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CHAPTER ONE

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

TECHNICAL REPORT: 73-33

JAMES PECK, RICHARD SCHORFHAAR, ASA T. WRIGHT

Editor's Note: Unless otherwise noted, common names used in the text conform to those established in The List of Common and Scientific Names of Fishes from the United States and Canada, (3rd Edition). American Fisheries Society, Special Publication No. 6, Washington D.C., 1970. 150p.

S.V. BLUE FIN
MARQUETTE, MICHIGAN
VESSEL ASSIGNMENT:

LAKE SUPERIOR & NORTHERN LAKE MICHIGAN

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AND RECOMMENDATIONS FOR COMMERCIAL HARVEST

OVERVIEW

Lake Superior, the largest, coldest, deepest, and least productive of the Great Lakes has provided a substantial commercial fishery since the 1830's. The principal types of commercial gear used to catch fish in the Michigan waters of the lake have been the pound net, trap net, and gill net. The principal, commercially fished species were lake trout, lake whitefish, lake herring, and chubs (*Coregonus hoyi*, *C. nigripinnus*, *C. kiyi*, and *C. zenithicus*). Other species--smelt, perch, sturgeon, walleye, suckers, round whitefish, and northern pike have also been harvested, but comprised only a minor portion of the catch because of either the small sizes of the stocks or their low value.

The commercial fishery was unregulated until the late 1800's and since has declined due to over-harvest, market fluctuations, and the invasion of new species. Although regulations designed to control the fishery have been on the books for many years, they have not always been effective in accomplishing their purposes. Past regulations have controlled gear without limiting the total catch. The net effect of commercial regulations has been to increase inefficiency in harvest. This system of regulation has not been very successful since it did not curtail the American fisherman's ingenuity in increasing his catch when faced with a new regulation. Enforcement of regulations with an unlimited number of fishermen and complex laws and rules has also been a problem.

A more logical approach to management of the fishery is to control the harvest on a quota basis. A quota system should be based on the: (1) geographic distribution of the fish stocks; (2) amount of surplus; (3) most economical time and way to harvest; and (4) selectivity of the available gear.

This report briefly reviews the history of the important commercial stocks of fish at the present time in the Michigan waters of Lake Superior. It is being presented at this time as a guideline for the establishment of commercial harvest quotas in the Michigan waters of Lake Superior and makes recommendations on:

1. Which species should be fished commercially (1974-80)

2. How many pounds can be taken on a sustained basis

3. How and when the fishery should operate

4. What types of capture gear should be utilized for harvesting the fish

The quota recommendations take into account for each stock the record of stability, present magnitude, need to increase or decrease the size limits, recent trend of the stock in response to increases and decreases in fishing pressure, and recent changes in growth and age composition.

Table 1 presents recommendations for establishing a quota-managed fishery in the Michigan waters of Lake Superior for the period 1974-80. The table presents the quota recommendations for those species which are thought to be able to withstand commercial fishing exploitation during this period (whitefish, chubs, herring, smelt, suckers, and offshore lake trout). Also included are recommendations on the areas (statistical district and grids), seasons, and gear for harvesting these species. The common names of these species approved by the American Fisheries Society (Spec. Publ. No. 6, 1970) are used throughout the text. A map showing the statistical districts and grids of Lake Superior is presented in Fig. 1.

TABLE 1. COMMERCIAL FISHERIES RECOMMENDATIONS FOR LAKE SUPERIOR[1/]
(DEPTHS IN FATHOMS; QUOTAS IN THOUSANDS OF POUNDS)

	Statistical District					
	MS1	MS2	MS3	MS4	MS5	MS6
LAKE WHITEFISH[2/]						
Gear	Gill net (4.5")	Pound and trap	Pound and trap	Pound and trap	Pound and trap	Pound and trap
Depth	≤15	≤15	≤15	≤15	≤15	≤15
Months	May-Oct.	May-Oct.	May-Oct.	May-Oct.	May-Oct.	Feb.-Oct.
Grids	All	All	1224, 1126, 1125	Big Bay - Marquette	All	1443, 1444
Quotas (1974-80)	10	15	5	40	10	25
Grids	--	--	1325, 1326	Munising area	--	1544, 1644
Quotas (1974-80)	--	--	10	75	--	150
Grids	--	--	--	--	--	1545, 1645 1646
Quotas (1974-80)	--	--	--	--	--	25
CISCOES (CHUBS)						
Gear	Gill net (2.5-3.0")	Gill net (2.5-3.0")	Gill net (2.5-3.0")	Gill net (2.5-3.0")	Gill net (2.5-3.0")	Gill net (2.5-3.0)
Depths	>50	>60	>60	>60	>60	>60
Months	May-Oct.	All	All	All	All	All
Grids	All	All	Several[3/]	Several[4/]	All	All
Quotas (1974-80)	17	200	395	155	25	10
LAKE HERRING						
Gear	Gill net (2.5-3.0")	--	--	--	Gill net (2.5-3.0")	--
Depths	Surface	--	--	--	10-30	--
Months	May-Oct.	--	--	--	May-Aug.	--

TABLE 1, continued

	Statistical District					
	MS1	MS2	MS3	MS4	MS5	MS6
LAKE HERRING (continued)						
Grids	523, 622	--	--	--	Caribou Island	--
Quotas (1974-80)	5	--	--	--	10	--
Grids	718, 818, 819	--	--	--	--	--
Quota (1974-80)	5	--	--	--	--	--
LAKE TROUT[2/]						
Gear	Gill net (4.5")	--	--	--	Gill net (4.5")	--
Grids	623,624	--	--	--	Caribou bank	--
Depths	20-40	--	--	--	10-100	--
Month	May	--	--	--	May-Aug.	--
Quotas (1974-80)	5	--	--	--	80	--
Grids	522, 623	--	--	--	Big Flats	--
Depths	0-15	--	--	--	40-100	--
Months	May-Sept.	--	--	--	May-Aug.	--
Quota (1974-80)	2	--	--	--	25	--
Grids	718, 721	--	--	--	--	--
Depths	0-15	--	--	--	--	--
Months	May-Sept.	--	--	--	--	--
Quota (1974-80)	2	--	--	--	--	--

1/ No quotas are assigned to any district for the incidental catch of herring in chub nets and incidental catches of suckers, smelt, round whitefish, and burbot either in commercial netting or the research fishery.

2/ Minimum length of lake whitefish = 19.0"; lake trout = 16.0".

3/ Recommended quotas (1974-80) for certain grids in MS3 are as follows (thousands of pounds): grid 926 - 10; 927 - 10; 1028 - 45; 1122 - 15; 1225 - 40; 1226 - 75; 1127 + 1227 - 60; east of Keweenaw Peninsula (offshore research) - 40; and west of Keweenaw Peninsula (offshore research) - 100. The latter two are for 1974-76 only.

4/ Recommended quotas (1974-80) for certain grids in MS4 are as follows (thousands of pounds): grid 1430 - 50; 1530 - 10; 1532 - 25; 1533 - 20; 1534 - 20; and 'virgin' - 30.

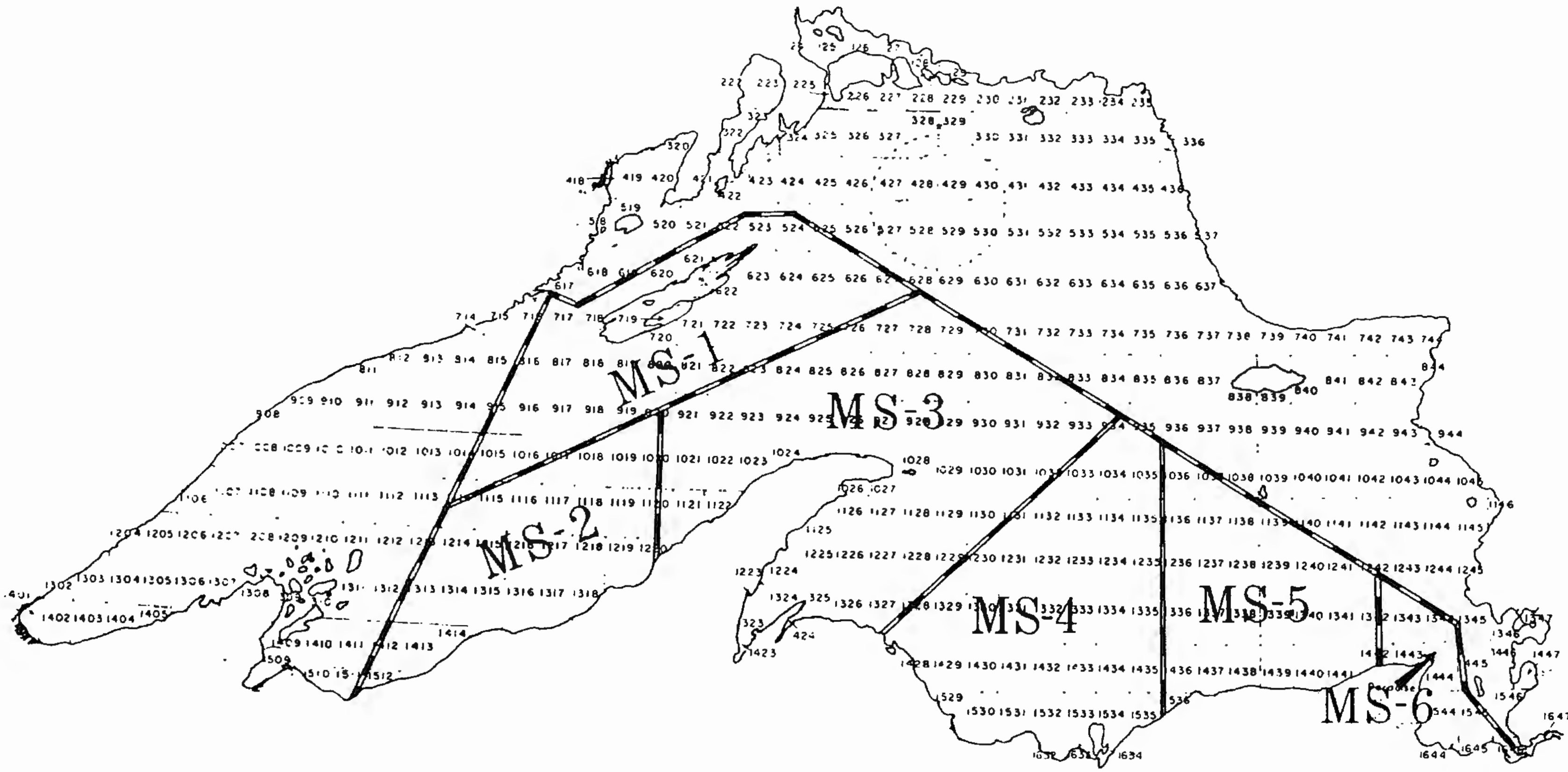

Figure 1. Statistical grid map of Lake Superior.

LAKE WHITEFISH

History of the Fishery in Lake Superior

Maximum recorded yield of whitefish from Lake Superior was 5.2 million lb. in 1885, while production in Michigan waters peaked at 3.8 million lb. in 1891. Catches declined from that time until 1920 when only about 524,000 lb. were produced lake-wide; 200,000 lb. in Michigan. Lawrie and Rahrer (1972) believe this decline is related to a "fishing up" process in which stock after stock are exploited beyond their capability of sustaining high yields. This process also is related to the capability of the fishery to move farther and farther from port. Ryder and Johnson (1972) suggest that the dumping of large amounts of woody material during the lumber era also had a deleterious effect on Lake Superior whitefish.

This initial period of decline was followed by a period of general upward trend in harvest from 1920 to 1955. Catches around the lake rose to 1.5 million lb., and the Michigan catch rose to 665,000 lb. in 1954 (Appendix A). Lawrie and Rahrer tend to equate this trend with a general improvement of the stocks possibly due to improvement of the environment. However, fishing intensity was also increasing during this period and new areas were being exploited, both of which were responsible for at least a portion of the higher catch.

The whitefish harvest between 1955 and 1960 again declined drastically. By 1960 the lake-wide catch was only 384,000 lb.; 156,000 lb. in Michigan waters. This decline probably was due to the increased abundance of sea lamprey. Spangler (1970) demonstrated that the pattern of whitefish mortality was closely related to periods of lamprey activity in Lake Huron.

The period 1960-69 was characterized by an increase in whitefish harvest, with Michigan catches exceeding 500,000 lb. and lake-wide catches that exceeded 700,000 lb. by 1969. The catch per unit of effort (CPE) generally increased also during this period. This apparent increase in whitefish populations can be attributed to a combination of factors including: increased density of lake trout stocks which provided a buffer between whitefish and lamprey; reduction of sea lamprey numbers; and a decrease in commercial fishing effort. Commercial fisheries restrictions instituted by the Michigan Department of Natural Resources since 1968 provided further protection to the stocks. The harvest (1969-72) has averaged 420,000 lb.

Effects of Exploitation

Whitefish were the most sought-after species in the early fisheries of the four upper Great Lakes and were also the most sensitive to exploitation (Smith, 1972). Smith also indicated that they are the most resilient after depletion.

Regier and Loftus (1972) referred to a paper by Cristie and Regier (1972) in which it was suggested that mature whitefish in the catch should be assured the opportunity of spawning at least 1.5 times if the population is to maintain itself.

Selection of Gear

Gill nets, trap nets, and pound nets have all been used extensively to harvest whitefish in the past. From the standpoint of protecting non-target and undersized target species, the gill net is the least desirable gear for harvesting whitefish.

Incidental take in impoundment gear is quite high at times, but with proper care most of the fish can be released unharmed. During times of strong currents or bad storms, gilling of fish in impoundment gear can be a problem. Limiting the fishing depth of the impoundment gear to 15 fathoms should make it possible to release the undersized and protected species unharmed. Changing the tops of the trap nets to 5.0" mesh would provide additional escape routes for undersize fish. This technique has been successful in reducing the catch of juveniles in the experimental fishery in Little Bay de Noc (Lake Michigan).

Limited data on size and age at maturity were gathered from Whitefish Bay and Marquette during October, 1972. Average length at each age is presented in Table 2. Mean age at maturity in Lake Superior is age IV and one-half and the mean age in the trap net catch is approximately five and one-half years. Thus the 4½" mesh trap net fishery at the present locations closely fits Cristie and Regier's criterion for sustaining a whitefish population. Increased trap net effort will change the exploitation pattern and could very well increase the catch of immature fish. To protect against this change, the legal size should be raised to 19.0" total length. On the average lake wide between 50 and 55 percent of the whitefish under 19 inches are immature.

TABLE 2. AVERAGE LENGTH OF AGE GROUPS OF WHITEFISH FROM WHITEFISH POINT, MUNISING, AND MARQUETTE, 1972

Port	AGE GROUP					
	III	IV	V	VI	VII	VIII
Whitefish Bay	16.5	18.5	20.5	23.0	24.2	26.7
Munising	16.4	18.5	20.2	22.9	23.9	26.5
Marquette	----	18.6	21.5	22.8	----	26.6

Full recruitment into the present trap net fisheries (4 1/2 - 4 3/4" stretch mesh) occurs at age V in all three areas (Table 2).

