)	7 (30.3)	45 (40.1)	44 (74.3)	154 (60.9)	311 (71.1)
1963	516 (63.2)	1 (5.4)	7 (18.5)	5 (28.2)	32 (38.1)	46 (83.3)	193 (75.3)	244 (76.8)
1964	196 (27.2)	7 (36.9)	...	6 (18.3)	51 (54.2)	61 (44.2)	327 (50.0)	1,632 (83.0)
1965	63 (18.9)	1 (25.0)	2 (20.3)	1 (24.5)	5 (16.6)	7 (26.2)	68 (27.7)	619 (48.7)
1966	37 (23.5)	<1 (9.6)	<1 (7.3)	<1 (18.3)	2 (18.0)	7 (26.9)	17 (19.4)	312 (44.8)
1967	65 (25.0)	...	<1 (2.6)	<1 (8.3)	2 (12.3)	6 (19.4)	12 (31.8)	353 (56.9)
1968	25 (22.0)	0 0	<1 (3.4)	0 0	...	1 (13.0)	7 (33.6)	144 (52.3)
1969	26 (21.3)	1 (9.1)	1 (9.1)	...	<1 (3.0)	<1 (8.8)	4 (15.2)	213 (65.7)

presented below wherein is summarized, by sex, the mean lengths (inches) at capture in June for perch taken in graded-mesh gill nets (1.5, 2.0, 2.5, 3.0 and 4.0 inches):

	II	III	IV	V
Male	6.4	8.0	9.3	9.8
Female	6.9	9.0	10.5	11.2

In addition, 18 yearling perch captured by seine in June averaged 3.3". New growth does not commence until the last half of June. Spawning generally occurs in this vicinity (South Haven) around mid-June. Maturity data are scanty but 3 out of 20 (15%) age-II females were mature and 21 out of 23 (91%) age-III females were mature. All 2- and 3-year-old males were mature. Hile and Jobes reported that 59% of age-V female perch in Green Bay were mature.

The 1969 year class presently dominates the perch population. The percentage age distributions of perch captured in gill nets near South Haven are shown in Table 19. Perch were collected four times each year from 1968-1972 but the few fish taken in May were omitted. Perch in southeastern Lake Michigan generally do not move into the shallower waters (<40 feet) before June. Few perch older than 5 years have been captured; none since 1969. The dominance of the 1969 year class is revealed by the high percentages of age-group I in October 1970, age-group II in the 1971 catches, and age-group III in 1972. Further corroboration of the dominance of this 1969 year class comes from trawling data by the R/V Cisco and the age composition of gill-net catches by the S/V Steelhead at index stations at Holland and Benton Harbor. Seventy-seven percent of the 229 perch taken at Holland in 1972 were 3-year-olds; 71% of the catch of 588 fish at Benton Harbor. This may not be a lake-wide occurrence since 4-year-olds comprised 55% of the perch catch at Manistee, followed by 3-year-olds at 39%. Fairly large numbers of perch were captured in Big Bay deNoc in May 1972 by trawling (mostly 5" perch), and large numbers of 5.0-14.0" fish were taken in the gill nets in both Little Bay deNoc and Big Bay deNoc. The age structure of these populations is not known. Some of the field biologists suspect these large catches came at a time when perch invaded the bay only temporarily for spawning because angling was poor the rest of the year.

Mortality data are not available for perch. It is expected, however, that some information on total mortality will be forthcoming from index sampling at the Palisades power plant site. Currently, the presence of the strong 1969 year class interferes with developing such data from the age composition of sample catches.

Perch populations are probably fairly discrete. Smith and Van Oosten (1940) reported from a tagging study that few fish traveled further than 25 miles. One perch was recovered 57 miles away 9 months after release. Mraz (1952) marked a large number of fish in southern Green Bay in 1950. Most of his recoveries were made soon after near the tagging site. However, 6.5% were caught 20 to 40 miles away during the same summer and one perch had moved 50 miles in 2 1/2 months.

TABLE 19. PERCENTAGE AGE DISTRIBUTION OF YELLOW PERCH CAUGHT IN EXPERIMENTAL GILL NETS NEAR SOUTH HAVEN, 1968-1972.

Month and Year	Age[1] I	II	III	IV	V	Total catch
June						
1968	..	54	43	(1)*	..	93
1969	..	12	40	25	..	161
1970	..	6	32	53	8	384
1971	..	52	21	23	4	201
1972	..	10	64	16	10	222
August						
1968	..	70	17	(1)	(1)	30
1969	29	23	27	21	..	473
1970	31	27	19	21	2	595
1971	1	81	11	5	1	380
1972	1	45	50	3	1	851
October						
1968	17	31	35	10	2	116
1969	(1)	38	38	16	..	13
1970	55	15	19	11	..	522
1971	15	73	10	1	1	314
1972	16	17	41	20	5	76

[1] A few perch as old as 9 years were taken in 1968 and 1969, none since.