Cucin and Regier (1966) determined that whitefish between 19.0 and 20.0" long in Georgian Bay (Lake Huron) were fully vulnerable to 4 1/2" gill nets, slightly shorter than the 20.0 - 21.0" presently seen in the trap nets of 4 3/4" mesh. Fish of this size in Lake Superior would be between ages IV and V.

Proposed Quotas

Recommended quotas for each of the six statistical districts are summarized in Table 1. The basis for each of these recommendations is discussed below:

MS 1: Whitefish catches in MS 1 since 1929 have never exceeded 33,000 lb. and only rarely has it surpassed 20,000 lb. During the past 10 years the average yield was 12,800 lb. Recently, effort in MS 1 has shown a steady decline while the CPE has risen from a low of 9 lb. per 1,000' of gill net in 1960 to a high of 99 lb. per 1,000' in 1972. This is at least partly related to aging of the fishermen. They are not able to fish as much gear as formerly, and tend to concentrate their effort at areas and times that are most productive.

The fisheries at Isle Royale should not be expanded and those that exist retained as a historical fisheries operated to provide interpretive material. It is a minor source of commercial fish and a means of monitoring the fish stocks. A 10,000 lb. quota taken with gill nets 4 1/2 - 4 3/4" stretch mesh should be sustainable and will yield enough data to document any major changes in the population. Fishing should be done in May and October to be consistent with past effort. At present four fisheries are well-spaced around the island with a fishery at Washington Harbor, Siskiwit Bay (Fisherman's Home), Rock Harbor, and Crystal Cove. Formerly, as many as 20-25 fishermen were located on the island.

MS 2: Whitefish yields from MS 2 have been as high as 158,000 lb. since 1929. Catches during this period varied greatly with peaks occurring in 1935, 1940, 1947, and 1954. The mean catch in the period 1929-59 was 40,000 lb. The harvest has been very low since 1959, never exceeding 5,000 lb. Commercial fishing has been curtailed for several years and lamprey populations have declined in this area. During peak harvest periods gill nets, pound nets, and trap nets all had good CPE's. The gill net CPE reached as high as 24 lb. per 1,000'; trap net CPE - 165 lb. per lift, and pound nets - 297 lb. per lift. A quota of 15,000 lb. is proposed for 1974-76 to determine the present status of these stocks. The initial quota should be taken in May-October with impoundment gear in <15 fathoms so that protected species caught incidentally may be released. Because of the extremely exposed shoreline, most of the fishing will probably take place June-August. MS 2 is also a popular sport-fishing area, so the commercial netting efforts will need to be carefully tailored to avoid conflicts between fishing interests.

MS 3: Whitefish catches in MS 3 during the period 1929-56 averaged about 60,000 lb. annually with a low of about 25,000 lb. and a high of about 190,000 lb. From 1957 to 1969 the catch averaged 20,000 lb. annually and effort during this period was also proportionately lower. The CPE averaged about 4 lb. per 1,000' of gill net from 1929-58 and then increased gradually to about 13 lb. per 1,000' of gill net by 1968. The 1929-55 trap net catch averaged 60 lb. per lift. Lake trout assessment fishing (September, 1972) near Bete Grise produced 2,358 lb. of whitefish for a CPE of 98 lb. per 1,000' of 4 1/2" gill net, indicating a fair abundance. A preliminary quota of 5,000 lb. for 1974-76 is recommended for grids 1224, 1126, and 1125 in this area, using impoundment gear.

The Huron Bay complex (grids 1325 and 1326) produced most of the 20,000 lb. from 1957-1969, and an impoundment gear quota of 10,000 lb., on a trial basis, is recommended for 1974-76. The fish should be taken during May-October in water no deeper than 15 fathoms.

Other areas that formerly produced whitefish should be experimentally explored by Department biologists before any harvest is allowed. These include Big and Little Traverse Bays, Rabbit Bay, and possibly areas further within Keweenaw Bay.

Before a more precise projection can be made on the capability of MS 3 to produce whitefish it will be necessary to do considerable survey work. Based on past records, it is not expected that sustained yields could exceed 60,000 lb. per year even under intensive management.

MS 4: An average of 84,000 lb. of whitefish were taken here from 1940-72. From the low catches of 1960-1972 the average has been 90,000 lb. A record 178,000 lb. was caught in 1972. Gill net effort in 1960-72 declined greatly from about 7.5 million feet to about 800,000' in 1972. Gill net CPE's during this same period increased dramatically from 6 lb. per 1,000' to 51 lb. per 1,000'. Commercial production has risen although the catch has been erratic.

Part of the reason for the CPE's having increased so dramatically was that some less efficient operators quit and the gill net fishery changed from a year-round fishery to fishing from December through May when success is normally better than during other months. Further, some of the earlier gill net data analysis included incidental catch data from nets fished expressly for lake trout.

Trap net CPE's and total catches have increased greatly since 1966. From 1929 to 1966 the CPE averaged around 50 lb. per trap net lift; since 1966, CPE's have risen to the 1972 high of 358 lb. per trap net lift. The average size of the fish also increased. Exploitation of new ground accounts for some of the tremendous increase in CPE as does change in net design.

Samples of trap net catches in the fall of 1971 in Marquette indicated few age-IV fish. Further sampling in 1972 confirms that this age class (1967) was poorly represented in the catch. In numbers, these fish would normally have been expected to dominate the 1972 catch as five-year-olds. Yet, in the face of an apparently weak year class, a record yield of whitefish was achieved in 1972 from the Marquette area. Age IV and VI fish provided most of the harvest in 1972, and both appear to be strong year classes. The 1973 harvest should be highly dependent on age V, VII and IV recruitment.

We know that the fishermen are extending into new areas near both Marquette and Munising and that CPE's are increasing greatly at this time, but the real status of the whitefish population is not known. The population seems to be expanding and an impoundment quota equaling the mean catch (115,000 lb.) for the last 3 years is recommended for 1974-76. Since this level of projection is very liberal in light of the 1929-72 average, no projection for 1977-80 was made pending the degree of stability shown during the next 3 years of harvest.

This annual quota should be divided between the Marquette and Munising areas with 40,000 lb. being allotted to Marquette and 75,000 for the Munising area annually. Fishermen can operate from May to October in the Marquette area and could possibly operate under the ice in Munising. Fishing again should be restricted to less than 15 fathoms of water so that incidentally caught game species can be released unharmed.

MS 5: The past history of fishing in MS 5 reveals little about the commercial whitefish production capability. During the 1972 season one trap net fisherman operated at nearby Au Sable Point and made good catches. This same operator has indicated a desire to fish MS 5 between Au Sable Point and Crisp Point. The best catch since 1929 was about 20,000 lb.

An initial quota of 10,000 lb. from grids 1436 - 1442 and 1536 is recommended. The quota should be taken in trap nets and pound nets during the period May-October in <15 fathoms.

MS 6: The whitefish catch in this district is mainly from a winter and spring gill net fishery in the Tahquamenon Bay area; and a trap net fishery between Whitefish Point and Tahquamenon Bay, and from the Dollar Settlement area during May-October.

Dryer (1963) indicated that fish from Whitefish Point and Dollar Settlement may be separate stocks, using as evidence different growth rates. The population at Whitefish Point grew fastest. A limited amount of sampling in 1972 continues to support this contention. Tag returns have shown that these stocks are also being exploited in the Canadian waters of Whitefish Bay.

October sampling indicated that age-V whitefish are completely vulnerable to the 4 3/4" (stretch mesh) trap nets presently being fished.

Using the trap net data from 1968 shown in Table 3, the average mortality estimate of fully recruited fish was calculated by a method described by Kennedy (1949).

The average proportion of fish which survive from one year to the next is calculated from the table as follows:

$$\frac{9.2}{20.4} + \frac{2.6}{9.2} + \frac{0.9}{2.6} = 0.394$$

TABLE 3. NUMBER OF WHITEFISH CAUGHT PER TRAP NET LIFT IN MS 6 IN 1968-72

Year	AGE GROUP				
	IV	V	VI	VII	VIII
1968	2.6	19.7	3.9	1.5	0.4
1969	5.8	21.1	13.0	2.3	---
1970	4.5	12.5	10.8	0.8	0.3
1971	4.6	25.0	6.9	3.4	0.4
1972	11.6	23.7	11.5	4.9	2.3
Mean	5.8	20.4	9.2	2.6	0.9

On the average, approximately 40% of the fish of a given age class survive to the next year and 60% do not. The mean CPE's within age groups indicate the relative strength of the year class.

For the trap net fishery the age at full recruitment is age V (Table 3).

Catch statistics for MS 6 show the CPE's for both trap nets and gill nets have had a slight upward trend since 1960, increasing by 6.16 and 1.01 lb. per year, respectively. Due to the variability of the data, however, the relationship is weak, and a conservative approach to establishing a quota is called for. Effort during this 1960-72 period decreased and the mean annual catch was 225,000 lb.

Three possible methods for establishing the quota are:

1. Use the mean annual production for 1960-72 as a starting point in 1974 and increase the quota by 5% per year (gill net CPE increased at 3% per year and trap net CPE at 7.3% per year). By this method the quotas would be 225,000 lb. for 1974, 260,000 lb. for 1977, and 290,000 lb. for 1980.

2. Use the 1960-72 average annual catch (225,000 lb.) for 1974-80.

3. Project a quota of one standard error below the mean which amounts to approximately 200,000 lb. for each year, 1974-80.

Using method No. 3, a quota of 200,000 lb. annual (1974-80) is recommended. Since the Canadians intend to continue increasing exploitation in the adjacent Statistical District OS 7, their catch may affect the stability of whitefish in MS 6. Commercial catches from OS 7 increased from 26,000 lb. in 1960 to 212,000 lb. in 1968 but dropped to 147,000 lb. in 1972.

The MS 6 quota should be apportioned to the following grids: 1443 and 1444 - 25,000 lb.; 1544 and 1644 - 150,000 lb.; and 1545, 1645, 1646 - 25,000 lb. These are approximately the same proportions in which whitefish are now taken from the Whitefish Bay area. This quota should be taken in impoundment gear in 15 fathoms of water or less, February-October. Although it is not presently done, the gear could be fished under the ice in grids 1544 and 1644 during February and March.

CISCOES (CHUBS)

According to Lawrie and Rahrer (1972), the history of chub fishing in Lake Superior entails the sequential fishing-up of three species from largest to smallest: blackfin cisco (Coregonus migripinnus), shortjaw cisco (C. zenithicus), and bloater (C. hoyi). The fishing-up of the blackfins began in the late 1800's following over-exploitation of stocks in the lower Great Lakes. Blackfin cisco were commercially extinct by 1907. Intensification of the shortjaw cisco fishery began in 1925, also following a decline in abundance in the lower Great Lakes. Shortjaw cisco were commercially extinct by 1950. Fishing pressure intensified on the small bloater chub and lake herring in Lake Superior during the mid-1950's because whitefish and lake trout stocks had been reduced to low levels. Intensified fishing effort on bloater chubs has been maintained through 1972. Some declines in chub abundance (CPE) have recently developed. Fishermen have shifted some effort into deeper water, probably catching a greater percentage of kiyi (C. kiyi) and thereby masking an even greater decline in bloater abundance. This is speculation, however, because the species composition of commercial chub catches from various depths is not known at this time. Regardless of species composition, the shift to netting deeper water represents a form of sequential exploitation.

The chub fishery has been largely unregulated. Recent regulations in Michigan waters governing the mesh size, footage, and location of small mesh gill nets have been aimed at reducing the incidental lake trout catch in chub nets. Further prohibition of bottom nets inside 50 fathoms should have afforded some protection to bloater chubs. Chub effort has not been affected by limited entry or zone management regulations implemented in 1970.

Michigan's chub harvest has increased steadily since 1968. The demand for Lake Superior chubs increased as stock abundance in Lake Huron and Lake Michigan declined, and fishermen have shifted effort from declining herring stocks to chubs. Bloater stocks appear to be going through the same fishing-up process as blackfin ciscoes and shortjaw ciscoes did earlier.

Chub abundance (CPE) has declined in some statistical districts since 1968 with most traditional chub grounds reflecting the decline. Chub CPE has declined in certain grids although the CPE for statistical districts has varied without trend, thus pointing out a need for management on a grid basis in major chub-producing districts. Regulation of catch on a district or grid basis is the most obvious means of maintaining abundance of chub stocks. Recommended quotas in Table 1 exemplify this type of approach. Quotas were based on catch-effort trends in the district or grid with special consideration given to recent data.

Stock Status

There is very little known about the status of chubs in Michigan waters except that which can be interpreted from commercial catch-effort statistics. Distribution, growth, and food habits of chubs have been documented for western Lake Superior (Dryer, 1966; Dryer and Beil, 1968; Anderson and Smith, 1971), but nothing has been published on chubs in Michigan waters. However, certain of this information from western Lake Superior applies to Michigan chubs. Recent unpublished age-composition and length-frequency information has been gathered for some Michigan stocks and these data (Table 4) were similar to that reported for bloaters by Dryer and Beil (1968). Recent samples from Michigan waters included chubs as large as 16.0", whereas Dryer and Beil (1968) did not report any bloaters larger than 12.5". The Michigan samples were not identified to species so it is not known if the 13.0-16.0" chubs were bloaters.

TABLE 4. PERCENTAGE AGE COMPOSITION OF COMMERCIAL CHUB LANDINGS FROM FIVE MICHIGAN STATISTICAL DISTRICTS IN LAKE SUPERIOR, 1971-72[1/]

Statistical District	Grid(s)	Number of Fish	Age Composition (%)					
			IV	V	VI	VII	VIII	IX
MS 1	718-818	27	22	26	44	8	--	--
MS 2	1021, 1119	84	1	29	37	25	6	2
MS 3	1126	44	9	36	34	16	5	--
MS 4	1530	31	6	16	36	36	3	3
MS 6	1343	32	9	19	35	25	9	3

[1/] Gill nets of 2 1/2 - 2 3/4" mesh were used.

Chub abundance is based on commercial catch per unit effort (CPE), where catch is measured in pounds and a unit of effort is 1,000' of 2 1/2 - 2 3/4" mesh nylon gill net. The present expansion of the chub fishery started in 1957 (Fig. 2) so annual chub CPE's for 1957-71 were employed in the trend analysis and abundance projections. Linear regression analysis of annual CPE for each statistical district on year was used to establish CPE trends and project CPE's with 95% confidence limits for 1974, 1977, and 1980. Bloaters experienced a growth increase similar to herring. CPE based on number, therefore, would be a better abundance index than a CPE based on pounds. Unfortunately, information on change in average chub size in commercial landings is lacking.

Commercial CPE data is usually biased by gear selectivity, alteration of nets, shifts in fishing patterns, etc. Trends calculated from 1957-71 for CPE's in the three most extensively fished statistical districts (MS 2, MS 3, and MS 4) are suspect because of the sharp unexplained rise in CPE during the mid-1960's. Depletion of herring and lake trout stocks may have permitted a chub population explosion and the CPE's would be an

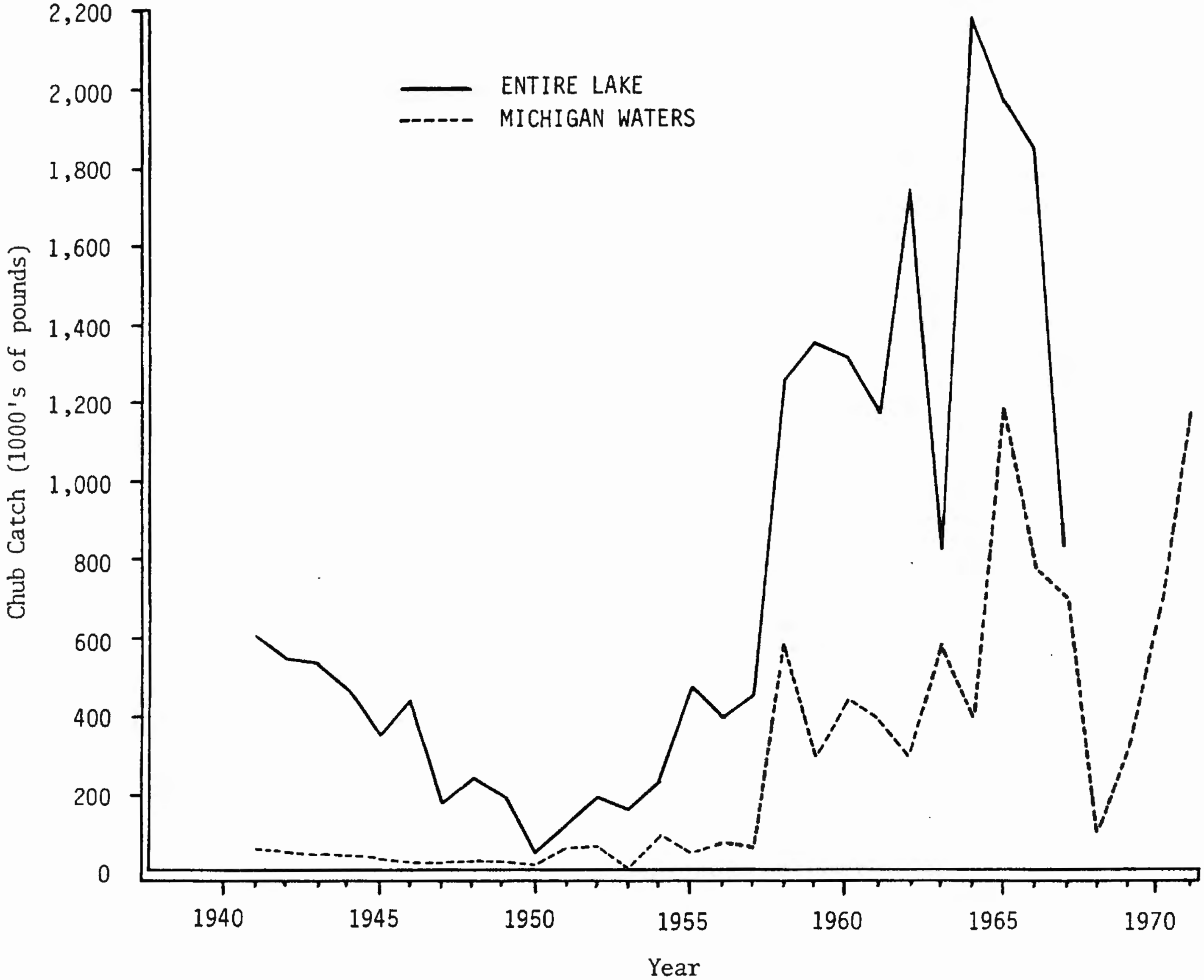

Fig. 2. Chub harvest in Lake Superior, 1941-1971

actual measure of this increased abundance. Anderson and Smith (1971) reported a substantial rise in chub abundance in Minnesota and Wisconsin waters during the early 1960's. On the other hand, low chub CPE's during 1957-64 may have been the result of the incidental catch in the herring fishery as it expanded offshore into chub water. Herring nets that caught chubs were reported and included as part of the chub effort but the take of chubs was small. Collapse of these herring fisheries and shifts to chub fishing could induce an artificial increase in chub CPE during 1964-65. No attempt was made to separate early effort as to species sought.

Variability of species composition of chub landings is another potential bias in using chub CPE as an index of abundance. Only three species of chubs exist in significant abundance in Lake Superior today. The bloater chub is the most abundant in commercial landings, kiyi is second, and the shortjaw cisco while not previously reported common in Michigan waters, appears to be abundant in western Lake Superior. Restriction of bottom nets to depths over 50 fathoms in 1970 undoubtedly resulted in an increased catch of the kiyi. Dryer (1966) found bloaters to be most abundant at 40-49 fathoms and the kiyi most abundant at 70-89 fathoms during all seasons in the Apostle Islands region, 1958-63. Bloater abundance declined rapidly between 50 and 90 fathoms but Koelz (1929) stated that, except during the spawning season, the majority of kiyi were taken from at least 100 fathoms and only rarely were they caught with bloaters. It is now apparent that kiyi are present in less than 100 fathoms at times other than the spawning season. Chub fishermen gradually have been fishing more in deeper water during the last few years, some as deep as 80-90 fathoms. This shift should bring more kiyi into the catch and mask any decline in bloater abundance because the chub CPE could be maintained or even increased by fishing deeper and harvesting a greater percentage of kiyi. Information regarding species composition of chubs at various fishing depths is sorely needed. The commercial catch could then be stratified by depth and species, thus providing a more reliable index of abundance.

The present bottom-net chub fishery and herring float-net fishery are now easily separable, but some chubs are caught incidentally in herring nets especially when the float nets inadvertently (or otherwise) sink. Incidental catches of herring in chub nets also act to lower chub CPE. The highest incidental catches of herring usually occur during November-January when chub CPE is also highest. Herring apparently move into deeper water during this period and generally account for 10-30% of the total CPE in November-January chub sets. A few sets have captured more herring than chubs.

Fishing Methods

Chub fishing is presently conducted with 2 1/2 - 2 3/4" mesh gill nets. The Bureau of Commercial Fisheries conducted bottom-trawl explorations in Lake Superior during 1963-65 and located several trawlable chub concentrations (Reigle, 1969), but no successful trawl fishery for chubs was developed. Based on Reigle's report it would appear that chub trawling would be most successful at depths less than 50 fathoms where the incidental catch of lake trout would be highest. Few trawlable fishing grounds were located east of Keweenaw Bay.

Fishing Seasons

The chub fishery is conducted all year, weather permitting, especially during recent years. Most fishing is done from May to December. CPE's generally were highest during November-January in MS 3 and MS 4 during 1970-71. June-August CPE's were consistently low in both districts, probably because of a chub movement to water less than 50 fathoms. There have been a few shifts in fishing effort among months in 1956-72. Effort declined in August and increased in October in MS 2; decreased during July through September, and increased in November and December in MS 3; decreased in July and increased in November in MS 4. These shifts conceivably could be responsible for some of the increase in annual CPE. However, CPE trends for all months during 1965-72 were similar to that of the annual CPE trend indicating that the increase in annual CPE was not the result of a shift in fishing effort within years.

Depth Distribution

The gill net chub fishery is presently restricted to 50 fathoms and deeper, although both Dryer (1966) and Reigle (1969) found chub abundance greatest at depths less than 50 fathoms. Many lake trout and herring are taken incidentally even in these deep chub sets, and this incidental catch would probably be much higher inside 50 fathoms. Approximately two-thirds of the lake trout taken in chub sets are reported as siscowets, commonly referred to as fat trout by the fishermen. Lean trout (recognized as planted, clipped fish) comprise the remaining one-third, and the CPE averaged about 1-2 fish per 1,000' of net in most areas. However, an accurate subspecies breakdown of native (unclipped) lake trout caught incidentally in chub nets is needed. Although chub fishing takes place outside sport-fishing grounds, a possible conflict could develop if the incidental lake trout catch depletes stocks which contribute to the sport fishery and to rehabilitation of the stocks. The incidental catch of herring is significant only during November-January. Occasionally, the incidental catch of herring in some net sets during this period has equaled or exceeded that of chubs. Burbot are often taken in chub nets, but the CPE rarely exceed 10 lb. per 1,000' of net.

Proposed Quotas

Management of chub stocks in major chub-producing districts should be done on a grid basis as soon as sufficient data becomes available. Although discreteness of chub stocks has not been determined, there are likely more than one stock in each district and perhaps also in each grid. Catch-effort statistics from grids in MS 3 and MS 4 were used as guidelines to establish quotas, but there were not enough data available for a quantitative analysis of trend. A summary of quota recommendations is presented in Table 1. A discussion for each statistical district follows:

MS 1: Annual catch statistics since 1966 show that the chub CPE (pounds per 1,000' of 2 1/2 - 2 3/4" mesh gill net) varied without trend. Projection of the 1966-71 average CPE (119 lb.) and average annual catch (17,000 lb.) to 1974, 1977, and 1980 is justified as of now. The potential harvest is likely greater but beyond the capabilities of the present.

fishery. Approximately 215,000' of gill net would be required to harvest the recommended quota. Lake trout were taken incidentally in chub gear at rate of 1.2 fish per 1,000' of net during 1970-71 and some 258 would be taken annually in obtaining the projected chub quota of 17,000 lb. (Table 1). It is not known what percentage of the incidental catch is fat trout and lean trout. The incidental catch did not appreciably vary by month but nets set at less than 50 fathoms in 1968 caught 5 times as many lake trout (CPE = 6.14) as sets deeper than 50 fathoms in 1970-71 (CPE = 1.2). Age VI chubs comprised 44% of a 1971 sample from 2 11/16" mesh (Table 4). Chub length frequency in this sample ranged from 10.0-13.0" with a mode of 11.0".

The gill nets now used in this fishery are expected to be used in the future. The fishery is conducted during July-November with best catches during September-November. There is no reason to prohibit chub fishing during any of these months. Fishing depth should be restricted to deeper than 50 fathoms to reduce the incidental trout catch.

MS 2: Commercial chub fishing in MS 2 was suspended in 1968. Some chub fishing research permits were issued to commercial fishermen in 1971-72 for grids adjacent to or straddling the boundary with MS 3 (920, 1020, 1120, and 1119). Age composition of the 1971-72 catch (Table 4) was dominated by ages V (29%), VI (37%), and VII (25%). Length frequency of chubs in the 2 5/8 - 2 3/4" mesh ranged from 9.0-16.0" with a mode of 11.0".

Chub CPE's from 1956 to 1968 showed a highly significant upward trend, increasing 4.4 lb. per year. Projected chub CPE's with 95% confidence limits are 105 ± 46 for 1974; 118 ± 51 for 1977; and 131 ± 57 for 1980. CPE's for MS 2 grids fished in 1971 ranged from 75 to 118 and corresponded rather well to the calculated trend. Landings averaged 105,000 lb. during 1958-68 with a high of 205,000 lb. in 1965. The CPE in these relatively unexploited grids was on a par with the more intensively fished grids in Keweenaw Bay (MS 3). A conservative annual quota of 200,000 lb. is recommended initially for the district providing that annual quotas for individual grids do not exceed 20,000 lb. This would require that at least ten grids be fished. Quotas could be adjusted on an individual basis when sufficient data become available. Forty-four thousand pounds were reportedly taken from the aforementioned boundary grids during 1971 research fishing.

In 1968 the incidental CPE of lake trout in MS 2 chub nets was 6.3 fish. The incidental lake trout CPE reported by fishermen during the August-November 1971 chub research fishery was 4.3 fish of which 13% were planted lean trout and 87% were presumably native siscowets.

Attempts to establish a trawl fishery in 1966-67 failed because of inexperience with the new gear and lack of a sufficient market. Although exploratory trawling by the U. S. Bureau of Commercial Fisheries (Reigle, 1969) yielded some commercially significant CPE's (500 lbs/hr.) in MS 2, efforts by the commercial fishermen yielded catches in 1966 and 1967 of 33 lb./hour and 44 lb./hour, respectively. Reigle (1969) reported that the incidental catch of lake trout in the trawls declined from 38.3 trout per 1/2 hour to 2.9 trout at 50 fathoms.

Recent data are insufficient to determine either periodicity of monthly chub abundance or the incidental catch of lake trout. Abundance is no doubt similar to other districts with the potential for greatest CPE being highest during November-January and lowest during June-July. Variations in lake trout CPE would probably be independent of month as evidence in other districts. Fishing beyond 60 fathoms should reduce the incidental catch of trout and not markedly affect the potential harvest of chubs.

MS 3: Chub CPE's increased in MS 3 during 1957-68 and especially since 1963. It has risen nearly 5 lb. per year and, based on this trend, predicted CPE's with 95% confidence limits are 122 ± 55 for 1974; 137 ± 59 for 1977; and 152 ± 65 for 1980. However, the downward trend in catch since 1968 suggests a conservative approach to setting quotas for 1974, 1977, and 1980. The rate of CPE decline has been 11% per year since 1968 and all grids fished in Keweenaw Bay exhibited this decline. The decline is most likely due to increased commercial fishing pressure, but the increase in numbers of predaceous burbot and lake trout may also be exerting some effect. The deep-water predator population is being re-established through lake trout planting, successful trout and burbot spawnings, and sea lamprey control. Chub fishing has intensified since the exceptionally low effort in 1968 but did not exceed the 1958-71 average until 1970.

The chub harvest must be reduced in the traditionally fished grids in this district until this decline is halted. Grid quotas in Table 1 are lower than the respective 1971 catches and are prorated upon the severity of decline and the availability of 60+ fathoms of water. An additional quota of 140,000 lb. is recommended for distribution among relatively unexploited offshore grids in Keweenaw Bay and west of the Keweenaw Peninsula (1974-76) to test the effect of exploitation.

Sequential fishing exploitation has taken place in MS 3, but it can be clearly demonstrated only in grid 926 (Fig. 3). Grid 926 was fished by only one fisherman during 1968-71. Chub CPE has declined much faster in this grid than in the whole district and the fisherman has shifted some of his effort to grid 1028 since 1970. The MS 3 chub fishery expanded during 1968-71 with five grids fished in 1968, 10 grids in 1969, 11 grids in 1970, and 19 grids in 1971. The expansion in 1971 resulted in part from selected fishermen operating under research permits from the Department of Natural Resources. CPE's in the new grids were generally not higher than previously fished grids. In fact, the average CPE (84) by permit fishermen was lower than the regular CPE (102) and contributed to the low district CPE (95) in 1971. Although the limited amount of sequential fishing has not yet distorted the overall CPE trend in MS 3, future quota recommendations should be made on a grid basis--at least for the grids which are traditionally heavily fished. The research-permit quotas should be issued for previously unfished or lightly fished offshore grids.