* One fish.

All indications point toward a revival of the perch stocks in Lake Michigan. Much of the abundance is due to the high survival of the 1969 brood and, until such time as several broods become re-established, no commercial quota is recommended for 1974. If this year class produces successful broods in 1973 and 1974, probably a selective fishery could be allowed by 1977. Further reason for optimism is mounting evidence that alewife abundance has peaked and may have stabilized at a level compatible with the perch population. With the sport fishery harvesting over 300,000 lb. annually, possibly a quota of 200,000 lb. will be feasible for southeastern Lake Michigan in 1977 (Table 1). By 1980, it is conceivable that, with the stabilization of the alewife population and the reduced commercial harvest, perch stocks will have rebounded to near their former abundance, and the allowable quota may approach 300,000 lb. It is doubtful if a commercial fishery should be permitted elsewhere since perch never were very abundant elsewhere except in Green Bay. A future commercial perch fishery in Green Bay is a possibility, in view of the large sample catches made last spring, but the Bay deNoc areas should be reserved for a sport fishery.

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APPENDIX A. COMMERCIAL HARVEST OF EIGHT SPECIES IN THE MICHIGAN WATERS OF LAKE MICHIGAN, (INCLUDING GREEN BAY), 1930-1972[1]

(thousands of pounds)

Year	Alewife	Burbot	Ciscoes (chubs)	Round Whitefish	Rainbow smelt	Suckers	Lake Whitefish	Yellow Perch
1930	--	14	764	202	--	1,253	4,813	150
1931	--	14	435	129	*	1,222	3,824	178
1932	--	19	328	88	23	1,293	3,332	202
1933	--	10	316	96	9	1,108	2,236	218
1934	--	8	948	98	17	1,392	1,932	306
1935	--	10	1,801	91	45	2,003	1,432	474
1936	--	7	1,501	38	120	1,899	876	361
1937	--	6	1,050	37	196	1,726	947	563
1938	--	7	1,439	54	681	1,301	1,117	704
1939	--	5	972	32	613	1,152	840	615
1940	--	7	237	23	2,419	1,227	754	349
1941	--	4	309	47	3,020	1,044	896	395
1942	--	4	363	45	2,229	1,106	1,061	466
1943	--	7	389	165	1,723	1,199	1,152	338
1944	--	6	479	125	*	1,185	1,403	254
1945	--	15	1,143	110	44	1,265	1,326	387
1946	--	8	1,065	150	66	1,007	1,822	295
1947	--	7	1,386	98	337	894	4,018	259
1948	--	12	2,083	101	627	1,249	4,263	299
1949	--	3	2,411	96	1,051	1,180	3,007	379
1950	--	1	2,330	81	1,625	831	2,102	486
1951	--	*	2,839	51	2,443	761	971	341
1952	--	*	3,288	41	4,024	488	1,481	507
1953	--	*	3,546	8	4,165	446	858	636
1954	--	*	3,137	16	4,765	280	592	1,002
1955	--	*	3,735	12	4,859	326	278	1,012
1956	--	--	3,616	10	5,886	257	39	966
1957	34	*	3,711	8	5,395	247	12	685
1958	378	--	3,525	2	6,155	307	40	909
1959	524	*	2,382	9	3,897	258	11	626
1960	1,679	*	3,406	6	2,190	286	56	1,294
1961	1,082	*	2,889	8	1,241	125	252	1,528
1962	1,395	*	3,718	10	1,086	42	188	1,034
1963	1,578	*	2,329	12	927	77	243	1,074
1964	3,330	*	1,357	9	802	38	584	2,366
1965	3,140	*	2,764	14	702	44	832	782
1966	6,438	*	2,313	19	1,018	23	1,280	386
1967	13,370	1	3,730	60	1,100	34	773	456
1968	9,038	33	3,518	51	1,659	21	826	178
1969	7,490	21	2,895	143	2,063	120	1,182	248

(Continued)

APPENDIX A, Continued.

Year	Alewife	Burbot	Ciscoes (chubs)	Round Whitefish	Rainbow smelt	Suckers	Lake Whitefish	Yellow Perch
	(thousands of pounds)							
1970	5,981	51	4,028	177	1,700	522	1,418	--
1971	3,895	99	2,002	172	1,084	425	2,389	--
1972	5,196	58	2,549	244	603	185	2,806	--

[1] Sources of data: 1930-1968. Baldwin and Saalfeld (1962).
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* Less than 1,000 lb.