The chub fishery in MS 3 occurs year-round with February or March occasionally missed due to ice conditions. The best CPE's are achieved during November-January. Incidental herring catch in chub nets is highest in November-January, but the incidental catch of lake trout shows

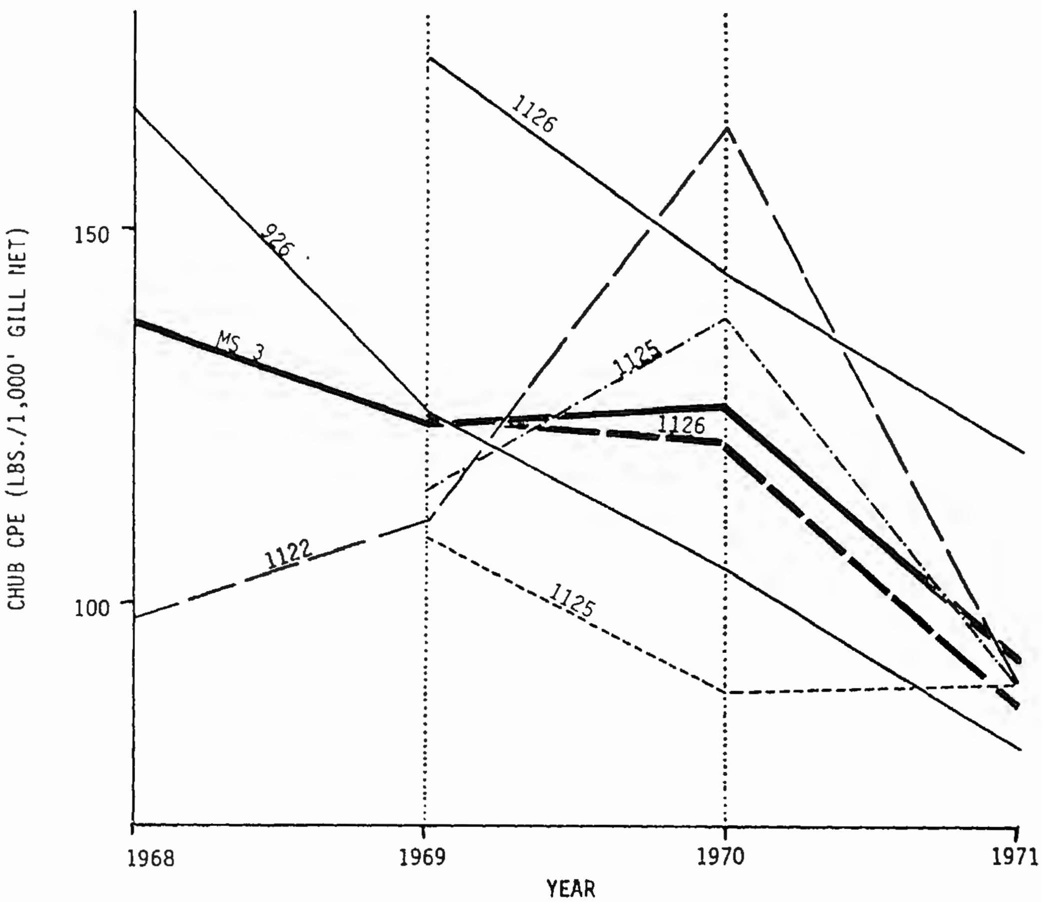

FIG. 3-POUNDS OF CHUBS CAUGHT PER 1,000' OF GILL NET IN CERTAIN GRIDS IN MS 3, LAKE SUPERIOR, 1968-71.

no significant variation over a 12-month period with CPE's ranging from 2 to 4 fish. Planted lake trout accounted for 50% of the incidentally caught lake trout. Chub quotas may be limited more by this incidental catch than by actual chub abundance. Harvest beyond 60 fathoms should substantially reduce the incidental lean trout catch while not affecting the chub harvest. Gill nets are presently the only gear used to catch chubs in MS 3. Trawling was attempted in 1966-67 but failed as in MS 2.

MS 4: The chub fishery in MS 4 fluctuated considerably between 1958 and 1971. Catches have historically fluctuated with demand and inversely with the abundance of more desirable species. The record landing of 243,000 lb. in 1971 was a result of both high demand and the scarcity of more desirable species. Chub CPE remained at a low level from 1958 to 1964, whereupon it rose to heights not achieved since the early 1930's when the shortjaw cisco was under heavy exploitation. Chub CPE's during 1958-64 were almost certainly depressed artificially by the high incidental catch in the herring fishery which was expanding and intensifying during this period. Herring effort dropped to low levels by 1965, and in subsequent years the effort was more apt to be actual chub effort. An increase in actual chub abundance very likely occurred during the early 1960's and is partially responsible for the rise in CPE.

Chub CPE's in MS 4 rose at a rate of 614 lb. during 1957-70. Based on a highly significant regression [$Y = 60.9 + 6.4\ (1964 - X)$] projected CPE's with 95% confidence limits are 125 pounds ± 77 for 1974; 144 pounds ± 83 for 1977; and 163 pounds ± 91 for 1980. However, use of this regression as a guide for quota establishment is suspect because of the radical CPE change after 1964. A regression analysis of 1965-71 CPE's indicated no trend with an average CPE of 97 lb. Projection of this 1965-71 average CPE to 1980 may have greater validity than those derived from the 1957-71 data and certainly would be a more conservative approach.

The 1971 chub catch of 243,000 lb. was the highest on record. The average annual catch since 1957 was about 80,000 lb. There has been no evidence of sequential exploitation based on 1968-71 catch statistics by grid. However, the chub catch was low until 1971 so it is not known whether traditionally fished grids can sustain the 1971 level of harvest. Between 1968 and 1971 the fishery expanded from one to three grids at Marquette and from two to four grids at Munising. Grids 1430, 1532, and 1534 accounted for 71% of the chubs landed in 1971. Chubs were as abundant in Marquette waters (CPE = 90) as in Munising waters (CPE = 89). A quota of 125,000 lb. divided between Marquette and Munising and further spread over the traditionally fished grids in each area should be possible (Table 1). Research quotas of 30,000 lb. for previously unfished grids could be issued for 1974-76 to test the effects of exploitation in these areas. Ages VI and VII were equally represented in a 1971 chub sample from 2 5/8" mesh gill nets (Table 4). Length frequency ranged from 9.0-13.0" with a mode of 11.0".

Incidental catch of lake trout in MS 4 averaged about 1.0 per 1,000' of net in 1970-71. There were no appreciable differences among months, and the percentage of lean trout was not known. As in other districts, the incidental catch of herring was greatest during November-January. Herring CPE's range from 7-68 lb. in 1970-71 and totaled 8,400 lb. in 1970, 30,000 lb. in 1971. Burbot are also taken regularly but CPE's averaged only 2-4 lb. during 1970-71.

MS 5: Chub landings ranged from 80 to 55,000 lb. annually between 1960 and 1966. Only 721 lb. were landed between 1967 and 1971.

Chub abundance is low. Since 1967, CPE's ranged between 16 and 43 lb. with an average of 34 lb. The poor CPE's may be due to either a mostly incidental chub catch in herring nets, fisherman inexperience, or actual low abundance. Reigle (1969) found chub abundance lowest at the east end of the lake. Some research fishing should be done in this statistical district to gather the information necessary to determine quotas. Gill nets would be required as Reigle (1969) found few trawlable areas in MS 5. An experimental quota of 25,000 lb. should be adequate to determine the status of the stocks and the problems to be encountered in their harvest.

MS 6: Catch statistics for MS 6 have fluctuated considerably. Catch and effort was greatest during the early 1960's and then declined irregularly. CPE fluctuated widely in 1959, 1960 and 1966. Although a regression for the 1961-71 annual CPE indicated a slight downward trend [Y = 54 - 2.02 (1964 - X)], it was not statistically significant. Lack of significance was largely due to an unusually high CPE in 1966 so the downward trend may be more appropriate than assuming no trend and projecting the average CPE (54). By extrapolation, projected CPE's would be 38 in 1974; 32 in 1977; and 26 in 1980. A quota below the 1961-71 average catch of 46,000 lb. is suggested for the limited area in MS 6 deeper than 60 fathoms to halt the decline in chub abundance and to reduce the incidental catch of lake trout. A quota of 10,000 lb. from depths of 60+ fathoms is recommended. Reigle (1969) found few areas suitable for trawling in MS 6 so the chub fishery presently relies on gill nets.

In 1970-71 the MS 6 chub fishery operated during April-December. Monthly CPE's were similar during this period with no increase in November and December, as noted for other districts. Lake trout CPE ranged from 0.03 in July, 1971, to 9.0 in April, 1971 and averaged slightly more than 1.0 fish per 1,000' of net. Age VI (34%) dominated a 1971 chub sample from 2 5/8" mesh gill nets (Table 4). Ages VII (25%) and V (19%) also were well represented. The length-frequency of this sample ranged from 9.0-14.0" with a mode of 11.0".

CISCO (LAKE HERRING)

The lake herring has provided most of the commercial fish harvest from Michigan waters of Lake Superior since 1941 when herring catch statistics were separated from chub statistics (appendix A). Lake herring became even more important after the mid-1950's when lake trout and whitefish stocks were driven nearly to commercial extinction by fishing pressure and sea lamprey predation. Fishermen then turned to the herring and, to a lesser extent, the bloater chub. Herring fishing had previously been conducted primarily during the fall spawning season with gill nets fished on the bottom. Fishermen soon learned, however, that by floating their nets profitable catches of the pelagic herring could be made year-round.

Although fall CPE's had been declining since 1954, catches increased because of increased fishing effort. Landings peaked in 1961 and the effort in 1962, whereupon the present decline in both began. Decimation of the inshore stocks forced marginal, ill-equipped fishermen out of business which accounted for much of the initial decline in effort. The remaining fishermen were forced to move progressively farther from shore to find herring. This increased running time and still-declining CPE discouraged fishing effort. Increasing whitefish abundance and an improved chub market also prompted a decrease in herring effort, particularly in recent years.

The herring fishery in Michigan waters of Lake Superior was largely unregulated. Limits on mesh size of gill nets were raised from 2 1/4 - 2 3/4" to 2 1/2 - 3.0" in 1968 with 3.0" mesh not to be set in depths exceeding 100'. Fishermen were restricted to 36,000' of net per year in 1968 and to 24,000' per year in 1970. Limited entry regulations were imposed in 1968 and strengthened in 1970. Limited entry eliminated the casual fisherman and, therefore, some fishing pressure on herring. Also, commencing in 1970 fishermen were prohibited from fishing small-mesh bottom nets inside 50 fathoms, and neither bottom nor float nets in this area during November. The prohibition of herring fishing during November may have afforded some protection to spawning concentrations, but allowing only float nets inside 50 fathoms likely afforded none, as a float net need only be fished 6' off the bottom and herring are pelagic. The zone management plan, enacted in 1970, also "prohibits gill netting in certain inshore areas designates as 'sport fishing zones'". Unfortunately, these zones are small and herring stocks do not stay entirely within them. These regulations have not noticeably affected herring CPE, as yet; nor have they halted the decline of Michigan's herring stocks.

The 1971 catch of 728,000 lb. was only 10% of the record 7.3 million lb. landed in 1961. The largest decline occurred in MS 3, Michigan's best herring producing district. Herring stocks declined less severely or held its own in other, less-exploited districts, although the mean age of the herring has increased. The decline of the herring stocks in Minnesota and Wisconsin waters preceded that in Michigan. Herring are now virtually extinct commercially on what was formerly these states most productive fishing grounds. A study by Anderson and Smith (1971) from the University of Minnesota suggests that competition from smelt and bloater chub could have been a major factor causing decline of herring stocks in Minnesota and Wisconsin waters in recent years. Many Lake Superior fish biologists disagreed with this conclusion and place more blame on the fishery, particularly for the initial declines. In 1972, the Lake Superior Committee of the Great Lakes Fishery Commission established a Lake Herring Subcommittee. The subcommittee reviewed the available information on herring stocks and formulated research and management recommendations. They concluded that: (1) exploited herring stocks are declining and remedial action should be taken to halt the decline, (2) commercial exploitation has been the major factor causing the decline of lake herring stocks, (3) smelt and bloaters may be contributing to the herring decline, but through replacement rather than displacement, (4) more information on the herring, smelt and bloater interspecific relationships are necessary to clearly define this factor's role in the decline of Lake Superior herring stocks, (5) discreteness of herring stocks has been inadequately defined and warrants further study, particularly where stocks may exist in inter-agency borders, and (6) future catch statistics will have to be recorded from smaller units than Statistical Districts if they are to be used to predict changes in individual stocks.

The subcommittee recommended that:

1. Commercial harvest be reduced on declining herring stocks.

2. Herring stocks exhibiting severe declines be closed to commercial fishing.

3. Closed areas be monitored for signs of recovery. Monitoring methods should be standardized among the respective agencies to facilitate exchange of information.

4. Herring, smelt, and bloater chub food competition studies be conducted to determine the extent that herring abundance has been affected by competing species and determine management procedures necessary to rehabilitate some herring stocks that are below levels capable of natural rehabilitation.

5. Quantitative information on the discreteness of herring stocks be obtained. (Tagging, electrophoresis studies, and experimental closures were considered. However, because herring rarely survive in gill nets, tagging would require a source of herring from impoundment gear. Such a source is not available at present. - Electrophoretic analysis may have to be quite refined and should be contracted to a university. Stock differences may be detected even within the statistical district. - Differences in abundance (CPE), age composition, or some other parameter between exploited and unexploited grounds also could be used to determine if herring on the respective grounds are discrete. Differences in catch statistics have been presented as evidence of discreteness by Michigan (Little Girls Point ground vs. Ontonagon ground), and Ontario (Black Bay vs. Thunder Bay). - A comprehensive monitoring program should be conducted to evaluate experimental closures.)

Stock Status

Declining abundance is the most important factor concerning the lake herring stocks in Michigan waters of Lake Superior. The decline first became evident in the CPE's from heavily exploited Keweenaw Bay (MS 3) after 1954. An analysis of herring age group CPE in the catches during 1949-72 revealed a continuous decline in year class strength since the advent of the 1953 year class (Table 5). Progeny of strong 1950-53 year classes failed to produce subsequent strong year classes, although fishing effort was relatively low when most of these herring were sexually mature and vulnerable to the fishery (1954-57). Herring abundance in the Michigan statistical districts has declined in direct proportion to the fishing pressure applied.

Age and Growth

Age and growth parameters of lake herring stocks in Michigan waters have changed since 1950. The most dramatic changes occurred during the 1960's when abundance and fishing effort rapidly declined. Scale samples from exploited stocks in Keweenaw and Marquette bays were collected annually since 1950, but only in recent years (1967-72) for other stocks. There are no age data available on herring in Michigan waters prior to 1950.

Age composition changed significantly in Marquette and Keweenaw bays during the 1960's (Tables 6 and 7), particularly after 1963. Marquette experienced the greater change with ages II and III disappearing from the fishery and ages V-VII supplanting them. Herring older than age VI were not present in Keweenaw and Marquette samples collected during the 1950's, but 6-year old fish now dominate, 8-year old fish are common, and herring 9 years and older are found in most stocks in Michigan waters. The average age of herring in Keweenaw and Marquette bays increased from 4 years during the 1950's to 5 years in 1965, and has since fluctuated between 5 and 6 years.

The decline in fishing effort and year-class strength undoubtedly were the factors primarily responsible for this shift in age composition. Older fish make up a greater proportion of the catch simply because fewer recruits are entering the fishery each year. Heavy fishing pressure during the 1950's and early 1960's probably initiated and/or accelerated the decline in year-class strength through harvest of spawning stocks. If their niche is also shrinking, protection of spawning stocks may or may not increase recruitment.

Growth in length and weight has increased during 1950-72 in Keweenaw and Marquette bays even though stocks are now composed of older fish and despite a decline in first year growth (Table 8). These older fish show surprisingly good growth with annual increments after the fifth year leveling off at or near 1.0" (Tables 6 and 7). Declining first-year growth in Keweenaw Bay and perhaps Marquette Bay supports the Anderson and Smith theory of competition from smelt and chubs during the larval stage of the herring. Herring grow faster in eastern Lake Superior than at the western end. Dryer and Beil (1964) found this evident during the 1950's and it holds true for recent years. The increased presence of older fish and a faster growth rate has increased the average size of commercially caught herring in Michigan waters during 1950-72. Dryer and Beil (1964) reported that between 1950-55 and 1956-59, herring weight at a given length increased 4.4% in Keweenaw Bay and 5.2% in Marquette Bay.

TABLE 5. NUMBERS OF HERRING CAUGHT PER 1,000' OF SMALL-MESH GILL NET BY YEAR CLASS AND AGE GROUP FOR THE KEWEENAW BAY FALL FISHERY, 1946-68

Year Class	Age group								
	III	IV	V	VI	VII	VIII	IX	X	Total
1946	280	290	247	9	--	--	--	--	826
1947	147	607	226	--	--	--	--	--	980
1948	202	549	32	--	--	--	--	--	783
1949	208	522	39	25	--	--	--	--	794
1950	384	648	49	--	--	--	--	--	1,081
1951	505	461	49	--	--	--	--	--	1,015
1952	212	477	119	6	--	3	--	--	817
1953	303	475	283	10	23	--	--	--	1,094
1954	182	309	178	54	18	--	--	--	741
1955	170	346	134	52	--	--	--	--	702
1956	91	302	217	31	8	2	--	2	653
1957	49	212	141	40	45	3	--	--	490
1958	52	185	149	107	25	4	--	--	522
1959	32	151	116	62	27	1	3	--	392
1960	30	54	104	98	8	9	7	--	310
1961	9	83	79	43	32	13	--	--	259
1962	10	55	66	65	12	3	2	--	213
1963	2	51	70	25	9	5	--	--	162
1964	3	22	41	34	41	2	--	--	143
1965	2	27	37	72	8	--	--	--	146
1966	11	76	60	23	--	--	--	--	170
1967	24	24	62	--	--	--	--	--	110
1968	7	30	--	--	--	--	--	--	37

TABLE 6. PERCENTAGE AGE COMPOSITION OF LAKE HERRING IN THE FALL CATCH AT KEWEENAW BAY, 1960-72

Age Group	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970[a]	1971	1972
III	10	9	8	8	--	4	1	2	2	15	--	4	6
IV	53	37	47	40	19	28	21	19	13	29	--	12	22
V	24	38	36	40	37	36	30	42	46	32	--	28	44
VI	10	9	8	10	32	21	37	31	29	20	--	34	19
VII	4	3	--	2	10	9	10	4	6	2	--	19	7
VIII	--	--	--	--	1	1	1	2	4	2	--	3	2
IX	--	--	--	--	--	--	--	--	--	--	--	1	--
X	--	--	--	--	--	--	1	--	--	--	--	--	--
Avg. Age (yrs.)	4.4	4.5	4.4	4.6	5.3	5.0	5.4	5.2	5.3	4.8	--	5.7	5.1

[a] 1970 catches not sampled

TABLE 7. PERCENTAGE AGE COMPOSITION OF LAKE HERRING IN THE FALL CATCH AT MARQUETTE, 1960-72[1]

Age Group	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
II	5	2	1	2	1	--	--	--	--	--	--	--	--
III	27	34	26	23	7	8	1	--	--	--	--	--	2
IV	49	42	43	58	27	30	23	--	4	20	--	--	10
V	17	18	24	11	48	38	44	--	31	32	--	--	37
VI	2	2	4	5	17	23	25	--	31	23	--	--	32
VII	1	--	1	--	3	1	5	--	20	20	--	--	15
VIII	--	--	--	--	--	1	2	--	13	--	--	--	4
IX	--	--	--	--	--	--	--	--	2	5	--	--	--
Avg. Age (yrs.)	3.9	3.8	4.1	3.9	4.8	4.8	5.2	--	6.2	5.7	--	--	5.6

[1] 1967, 1970 and 1971 not sampled

TABLE 8. AVERAGE CALCULATED TOTAL LENGTH OF HERRING IN MICHIGAN WATERS OF LAKE SUPERIOR

	Number of fish	Total length (inches) at end of year of life								
		1	1	3	4	5	6	7	8	9
Little Girls Point										
1967	62	3.9	6.7	9.4	11.3	12.5	13.1	13.3	--	--
Keweenaw Bay										
1950-55	597	4.8	7.2	9.1	10.7	11.4	12.2	12.9	--	--
1956-59	695	4.7	7.4	9.4	11.1	12.1	13.1	13.5	--	--
1967-71	904	4.4	7.2	9.5	11.4	12.5	13.4	14.2	15.1	16.0
Marquette										
1950-55	556	4.8	7.6	9.5	11.0	11.8	12.6	13.3	--	--
1956-59	554	5.0	7.9	10.0	11.7	12.5	13.5	14.6	--	--
1968-71	292	4.7	7.9	10.4	12.2	13.5	14.6	15.3	16.3	17.7
Munising										
1967	108	4.7	7.8	10.2	12.1	13.3	14.3	15.0	--	--
Caribou Island										
1969	71	4.8	8.7	11.0	12.8	14.1	15.1	16.0	16.5	16.9
Whitefish Bay										
1968-71	578	4.5	7.6	10.0	11.9	13.2	14.2	15.2	16.2	16.3

However, mean weights calculated from 1950-59 length-weight relationship (Dryer and Beil, 1964) were similar to those calculated from 1968-69 length-weight relationship (Dodge, 1970).

Fecundity and Sex Ratio

Fecundity has increased in Minnesota and Wisconsin waters and should also be higher in Michigan waters. Anderson and Smith (1971) reported that the number of eggs per ounce of fish increased from 842 in 1950-54 to over 1,000 in 1966-67, which could be expected in light of the increased average size of herring.

All lake herring stocks sampled since 1950 have been composed mainly of females, but sex ratios are so variable that little can be said regarding any trend. Dryer and Beil (1964) report that the percentage of females equaled or exceeded males in every age group sampled during 1950-59. The sex ratio in commercial samples did not change from 1960 to 1968, but the 1968 percentage of 85% was the highest since 1962 (Anderson and Smith, 1971). Clady (1967) showed that a strong dominance of females accompanied the sharp decline in herring abundance in Birch Lake, Michigan. Wisconsin DNR samples collected in 1968-72 from a herring ground contiguous with Michigan were 51 - 98% females (unauthored Wisconsin DNR report, 1973).

Discreteness of Herring Populations

There have been few studies to ascertain discreteness of herring stocks in Michigan waters of Lake Superior. Therefore, the herring's "cruising radius" has not been determined. Areas of inhabitance based mainly on known fishing grounds are shown in Fig. 4, with some consideration of bathymetric distribution and varying growth patterns. Some boundary portions cannot be established even with these criteria. Because herring are a pelagic species, the depicted areas of inhabitance are likely much narrower than they actually are, reflecting only the distance fishermen are willing to go to fish them. Each area of inhabitance may contain more than one discrete stock. These may be separated laterally, bathymetrically, or biologically (different spawning time or grounds) within the area. Some morphological differences have been noted for herring from the same district. Wisconsin biologists recognize "reef" and "deep water" spawning stocks in the Apostle Island area. Reef herring are larger, spawn in shallow water, and exhibit a 50:50 sex ratio. Deep-water spawners are small and have shown a trend toward femaleness for many years. Differences in age composition, growth rates, year-class fluctuations, and other parameters have provided evidence of discreteness among different areas of inhabitance. Differences in growth rates suggested to Van Oosten (1929) that the Lake Huron population was composed of localized races. These races grew in accordance with local conditions and little or no mixing occurred. Dryer and Beil (1964) observed differences in herring growth and year-class fluctuations among landings at three Lake Superior ports [Bayfield, Wisconsin; Portage Entry (Keweenaw Bay); and Marquette, Michigan] during 1950-59. Herring growth rates in Keweenaw Bay and Marquette Bay were still quite different in 1967-71. These growth-rate and year-class differences plus the distance separating districts support the assumption that herring within each statistical district are discrete and do not mix.

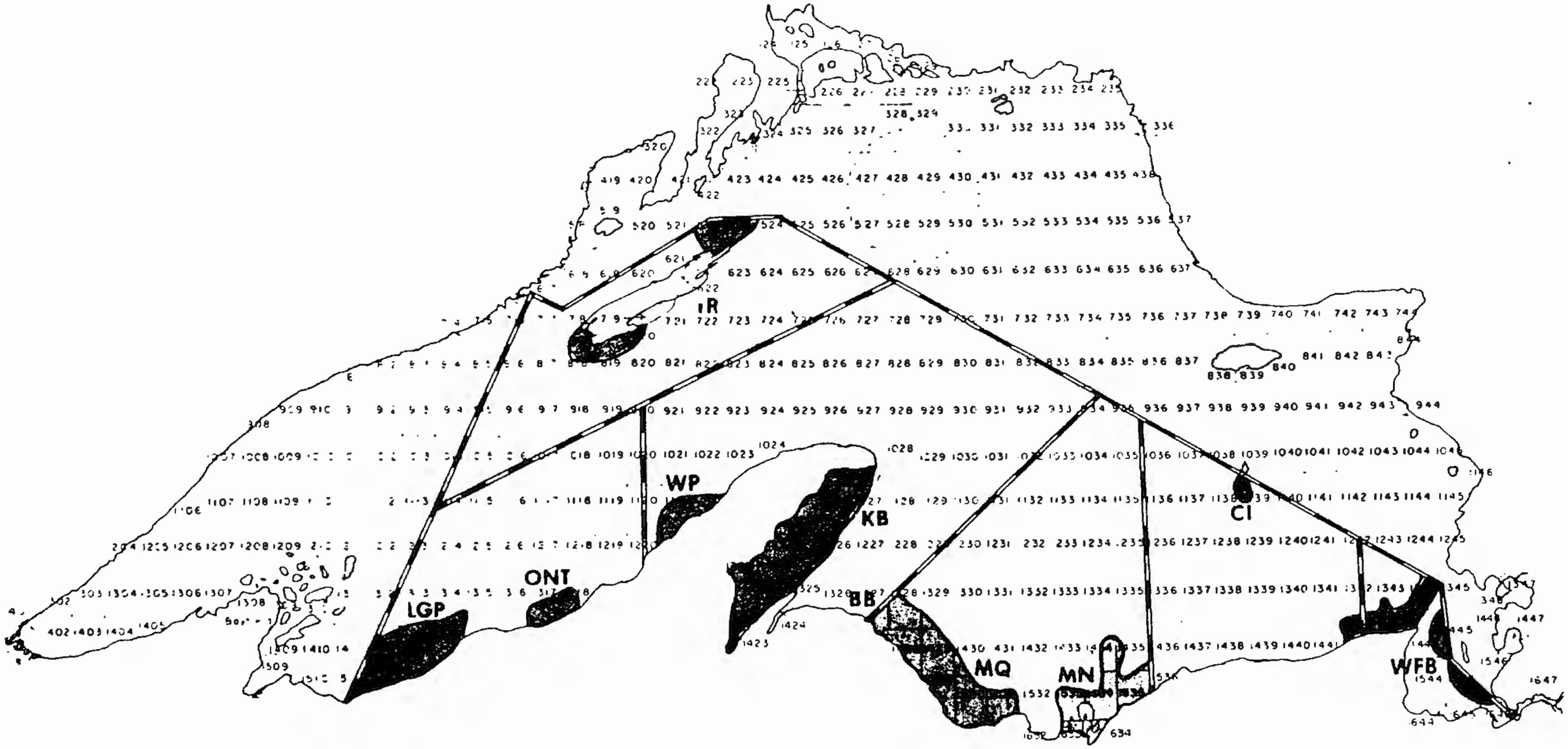

Fig. 4. Areas of Herring inhabitance in Michigan's Statistical Districts of Lake Superior.

LGP = Little Girls Point
ONT = Ontonagon
WP = West Portage, Keweenaw Bay
BB = Big Bay
MQT = Marquette

MN = Munising
WFB = Whitefish Bay
IR = Isle Royale
CI = Caribou Island Banks

Discreteness of stocks is a major concern of agencies managing herring stocks, especially those stocks on inter-agency borders. Tagging, electrophoresis, and experimental closures were considered as means of determining discreteness by the Lake Superior lake herring subcommittee. Wisconsin biologists launched an extensive effort to determine discreteness in 1972. They have collected herring for electrophoretic analysis, tagged herring captured in gill nets, and have evaluated fish and fishery parameters for herring from stations throughout Wisconsin waters. Final results of their tagging and electrophoresis work are not yet available but they found that pyloric caeca numbers, lateral-line scale counts, and anal-ray counts could be used in identifying discrete herring spawning populations. The ratio of head length to total body length was also found to be useful. Experimental closures have not been applied by Michigan or any other agency but differences in catch-effort statistics between fishing grounds documented by Michigan and Ontario suggest this discreteness in stocks.

Abundance Index

Commercial catch per unit effort (CPE) is the only index of herring abundance available for Michigan waters of Lake Superior. CPE is presented as either pounds or number of herring per 1,000' of gill net which usually contains 2 1/2 - 3" mesh. Number-per-unit-effort has been used in regression and yield calculations whenever possible because the weights of individual herring in the commercial catch have increased since 1950. CPE's based on number account for this weight increase and provide a more accurate picture of changes in abundance. Regression analysis of annual CPE was used to determine CPE trends and project them to 1974, 1977, and 1980 where possible. An equilibrium yield equation also was used for MS 3 herring, which is based on commercial catch-effort statistics (Ricker, 1958).

There are many potential biases associated with the use of the commercial CPE statistic to evaluate abundance. Factors which may discredit the use of long-term commercial CPE as a herring abundance index include (1) sequential exploitation of stocks within the statistical district or even grid, (2) withdrawal of inefficient or ill-equipped fishermen from the fishery as inshore stocks are depleted and only the scarce offshore stocks remain, (3) gear improvements which facilitate location of fish and increased fishing proficiency, and (4) recent regulations allowing only floating herring nets in waters less than 50 fathoms and prohibition of herring fishing inside 50 fathoms during November.

Sequential exploitation of herring stocks has occurred in MS 3, Michigan's major herring producing statistical district, and probably in MS 4 and MS 6. Records of four of the more efficient fishing units in MS 3 show that before and during intensification of the herring fishery (1951-63) fishing took place 1 - 2 miles from port. As the intensive fishing pressure depleted inshore stocks during the early 1960's, these efficient operators moved progressively offshore in search of herring: 3 miles out by 1964-65, 5 - 6 miles in 1965, and up to 9 miles in 1967. The movement described above took place within grid 1125 making it evident that even catch by grids can be too large to reflect effects of a fishery on population abundance. The elimination of inefficient fishing units as inshore stocks were depleted apparently resulted in the over-all CPE's declining at a rate slower than for some individual fishermen. Rate of CPE decline was faster for two of the four selected fishing units than for the entire fishery (Fig. 5). By the mid-1960's the total CPE was not different from that of the four individual units, indicating that by then most inefficient operators were out of business.