APPENDIX B. COMMERCIAL HARVEST OF EIGHT SPECIES IN THE MICHIGAN WATERS OF LAKE HURON, 1930-1972[1]

(thousands of pounds)

Year	Lake Whitefish	Round Whitefish	Channel Catfish	Yellow Perch	Carp	Suckers	Ciscoes (chubs)	Rainbow smelt
1930	2,879	57	82	719	868	2,237	513	--
1931	4,140	31	31	731	875	2,132	485	--
1932	4,050	31	31	690	1,011	2,403	543	--
1933	3,334	55	43	427	972	1,890	598	--
1934	2,568	48	36	523	1,023	2,123	447	--
1935	1,895	45	55	983	1,079	1,766	387	2
1936	1,442	45	98	1,175	770	1,814	335	--
1937	1,019	72	115	548	978	1,726	190	--
1938	558	54	135	500	631	1,788	192	*
1939	255	64	118	565	739	1,382	174	--
1940	188	44	245	528	644	1,343	148	--
1941	114	46	386	416	669	1,312	126	20
1942	95	61	397	575	753	1,196	80	1
1943	149	99	395	975	1,243	1,414	128	*
1944	185	49	325	604	1,151	1,236	221	*
1945	181	42	384	407	2,370	1,554	190	3
1946	545	76	254	341	1,669	1,646	40	3
1947	3,023	49	271	291	1,327	1,282	126	2
1948	2,972	26	193	694	1,459	1,305	159	*
1949	530	22	167	518	952	1,022	148	12
1950	114	35	162	405	1,181	977	83	116
1951	143	18	227	363	1,677	1,197	114	218
1952	168	13	303	494	1,637	1,199	63	227
1953	153	11	333	458	1,361	1,144	106	211
1954	91	8	256	507	1,432	1,185	248	161
1955	66	5	355	585	1,373	1,024	317	159
1956	30	5	338	415	1,218	611	301	296
1957	41	6	271	353	1,309	482	507	91
1958	72	5	286	377	2,212	451	1,343	101
1959	103	2	330	356	1,304	464	2,151	70
1960	338	3	277	509	1,333	454	2,936	78
1961	438	9	239	598	1,437	551	3,197	32
1962	305	14	177	372	1,638	707	2,300	29
1963	113	6	172	507	1,647	509	1,975	13
1964	165	3	153	836	1,003	438	1,256	32
1965	175	9	146	966	1,425	389	1,347	28
1966	172	12	166	1,318	832	313	807	30
1967	262	2	129	1,134	972	243	356	52
1968	281	12	101	885	1,016	162	104	28
1969	306	24	122	800	1,298	136	509	64

(Continued)

APPENDIX B, Continued.

(thousands of pounds)

Year	Lake Whitefish	Round Whitefish	Channel Catfish	Yellow Perch	Carp	Suckers	Ciscoes (chubs)	Rainbow smelt
1970	173	--	226	536	1,224	138	12	--
1971	203	1	365	597	1,388	134	--	*
1972	298	2	254	327	888	91	4	--

[1] See footnote, Appendix A, for data sources.

* Less than 1,000 lb.

APPENDIX C. COMMERCIAL HARVEST OF SIX SPECIES IN THE MICHIGAN WATERS OF LAKE ERIE, 1930-1972[1]

(thousands of pounds)

Year	Channel Catfish	Yellow Perch	White Bass	Freshwater Drum	Carp	Walleye
1930	7	34	--	63	631	40
1931	10	72	--	57	931	81
1932	16	97	--	62	1,093	95
1933	9	87	--	138	779	100
1934	10	48	10	72	527	152
1935	15	54	12	68	658	122
1936	12	17	6	93	679	128
1937	11	16	26	75	577	134
1938	22	25	23	133	709	177
1939	18	13	22	168	586	253
1940	28	14	17	123	461	286
1941	21	25	35	119	655	129
1942	40	36	42	169	764	116
1943	63	23	21	155	598	263
1944	35	20	55	121	599	226
1945	44	29	74	92	484	252
1946	37	46	53	82	539	494
1947	41	49	45	110	444	348
1948	27	17	33	80	534	403
1949	27	32	29	65	555	358
1950	24	52	71	73	465	331
1951	25	42	36	81	672	248
1952	28	41	65	32	893	285
1953	19	65	42	19	1,183	383
1954	33	88	136	29	1,138	221
1955	76	57	120	28	900	227
1956	86	72	93	44	711	235
1957	57	109	45	65	620	289
1958	73	228	52	41	997	292
1959	89	174	35	65	1,042	129
1960	93	118	99	108	1,341	103
1961	86	104	159	95	1,298	105
1962	52	97	210	82	1,276	53
1963	41	90	126	71	833	93
1964	48	37	100	100	636	122
1965	50	69	72	93	806	87
1966	32	137	65	94	929	76
1967	31	112	61	96	485	209
1968	22	173	50	83	347	85
1969	21	112	57	40	432	47

(Continued)

APPENDIX C, Continued.

	(thousands of pounds)					
Year	Channel Catfish	Yellow Perch	White Bass	Freshwater Drum	Carp	Walleye
1970	2	53	4	4	332	*
1971	--	*	48	*	115	*
1972	11	19	60	7	261	--

[1] See footnote, Appendix A, for data sources.

* Less than 1,000 lb.