The effects of some gear improvements can be accounted for in a quantitative analysis of the catch but increased proficiency of the fishermen is parctically impossible to quantify. The major, quantifiable gear improvement was the shift from cotton to nylon mesh nets. In this analysis, the increased efficiency of nylon was measured and catch statistics for cotton nets adjusted to those for nylon nets. Use of fish finders in the herring fishery has been insignificant. Improvements in vessels and communication equipment permit greater mobility but the quantitative effect on catch is not known. Since only the more efficient fishermen remain they undoubtedly have improved their ability to find and catch herring as the stocks became depleted. This increase in proficiency likely prevented the CPE from declining at a faster rate. Regulations thus far imposed on small-mesh gill nets (1970) have not noticeably affected herring CPE.

Herring fishing effort could become too low for CPE to adequately reflect herring abundance. Small amounts of effort could result in highly variable annual CPE's, especially if effort were inconsistently distributed within each year. CPE variability has increased with declining effort in MS 1 although most fishing has been conducted between August and October, 1970-72. Monthly CPE's in MS 3, MS 4, and MS 6 (Tables 9 - 11) were quite variable, both between months and within years. However, yearly fishing patterns in these districts have not changed much in recent years. These random variations are not sufficient to invalidate trend analyses based on annual CPE.

Fishing Gear

Small-mesh gill nets are presently the only fishing gear used for capturing herring in Michigan waters. Herring abundance is low and fishable stocks are now located offshore which discourages use of trawls or impoundment gear. Reigle (1969) was unsuccessful in locating trawlable concentrations of herring on the bottom of Lake Superior during 1963-65 but he suggested trawlable concentrations might be found in mid-water depths. Exploratory mid-water trawling might disclose an efficient means of harvesting the lake herring. The fishermen have demonstrated that float nets are more efficient than bottom nets for harvesting the present offshore stocks of herring. Not only are float nets more efficient most of the year but also the incidental catch of other species is much less. Re-establishment of the inshore stocks would make possible re-establishment of the herring impoundment gear fishery.

Fishing Season

Unlike the former bottom-net herring fishery, the present float-net fishery is able to capture commercial quantities of herring year-round. Fishing effort and CPE is generally highest during March - June and September - November, but there are many exceptions (Tables 9 - 11). Incidental salmonid catches generally have varied without trend throughout the year, but CPE's in July - September (1970-71) in MS 6 were higher

Fig. 5. Trends in the herring catch per unit effort (CPE) for the entire herring fishery during Jan.-Dec.; Nov.-Dec.; and of four selected fishing units (Nov.-Dec.) indicated by lines A, B, C, and D.

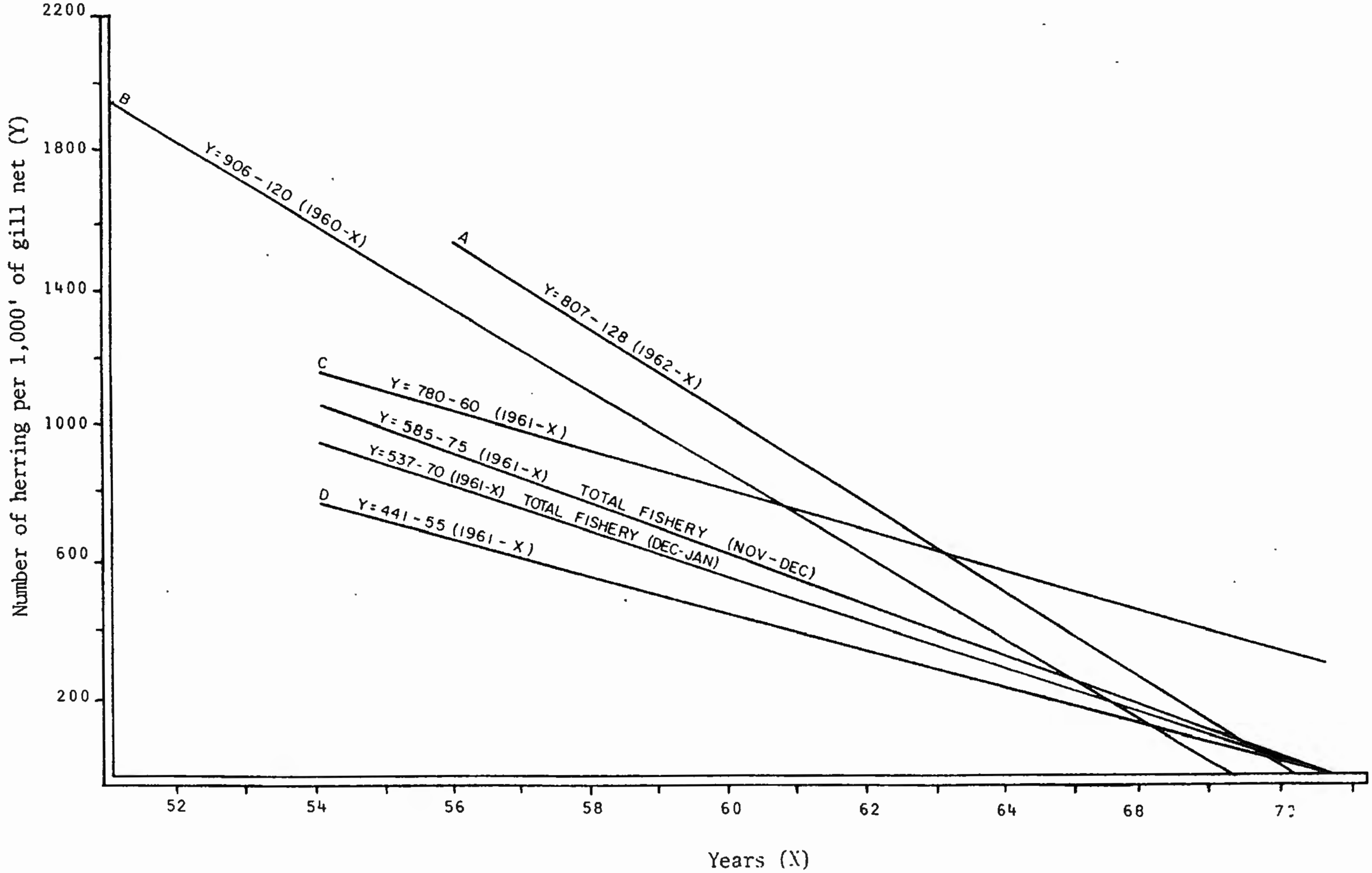

TABLE 9. MONTHLY DISTRIBUTION OF FISHING EFFORT AND CPE FOR HERRING AND SALMONIDS IN MS 3, 1970-72.

	1970			1971			1972		
Month	Effort (ft x 10^3)	Herring CPE (lbs)	Salmonids CPE (No.)	Effort (ft x 10^3)	Herring CPE (lbs)	Salmonids CPE (No.)	Effort (ft x 10^3)	Herring CPE (lbs)	Salmonids CPE (No.)
Jan.	58.9	116	0.12	47.9	164	0.42	--	---	--
Feb.	--	---	--	--	---	--	--	---	--
Mar.	10.0	273	--	11.0	134	--	--	---	--
Apr.	388.2	186	0.09	93.8	65	0.18	--	---	--
May	1050.6	170	0.13	165.6	113	0.33	25.6	89	0.04
June	1041.5	112	0.21	75.9	66	0.50	113.6	56	0.40
July	345.7	52	0.47	55.0	163	0.44	313.2	74	0.60
Aug.	236.8	65	0.31	49.8	100	0.54	126.8	78	0.30
Sep.	419.8	114	0.31	285.6	165	0.09	325.7	153	0.40
Oct.	356.6	126	0.18	554.5	129	0.39	235.5	100	0.30
Nov.	480.2	215	0.23	217.0	227	0.47	76.0	233	0.20
Dec.	144.7	192	0.24	26.9	112	0.30	22.0	103	0.30

TABLE 10. MONTHLY DISTRIBUTION OF FISHING EFFORT AND CPE FOR HERRING AND SALMONIDS IN MS 4, 1970-72

	1970			1971			1972		
Month	Effort (ft x 10^3)	Herring CPE (lbs)	Salmonids CPE (No.)	Effort (ft x 10^3)	Herring CPE (lbs)	Salmonids CPE (No.)	Effort (ft x 10^3)	Herring CPE (lbs)	Salmonids CPE (No.)
Jan.	2.0	59	1.0	2.0	390	---	--	---	---
Feb.	3.6	33	0.3	1.6	9	1.2	--	---	---
Mar.	4.8	25	---	--	---	---	--	---	---
Apr.	95.0	221	0.6	16.4	203	1.1	4.8	44	---
May	80.4	100	0.3	4.0	159	1.0	28.3	87	---
June	63.7	99	0.1	3.0	122	---	19.8	74	0.6
July	96.9	18	0.4	50.8	53	1.0	130.2	8	0.3
Aug.	286.8	39	1.0	316.0	85	0.6	70.4	33	0.6
Sept.	114.4	76	0.7	353.0	60	0.7	16.4	15	---
Oct.	240.5	55	0.7	72.0	24	0.8	3.6	81	---
Nov.	228.5	162	0.3	130.7	290	0.2	62.8	323	0.3
Dec.	38.4	147	0.3	62.8	407	0.1	73.0	441	0.3

TABLE 11. MONTHLY DISTRIBUTION OF FISHING EFFORT AND CPE FOR HERRING AND SALMONIDS IN MS 6, 1970-72

Month	1970 Effort (ft x 10^3)	1970 Herring CPE (lbs)	1970 Salmonids CPE (No.)	1971 Effort (ft x 10^3)	1971 Herring CPE (lbs)	1971 Salmonids CPE (No.)	1972 Effort (ft x 10^3)	1972 Herring CPE (lbs)	1972 Salmonids CPE (No.)
Jan.	31.6	53	---	--	---	---	6.0	21	---
Feb.	26.4	82	0.4	155.6	162	0.04	154.8	113	0.03
Mar.	82.05	64	0.2	276.8	139	0.1	296.5	91	0.03
Apr.	22.4	129	0.1	212.4	64	0.4	71.4	104	---
May	295.5	12	0.1	307.0	32	0.7	68.1	56	0.05
June	364.1	44	0.4	395.5	23	0.8	10.7	185	0.19
July	355.8	48	0.8	424.8	65	1.4	109.5	28	0.07
Aug.	434.0	68	2.0	749.9	80	1.3	13.2	46	0.05
Sept.	216.0	49	2.7	174.3	22	1.4	13.8	43	---
Oct.	--	---	---	37.2	44	0.1	90.4	17	---
Nov.	9.0	65	---	36.0	73	---	46.8	48	---
Dec.	15.0	71	---	42.0	45	---	27.0	88	---

than during other months fished. Some experimental fishing with bottom nets and larger mesh was done at that time which may explain the higher salmonid CPE.

Proposed Quotas

MS 1: Fishing in MS 1 is largely confined to grids contiguous with Isle Royale (Fig. 4). The fishermen are not well equipped for an intensive fishery and their location on Isle Royale presents marketing problems. Fishing usually occurs during May - October with most effort during July - October. This district is not an important herring producer. The annual catch averaged 183,000 lb. during 1929-70. Production has declined since 1962 to less than 10,000 lb. in 1972. The fishermen reported that major declines in juvenile and adult fish were evident in the early 50's. CPE's have become more variable with the decline in fishing effort which may be due to either this lower effort or wider fluctuations in year-class strength. Lake herring numbers have not increased in response to declining effort and maintenance of commercial production at or below current levels is justified. A quota recommendation of 10,000 lb. per year is suggested until improvement in stock size is indicated by an increase in CPE.

Scale samples were obtained from commercial herring catches in 1971 and 1972. Herring ages in these samples ranged from II to X but most were either age V or VI. Empirical mean lengths are shown in Table 12. Herring stocks in MS 1 exhibit age composition and growth similar to the more exploited stocks in Michigan waters.

TABLE 12. MEAN LENGTHS (INCHES) AT CAPTURE FOR HERRING 2-10 YEARS OLD CAUGHT ON THE ISLE ROYALE FISHING GROUNDS, 1971-72

AGE	LENGTH
II	12.0
III	13.8
IV	13.5
V	14.3
VI	14.7
VII	14.7
VIII	15.5
IX	16.9
X	16.5

Herring populations on the two Isle Royale fishing grounds may be discrete. The northern grounds could be part of Ontario's Black Bay stock. Available biological data is insufficient to separate the stocks. The quota should be taken by 2 1/2 - 3.0" floating gill nets fished on the traditional grounds.

MS 2: There has been no commercial herring production from MS 2 since 1967. The traditional grounds off Ontonagon were fished until 1965 and previously unexploited Michigan waters of the Little Girls Point grounds were fished in 1966-67 (Fig. 4). The Ontonagon fishery produced an average of 67,000 lb. annually during 1934-65. CPE fluctuated considerably during this period with the November, 1965, CPE of 118 lb. being the lowest November CPE on record. CPE generally increased and decreased with effort although not at the same rate. Herring were much more abundant on the Little Girls Point grounds. November CPE's were 1,073 lb. in 1966 and 521 lb. in 1967. This difference in abundance indicates that Ontonagon herring are discrete from those on Little Girls Point.

No scale samples were obtained from Ontonagon herring but samples were collected from the Little Girls Point commercial fishery in 1967 and analyzed by Dodge (1970). Age composition and growth rate of herring on this relatively unexploited ground was similar to that on heavily exploited grounds. Six-year-old fish were dominant (39%) but ages V (32%) and VII (24%) were well represented. Mean calculated lengths were about the same as in Keweenaw Bay but less than for herring grounds in central and eastern Lake Superior (Table 8). No fish older than VII were found in the sample from Little Girls Point but this may be due to the relatively small sample.

The Little Girls Point ground lies on the Michigan-Wisconsin border and the Wisconsin portion has been traditionally exploited. Sampling from 1968 to 1972 by the Wisconsin Department of Natural Resources indicated that females dominated the stock (51-98%) and both age and length has increased recently. Most herring in the 1969 sample were age IV, but ages VI and VII dominated the 1970-72 samples. There is presently no information that would justify re-establishment of a commercial herring fishery in MS 2 in 1974. Sampling should be intesified in the Ontonagon area to further identify the biological parameters effecting the stock there.

MS 3: Most of Michigan's commercial catch has come from district MS 3. Changes that have occurred in MS 3 herring stocks also have occurred in the other districts, but the effect on herring production in these other waters has been less severe. Eshenroder (1968) described catch-effort trends in MS 3, but because this work is unpublished, a review is necessary. The first itensification of the fishery began in 1929-36. The 1936 catch exceeded the total Michigan catch in Lake Superior for the year prior to 1929. Effort between 1936 and 1948 remained near the 1936 level while abundance fluctuated without trend. Effort declined steadily after 1948 until a low was reached in 1953 and did not increase significantly until 1957. This decline in effort was attributed to a two-fold increase in November - December lake trout fishing effort. Apparently the fall herring fishery was curtailed in favor of lake trout which were in demand after collapse of trout fisheries in Lake Huron and Lake Michigan. While herring effort was declining after 1948, herring abundance increased to record levels. CPE peaked in 1954 then began to decline, but remained above pre-1948 levels until 1958. With the decimation of lake trout and whitefish stocks by the fishery and sea lampreys, fishing effort was intensified on the declining, but still abundant, herring stocks. Effort in November and December rose only moderately but fishing expanded to a 12-month basis, resulting in record yields between 1959 and 1963. CPE continued to decline during this period. This declining CPE and destruction of accessible inshore stocks probably initiated the catch and effort decline which began in 1961-62 and has continued through 1972. Catch and effort in 1972 were the lowest on record, amounting to only 3% and 6% respectively of the 1961-62 record high catch and effort.

Some herring are present in MS 3 waters west of the Keweenaw Peninsula off West Portage and grids bordering on MS 2. A few herring scale samples were collected from grids 1020 and 1119 in 1972. The herring ranged in length from 12.0 to 16.0" and in age from III to VII. Age V was dominant, followed by ages IV and VI, similar to the Keweenaw Bay populations.

Declining herring abundance in MS 3 warrants curtailment of the commercial fishery, especially on traditionally fished grounds in Keweenaw Bay. CPE has decreased at a rate of 32 herring per 1,000' of net since 1958 and theoretically would reach zero before 1975. Zero would have been reached in 1969 if based on 1954-68 CPE trend but there has been a slight increase since the record low in 1969.

The 1968-71 CPE's from traditionally fished grids (1125, 1126, 1225, and 1226) mirror the district CPE's for that period. Effort has declined about 90% in these grids between 1968 and 1971, but it is still too soon to see any response in herring abundance to this reduction in effort.

Average annual total mortality rates were calculated following Ricker (1958, p. 49) for age groups V-VIII in the 1960-70 Keweenaw Bay fall fishery as follows: V, 23%; VI, 47%; VII, 75%; and VIII, 80%. This method was also applied to age groups in the 1961-71 Keweenaw Bay year-round fishery with results as follows: V, 41%; VI, 55%; VII, 66%; VIII, 73%; and IX, 79%. Total mortality rates for ages V and VI in the fall fishery and age V in the year-round fishery decreased between 1960 and 1971. This is likely due to the effect of declining recruitment on the method of calculation (Ricker, 1958, p. 47), rather than an actual trend in mortality. Calculations for age groups VII-IX showed no such trend.

A most important goal in management of a fish stock is assessment of yield at different levels of fishing effort. Equilibrium yield per recruit determinations (Ricker, 1958, p. 210) were made for the herring fishery based on mortality rates calculated from both the total fishery and from four efficient fishing units. Some approximate methods were employed in obtaining estimates of growth and mortality rates.

Instantaneous rates of growth (g) were calculated for the Keweenaw Bay population during 1967-71. Length for an age = calculated length at formation of last annulus plus the last full-year's increment computed from the scales of all fish sampled in that age group (Ricker, 1958, pp. 189-190). Weight at age was determined from the length-weight equation, W(oz) = 2.71 L (inches) - 25.06, using mean length at age. Instantaneous rates of growth (g) were then calculated as per Ricker (1958, p. 19).

Fishing and natural mortality rates are perhaps the most difficult fish population parameters to estimate. Instantaneous rates of natural and fishing mortality were determined from 1950-71 catch-effort statistics for MS 3 using the linear method of Paloheimo (1961). Paloheimo's method derives instantaneous natural mortality (q) directly and a catchability coefficient which, when multiplied by fishing effort, yields instantaneous fishing mortality (p). Catchability coefficients based on 1950-71 annual data for the total fishery were not statistically significant but were significant for the July - December (1960-71) data. Therefore, the latter coefficients were used to calculate instantaneous fishing mortality rates for the January - December fishery. Instantaneous natural mortalities (q) are simply the differences between instantaneous fishing mortality (p) and instantaneous total mortality (i), rather than using "q" calculated by Paloheimo's method. Total mortality rates were derived from pairings of year-class CPE during successive years of culnerability in the 1969-71 year-round fishery (Ricker, 1958, p. 49) and converted to instantaneous rates (i). Catchability coefficients and instantaneous natural mortality rates calculated as per Paloheimo from November - December catch-effort statistics of the four fishermen were significant for all ages except age VI, so age-VI values of catchability and "q" from the entire fishery were substituted.

Harvest based on catchability coefficients for the entire fishery slightly exceeded recruitment (120 lb. vs. 111 lb.) under the 1971 fishing effort (1,583,000') but would be below recruitment (90 lb. vs. 111 lb.) at 3/4 of the fishing effort (1,187,000'). July - December catchability from 1960-71 data should be higher than year-round catchability because the inshore herring stocks would be in spawning concentrations during part of this period. There appeared to be little difference between year-round (January - December) and November - December CPE's.

A far different yield per recruit resulted when catchability coefficients from the four efficient fishing units were employed in the calculations. Harvest exceeded production even if only 100,000' of net were fished. This difference would certainly have been greater if an age-VI coefficient from the four units could have been used. On the other hand, coefficients from the combined data of the four fishermen are certainly higher than the total fishery because these are some of the most efficient, well-equipped, and experienced fishermen. Although one of the four fishermen had a lower CPE than the total fishery, this was more than compensated for by the other units. Catchability calculated from November - December data also should be higher than that calculated from July - December data because CPE's are generally higher during November - December. All coefficients are based more or less on bottom-net fishing of inshore stocks. How bottom-net coefficients relate to the present float-net fishery is unknown but is believed to be applicable since restriction of the fishery to float nets in 1970 has had little, if any, effect on CPE. Catchability of previously fished inshore stocks may be different from that of presently fished offshore stocks, but more years of data are required for evaluation.

These yield calculations coupled with the previously described CPE decline, growth changes, and changes in age composition provide reason enough for the lack of a quota recommendation for traditionally fished grids in MS 3. The incidental catch of herring in chub nets is high during November - January (see chub section) and this incidental catch is all that should be allowed in Keweenaw Bay. The incidental herring catch in MS 3 chub nets was 162,335 lb. in 1972 and accounted for 56% of the total MS 3 herring catch. With movement of the chub effort to beyond 60 fathoms of depth, it is expected that there will be a substantial decline in this incidental catch.

MS 4: Total annual catch and November - December effort trends in MS 4 generally followed those of MS 3. Effort was intensified during the mid-1930's and maintained at high levels until 1944. Effort declined by 1950, remained at or near the 1950 level until 1957, and then intensified. Catch and effort has declined irregularly since 1963. On a poundage basis, November - December CPE varied without trend during 1929-72 but, because average size has increased, the actual number of fish per unit effort has declined during 1958-72.

Herring production in MS 4 averaged 330,000 lb. annually since 1929 but amounted to less than 100,000 lb. in 1972. Fishing is conducted throughout the year, weather permitting, with most fishing done during August - November. Most of these herring are landed at Munising from grids 1533 and 1534. Munising fishermen apparently set their nets near or on the bottom because they take high incidental catches of burbot, suckers, and whitefish which usually are not far off the bottom. Herring landed at Marquette usually come from grid 1529 and those landed at Big Bay from grid 1327. Although grid 1327 is mostly in MS 3, the catch has been reported for MS 4. Discrete stocks probably exist at Munising, Marquette, and Big Bay but they cannot be separated with the data at hand.

Herring landed at Marquette were scale sampled in most years since 1950, whereas Munising landings were sampled only in 1967. Age composition and growth of Marquette and Munising herring are similar, although they are probably discrete stocks (Tables 7 and 8). Herring from MS 4 have exhibited the same change in age composition as in MS 3. In fact, the change was more drastic in that a fishery supported by age groups III and IV was supplanted by one supported by ages V and VI within the three years. Growth increased during 1950-71, and differences in growth increments among periods were greatest from the second through sixth year of life. The 1968-71 sample contained a greater proportion of older fish which exhibited either a steady or increasing growth rate. Average length of herring in the commercial catch has increased as follows: 1950-55, 11.9"; 1956-59, 12.8"; 1960-66, 13.5"; and 1967-71, 15.0".

Average annual total mortality rates calculated from the 1960-66 fall fishery were 39% for age V, 69% for age VI, and 71% for age VII. Declining recruitment apparently affected the results in that annual mortality rates for ages V and VI showed a decline between 1961 and 1966. Rates for age VII varied without trend during this period.

Herring quotas for the traditionally fished grids in MS 4 should be limited to the incidental catch in chub nets fished deeper than 60 fathoms because of the 1958-72 decline in abundance. Increases in CPE after 1970 are encouraging because all important herring grids in MS 4 (1327, 1529, 1533, and 1534) have exhibited this trend.

MS 5: There has been no significant herring fishery in MS 5. Since 1960 herring catches exceeded 100,000 lb. only in 1961. The catch has declined since then with none reported in 1971 and only 680 lb. reported in 1972. The herring fishery has been conducted on the offshore Caribou Island grounds by one fisherman during recent years. Three-inch-mesh gill nets are set on the bottom resulting in a higher CPE of incidentally caught lake trout (0.4 - 5.0 in 1970) than would be achieved with float nets. Fishing occurs during May - October with most effort in June.

Herring in a 1969 sample from the Caribou Island grounds were quite large and old. They ranged from 12.0-18.0" long with a mode of 16.0". Age VI was the dominant age group, but age-groups VII and VIII were next in abundance. Calculated length at age was greater than for any other Michigan herring stock (Table 8).

Although herring apparently have not been extensively exploited in MS 5, the sharp decline in effort after 1964 but with an increasing CPE is difficult to explain. The decline probably represents the withdrawal of fishermen after lake trout and whitefish stocks were decimated. Now, there is only one fisherman.

Herring on Caribou Island grounds may be under-exploited. Most of the 1970 MS 5 herring catch of 12,000 lb. came from these grounds. A quota of 10,000 lb. probably would be conservative, but a lake trout quota may be necessary to persuade fishermen to make the long run to these grounds. Inshore herring stocks are probably different than the Caribou Island stocks but may not be discrete from some herring stocks in MS 4 and MS 6. Further assessment will be necessary before quotas can be assigned to the inshore stocks. The inshore population is not expected to be large, however, as evidenced from past yields.

MS 6: Herring catches in Whitefish Bay (MS 6) are comparable to that in MS 4, with a previous average annual catch of 381,000 lb. As in the other districts, herring fishing intensified in the 1930's, declined to low levels in the late 1940's and early 1950's, then increased during the late 1950's. This effort was maintained at near record levels but the catch gradually declined through 1969 whereupon it dropped precipitously. CPE fluctuated without trend until 1952 but has since gradually declined.

Scale samples have been collected from herring in MS 6 since 1968. Age-group VI dominated each year's catch during 1968-72. Over-all age composition was as follows: III, 1%; VI, 5%; V, 28%; VI, 39%; VII, 22%; VIII, 3%; and IX, 2%. Average length of fish in the commercial catch was 15.0". Growth rate in MS 6 is much faster than in Keweenaw Bay but slightly slower than in MS 4 (Table 8). Dodge (1970) derived the length-weight relationship "Log W = 2.86 + 3.46 Log L" for Whitefish Bay herring (L = total length in inches and W = weight in ounces). Dodge concluded that these herring were heavier at a given length than those at Keweenaw Bay.

Herring fishing in MS 6 is year-round but most of the landings are made from March to September (Table 11). CPE's have generally been highest during February - April. CPE of incidentally caught salmonids is quite high in MS 6, especially during July - September. Experimental commercial fishing in July, 1970, revealed that the CPE in 3 1/4" mesh nets (56 lb.) was higher than in 2 3/4-3.0" mesh nets (26 lb.). Unfortunately, CPE of salmonids was also higher (1.1 vs 0.2). Bottom nets yielded a higher CPE (herring) than float nets (64 lb. vs 12 lb.) during September, but also caught more salmonids (3.0 vs 2.1). The 1970 ban on bottom sets of small-mesh gill nets inside 50 fathoms severely affected traditional herring fishing in MS 6 because most fishing in this district was on the bottom. A sharp decline in effort in 1970 was largely due to this regulation. A small amount of experimental bottom netting was permitted in 1970 and 1971. Although the over-all 1959-72 CPE trend is downward (Y = 73 lb. - 2.6(1965 - X), CPE's have increased slightly since 1970. No quota is recommended for 1974-76. However, if the current upward trend in CPE continues, it is recommended that the grounds be fished in 1977 with 2 1/2-3.0" gill nets fished a minimum of 12' off the bottom, or possibly use trap and pound nets instead.

Several herring grounds in MS 6 are on the Michigan-Ontario border (Fig. 4). It would be beneficial to both agencies if discreteness of stocks on these grounds could be determined so that management programs can be promulgated toward similar objectives.

LAKE TROUT (OFFSHORE STOCKS)

Offshore lake trout stocks constitute what perhaps is the largest unknown fishery in Lake Superior. The lake trout has achieved its greatest diversification in Lake Superior, but the taxonomy has not been firmly determined. Commercial fishermen recognize at least four (sometimes more) different types of offshore lake trout: leans, fats, humpers, and half-breeds. 'Leans' are typical lake trout, now mostly of hatchery origin, and most abundant in inshore waters where they provide nearly all of the lake trout sport fishery. 'Fats' are the siscowet (*Salvelinus naymacush siscowet*), the only recognized lake trout subspecies in Lake Superior. The fat trout (siscowet) has a flesh fat content 2 - 3 times that of lean trout. Eschmeyer and Phillips (1965) found that this difference was not a function of diet but appeared to be genetically determined. Siscowets characteristically inhabit depths greater than 50 fathoms but sometimes move to the surface and into shallow water closer to shore and are only occasionally caught by sport fishermen.

The 'humpers' exist in offshore, shallow-water areas (submerged ridges) generally less than 50 fathoms deep, around isolated islands. These areas are sometimes referred to as humps in Lake Superior, hence the name "humper". Humper populations are known to exist in Michigan waters around Isle Royale, Stannard Rock, and south of Caribou Island. Although the humper is not a recognized subspecies, it possesses certain characteristics which suggest a subspecies status. The humper is found only in these offshore areas. The humper is generally separated bathymetrically from siscowets although some overlap occurs. It rarely exceeds 25.0" and attains sexual maturity at 12.0-16.0", wheras leans seldom attain sexual maturity at less than 20.0" and fats at less than 18". The humper is spared much sea lamprey predation because of its small size. Eschmeyer and Phillips (1965) found the fat content of humper flesh to be higher than leans but lower than fats of comparable length. Khan and Qadri (1970) recognized the humper as distinct from lean and fat varieties based on morphological differences but did not assign it subspecific rank because of insufficient biological and distributional information.

What fishermen call 'half-breeds' have been determined to be mostly immature fats but some are large humpers. Trout identified as half-breeds in commercial nets usually are only 18.0-22.0" long and most are immature. A species represented only by immature fish would be strange indeed. Preliminary examinations of electrophoretic patterns of blood samples revealed only three distinct patterns for the LDH enzyme (lacto dehydrogenas dehydrogenase)--lean, humper, and fat (Laarman, 1971). Patterns for most half-breeds were identical to fats and the others were identical to humpers. Khan and Qadri (1970) found no morphological differences between siscowets and half-breeds and suggested that they be considered as one form.

Lean trout on the offshore grounds should be biologically similar to inshore lake trout because hatchery-reared fish constitute the majority of both stocks. However, there are many questions to be answered regarding their distribution and biology.

Humpers from Isle Royale (Rahrer, 1965) and Caribou Island grounds (unpublished data, Marquette Fisheries Research Station) have been the most extensively studied offshore lake trout. A yield equation was developed for the 1967-69 Caribou Island fishery (Patriarche and Peck, 1970). The calculated equilibrium yield was never harvested because three of the four fishermen dropped out of the fishery.

The siscowet, or fat trout, is the least understood of all lake trout in Lake Superior. They are distributed throughout the vast deep-water areas (deeper than 50 fathoms). Siscowets feed primarily on coregonids and cottids.

Although the offshore humper and siscowet biomass may be the largest of all secondary carnivores, its potential commercial value and density is low. Lean trout abundance on the offshore grounds presently fished (except Isle Royale and Stannard Rock) is extremely low and with the exception of Isle Royale and Stannard Rock, have never been able to support much harvest.

The high fat content in the larger siscowets acts as a depository for pesticides (DDT and PCB) and heavy metals which are recognized by FDA as dangerous to human health at the levels presently recorded. Young fat trout have a lower fat content and consequently contain less amounts of pesticides and heavy metals.

Humpers will support only a small commercial fishery in Michigan waters because they are limited to small offshore areas. They appear to meet acceptable safe food health standards established by FDA at this time for fish under 23.0" total length. The price per pound of fats and humpers is approximately half that of lean trout, and offshore fishermen face large operating costs because of the distance required to reach the grounds. Contamination by pesticides and heavy metals also loom as a potential harbinger of doom for any attempt to develop a viable offshore fishery for the "siscowet" and "humper" varieties of lake trout.

Stock Status

Except for the Caribou Island grounds, practically nothing is known about the stock status of offshore lake trout. The biology of Isle Royale humpers has been documented and data from the present research fishery has provided some information on stock status. The presence of a lake-wide population of siscowets has been established through incidental catch in chub nets, but its present biomass has not been calculated. The siscowet - lean trout composition of this incidental catch reported by commercial fishermen is suspect because of their vested interest and lack of good distinguishing taxonomic characteristics. Most fishermen, fisheries biologists, and taxonomists are unable to identify the young and immature specimens of the varieties of offshore lake trout.

Abundance Index

Commercial catch per unit of effort (CPE) presently provides the only index of abundance. Catch is measured either in numbers of fish or pounds and a unit of effort is 1,000' of 4.5" mesh gill net. The humper catch is relatively uniform so CPE based on weight is generally adequate. Siscowets in the catch can be anywhere from 2 to 30 lb., so a weight CPE could be very misleading. However, a numerical CPE is readily available because fishermen are required to measure each fish in their catch. Since nets below 50 fathoms take mainly siscowets and those above 40 fathoms catch mostly humpers, depth must be considered when using CPE as an index of either siscowets or humper abundance.

Fishing Gear

Gill nets of 4.5" mesh are now used but this mesh takes humpers and small siscowets under 13.0" total length. If a fishery is developed the mesh size should be raised to at least 4 3/4" for a humper fishery and 5 1/2" for a siscowet fishery. This would give the fish a change to spawn once, on the average, before harvest.

Size Limits

There is no need for a size limit on the offshore lake trout. A 16.0" minimum size limit is currently in effect with live sublegals being returned to the water and dead ones turned over to Department of Natural Resources personnel. The survival of those returned is questionable because most fish brought up in the nets have distended swim bladders and cannot immediately descend when released. These fish often fall prey to gulls.

Fishing Depths

The humper-siscowet catch composition appears to be depth dependent. A siscowet fishery should operate deeper than 50 fathoms whereas fishing in less than 40 fathoms would catch mainly humpers. Fishing in 40 - 50 fathoms would yield a variable catch composed of mostly humpers and some young siscowets, and is not to be encouraged if the mesh size is used to selectively regulate the minimum length in the catch.

Seasons

No particular fishing season is recommended for the offshore lake trout fishery. Nature imposes seasonal limits on the current offshore lake trout fishery. The grounds now fished are more than 30 miles from port and the danger of being caught in a storm increase with distance travelled. Fishing has taken place during May - October with most effort during June - September.

Conflict with the Sport Fishery

The prime offshore lake trout fishery (Caribou Island and Big Flats area) has generated no conflict with the sport fishery. The grounds do not overlap any sport-fishing grounds, and the recent incidental catch of lean trout has been low. Offshore lean trout on Caribou grounds probably contribute little to angling, but may be valuable as brood stock in developing a self-sustaining lean trout population. At Isle Royale, however, both the sport and commercial fishery have fished the humper and siscowet populations.

1967 catch of 53,900 lb. could have been harvested. The 1967 catch would have been excessive only if exploitation had reached 20%. Only a 50% increase over the 1967 catch (80,850 lb.) was recommended because the actual exploitation rate was unknown. However, the catch in subsequent years did not even reach the original 1967 quota of 60,000 lb. because of fishermen quitting the grounds.

Humper, siscowet, and lean trout CPE's on the three banks regularly fished by the one remaining fisherman indicate an increase for humpers, no change for siscowets, and a slight decline for lean trout during 1968-72. However, the increase in humpers and perhaps the decrease in lean trout is probably due to a shift from spring fishing (May - July) to early fall fishing (August - October) and is not a true picture of abundance trend. Because of the low effort involved, monthly CPE's were quite variable. July CPE went down and August CPE went up between 1968 and 1972 on the most intensively fished bank (Klondike).

The 1970 Caribou Island quota of 80,850 lb. is also recommended for 1974, 1977, and 1980. This quota should be 2/3 humpers (53,900 lb.) and 1/3 siscowets (26,950 lb.) in accordance with the composition of the 1967 catch and should be distributed over a number of banks. "Fishing up" of the closest banks would certainly occur if fishermen were allowed to fill the quota where they pleased. Banks such as 'Egg' which are populated mainly by leans should be closed to fishing.

Big Flats, the most distant offshore ground, is 40 - 50 miles from the nearest port (Grand Marais). Fishermen harvested 14,606 lb. of a 25,000 lb. quota in 1968 and it has not been fished since 1970. The catch is composed of more siscowets than most of the Caribou banks because the water is generally deeper. A quota of 25,000 lb. is recommended. An equilibrium yield for this ground should be determined if a fishery is established.

MS 6: There is no offshore lake trout fishery in MS 6. All but the extreme northwest corner of the district is less than 50 fathoms deep. Any siscowet population existing there probably would be too small to sustain a fishery. No offshore lake trout quota is recommended for MS 6.

RAINBOW SMELT

Smelt were first recorded in Lake Superior about 1930. They furnished a sport-dipping fishery on their spawning runs upstream and a limited commercial fishery. They have only been harvested commercially during the 1960's in Keweenaw and Munising Bays. Maximum production was 456,000 lb. in 1964 (Appendix A). The commercial catch was primarily with pound nets during the spawning runs and to a limited extent with gill nets in the winter. Smelt caught in pound nets sold for 1-10¢ per lb. and went primarily for pet and commercially raised mink food. Smelt from gill nets were sold for human food and bait fish for lake trout fishing. They were retailed at between 10¢ and $1.00 per lb.

Since the decrease in mink farming in the area, smelt have no large ready market. The long-distance shipping required to reach the pet-food markets puts Lake Superior fish at a disadvantage with the closer sources of smelt in Lake Michigan. Now there is only a local market for winter bait for lake trout and a limited market for human food. A pilot project of trawling for commercial quantities of smelt and then packaging them met with failure because commercial quantities were not obtainable and the shelf life was short (U.S. Dept. Int., 1968). Since then a similar operation has been successful in Minnesota, but their success is due primarily to better trawling grounds and a greater availability of smelt.

Smelt play a dominant role as prey for lake trout. Unpublished studies by Kenneth Dodge and the authors show that well over 90% by volume of their diet is smelt in Michigan's inshore waters of the lake. Smelt die-offs have occurred in recent years in the Minnesota and Wisconsin waters of the lake where densities are high, but none have been noted in Michigan waters.

Management

As the smelt has limited commercial value (except as noted above) and may be detrimental to the recovery of the herring stocks, its desirability in Lake Superior is open to debate. It does, however, provide many angler days per year to sport fishermen, and it is an excellent food for lake trout.

At present it appears that the pressure exerted on smelt by lake trout far surpasses anything that could be accomplished commercially--even under substantial subsidy. Therefore, it is recommended that the lake trout plantings be continued at a heavy density and commercial exploitation be encouraged with pound nets to determine if further reduction in an area can provide increased impetus to herring rehabilitation. (Suggested areas are outer Keweenaw Bay and the Munising area. It's further recommended that the bait fishery with gill nets be continued under special permit only in those areas where it can be monitored by district personnel and where it causes no harm to other species. No pound net quotas are needed until experience dictates otherwise. Gill net quotas should be limited by the value of the fishery, cost of monitoring, and the potential harm to other species.

SUCKERS

White suckers and longnose suckers have been taken commercially since the 1890's. Landings reached 378,000 lb. in 1937, but have been below 100,000 lb. since 1946 (Appendix A). Suckers are plentiful in the lake but their total biomass is unknown. Presently, their chief value is as a bait fish (up to $1.00 each) and to the sportsmen who dip them in the spring during their spawning runs for smoking. Their commercial value of 3-8¢ per pound makes them unattractive as a commercial fish as shipping costs equal their sale value most months of the year.

Recommended Management

The role of the sucker in Lake Superior is not well defined. However, it probably competes with young rainbow trout, brown trout, and salmon for food and contributes little to the forage base for the larger predators except northern pike in isolated bays. It is recommended that this resource be harvested with impoundment gear and markets sought for their disposal. In the past the main local market was for canning. With the closing of the canneries, the production has been limited to the sale of the incidental catch. No quotas are needed at present.

ROUND WHITEFISH

The round whitefish (menominee) inhabits inshore waters of the lake, usually in depths less than 150' but the population is not large. The spawning period is in late fall. Some fish move into streams to spawn but lake spawning is also thought to occur.

The round whitefish has provided a commercial harvest of up to 20,000 lb. since 1911 (Appendix A). At times there is also a substantial sport harvest around piers, jetties and around river mouths. The principal commercial method of harvest has been gill nets in recent years although considerable numbers were reportedly taken many years ago in pound nets. There is a moderate demand at the present time for the species which is primarily sold smoked. (Wholesale price in 1973 is 15-40¢ per lb., dressed.)

Since the population of menominees is small and their distribution not well known, it is recommended that only a research fishery be established for the period 1974-77. This investigation should attempt to delineate stock distribution, size and age structure before any quotas are established. The research fisheries should be limited to impoundment gear since menominee inhabit shoal areas with trout, salmon, and herring.

BURBOT

The size of the burbot populations in Lake Superior have not been assessed and little information exists on their response to exploitation. Their distribution is similar to that of the lean trout (less than 50 fathoms). Burbot are harvested only incidentally in gill nets set for other species although catches increased considerably in 1971-72 (Appendix A).

Adults feed primarily on smelt. They have a long life span, however, and may eat juveniles of species of greater value. Burbots migrate into streams in late winter and spawn under the ice. Little information is available on their early life history in streams or even whether or not they spawn successfully in the lake. Their fecundity is high so that they have been able to sustain themselves through the period of intense lamprey activity in the lake. The population is now expanding.

Presently, the only fishery exclusively for this species is a remnant hoop net fishery in some of the streams in MS 3. They are used primarily for personal consumption by the netters. Burbot taken by commercial fishermen are usually returned to the water or discarded because of their low value. One fisherman smokes a limited number of burbot for local marketing. The burbot, although very bony, is a very tasty fish either smoked, broiled or boiled. Boiled in salt water, it tastes very much like lobster.

The population of burbot in Lake Superior is low in comparision to whitefish or lake trout which occupy the same range. Presently there is no satisfactory method to selectively harvest burbot. Any harvesting expressly for the species should be conducted on a research basis during the period 1974-80. The most likely time to harvest is during the spawning runs either at the mouth of the streams or in the stream itself. Burbot caught incidentally in chub nets or impoundment gear could be sold, with little effect on present populations.

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APPENDIX A. COMMERCIAL HARVEST OF SEVEN SPECIES OF FISH IN THE MICHIGAN WATERS OF LAKE SUPERIOR, 1930-72.1/

(thousands of pounds)

Year	Lake Whitefish	Round Whitefish	Suckers	Ciscoes (chubs)	Lake Herring	Smelt	Burbot
1930	161	14	86	---	---	---	--
1931	410	1	89	---	---	---	--
1932	417	13	83	---	---	---	--
1933	442	17	124	---	---	---	--
1934	388	8	93	---	---	---	--
1935	429	20	161	---	---	---	--
1936	230	46	117	---	---	---	--
1937	258	10	378	---	---	---	--
1938	327	7	212	---	---	---	--
1939	385	17	119	---	---	---	--
1940	532	8	115	---	---	---	--
1941	446	9	103	42	5,954	---	--
1942	489	6	80	33	5,113	---	--
1943	461	20	81	36	4,360	---	--
1944	385	20	96	32	4,446	---	--
1945	368	156		24	3,109	---	--
1946	421	9	135	12	3,357	---	--
1947	321	6	38	12	3,263	---	--
1948	477	17	50	15	4,524	---	--
1949	504	13	34	17	4,122	---	--
1950	508	13	64	15	1,715	*	--
1951	244	12	83	68	2,829	*	--
1952	198	4	44	73	3,448	*	--
1953	430	5	24	25	2,415	*	--
1954	665	7	29	91	3,393	3	--
1955	497	18	18	50	3,443	2	--
1956	374	13	11	88	3,719	4	--
1957	236	26	25	68	5,017	*	--
1958	220	31	26	560	4,850	2	--
1959	260	11	16	334	6,242	21	--
1960	156	8	23	470	6,693	29	--
1961	249	15	22	408	7,306	127	--
1962	316	11	31	313	5,897	112	--
1963	357	12	25	587	6,155	200	1
1964	348	10	19	397	4,664	456	*
1965	385	16	9	1,185	3,629	182	2
1966	292	10	12	782	3,332	93	2
1967	364	10	19	707	2,710	36	1
1968	441	13	34	97	2,320	12	7
1969	533	9	54	530	1,554	10	18
1970	314	2	50	634	986	21	14
1971	413	*	34	1,165	728	4	40
1972	369	6	29	950	513	3	59

1/ Sources of data: 1930-68, Baldwin and Saalfeld (1962), burbot excepted. 1969-71 and all burbot data from annual summaries of Michigan, Ohio, and Wisconsin landings, Bur. Comm. Fish. 1972, Bur. Sport. Fish. and Wildl., Great Lakes Lab., Ann Arbor, Mich.
* Less than 1,000 lb.