ESTIMATE OF ABUNDANCE,
HARVEST, AND EXPLOITATION
OF THE

FISH POPULATION OF ESCANABA LAKE, WISCONSIN, 1946-69

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ABSTRACT

A complete compulsory creel census was conducted on 293-acre Escanaba Lake, northern Wisconsin from 1946 through 1969. On the average each year, anglers fished 65 hours per acre catching 20 lb/ acre at the rate of 0.84 fish per hour. Population estimates of the principal sport species were made from 1956 through 1969. The spring standing crop varied annually from 19 to 117 lb/ acre.

Walleyes, though not native, were the most important species, contributing 36 percent by weight of the harvest during this period. Standing crops and harvest of panfish, especially yellow perch and pumpkinseed, fluctuated greatly; those of predator fishes were more stable.

The exploitation rate for each species varied greatly from year to year but not significantly from the mean which was established over a number of years and is characteristic for each species. Northern pike (.46) and bluegill (.42) were the most heavily exploited, and yellow perch (.15) the most lightly. No relation could be demonstrated between rate of exploitation and other aspects of the fishery.

Species composition of the estimated spring standing crop and of the harvest was similar. Large fluctuations in the proportion of the various species occurred; but these were not thought to be the result of liberalized fishing regulations in effect on the lake.

The decline of panfish in the late 1950's and early 1960's is attributed to the increased predator species component during that period.

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CONTENTS

INTRODUCTION

Stocks of fish in the lakes and streams of Wisconsin constitute a large and important natural resource. Their greatest importance is not their intrinsic value as food, but their potential as a source of recreation. Each year, a million licensed anglers make some 15 million fishing trips in Wisconsin and catch 100 million fish (Churchill 1970).

Despite this high level of activity, very little is definitely known about the size of the fish stocks available or the degree to which they are utilized by this impressive number of anglers.

Escanaba Lake is one of five lakes (Escanaba, Mystery, Nebish, Pallettee, and Spruce Lakes) in the Northern Highlands Fishery Research Area which was established by the Conservation Commission in 1946 to study primarily the effect of liberalized fishing regulations on the fish populations. These five lakes were opened to fishing under experimental regulations with no size and bag limits or closed seasons on any species.*

A complete creel census was established in 1946 through which species composition, relative abundance, and harvest of the mixed warm water fish populations of Escanaba Lake were determined. Standing crops and exploitation rates were estimated annually from 1953 on for the walleye and from 1956 on for the other species of record. This report is intended primarily to document those voluminous data, essentially on the size of fish stocks available, the extent of utilization of those stocks by anglers, and the changes in both throughout the 1946-69 period. This paper also addresses itself to the question of the impact of liberalized angling regulations on the fish population of Escanaba Lake. Responses to that question were previously made after the first 5 years (Threinen 1951) and after the first 10 years of the study (Churchill 1957). Here we have the advantage of a 24-year perspective.

*A 22-inch minimum size limit on northern pike was put into effect on Escanaba Lake in 1964.

STUDY AREA

Escanaba Lake is located on undeveloped, state-owned land in the Northern Highlands State Forest in central Vilas County, northern Wisconsin (Fig. 1). It has a surface area of 293 acres, a shoreline of 5.1 miles and a maximum depth of 25 ft. Shoreline and bottom contours are irregular and there are several small islands with rocky bars and shoals (Fig. 2). An inlet and outlet, controlled by a low-level dam since 1963, are present at high water stages but free migration of fish is unlikely. The water has a total alkalinity of 20 mg/l and is relatively fertile for this

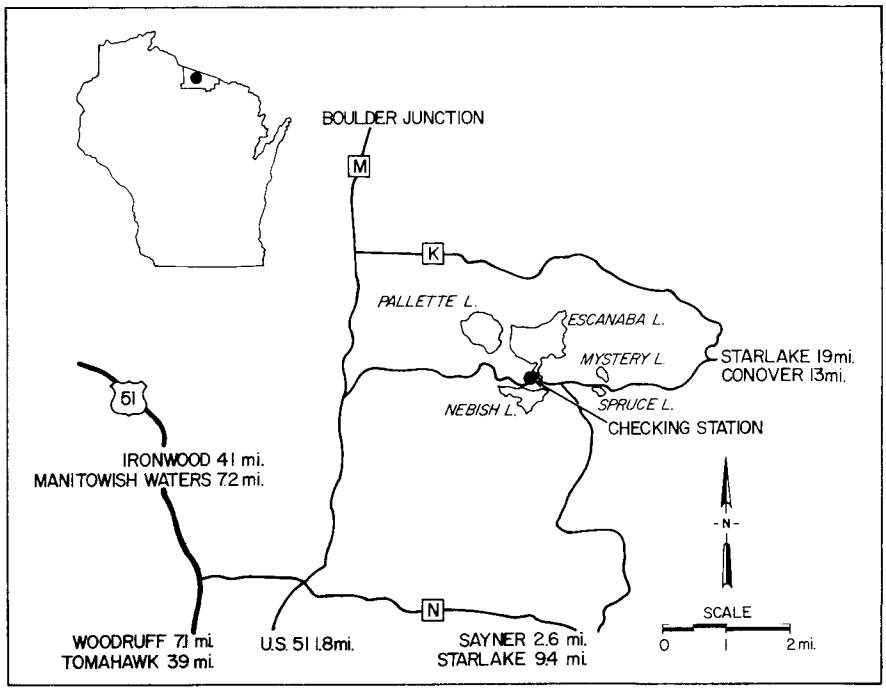


FIGURE 1.

Map showing location and environs of Escanaba Lake, one of the five study lakes in the Northern Highlands Fishery Research Area, Vilas County.

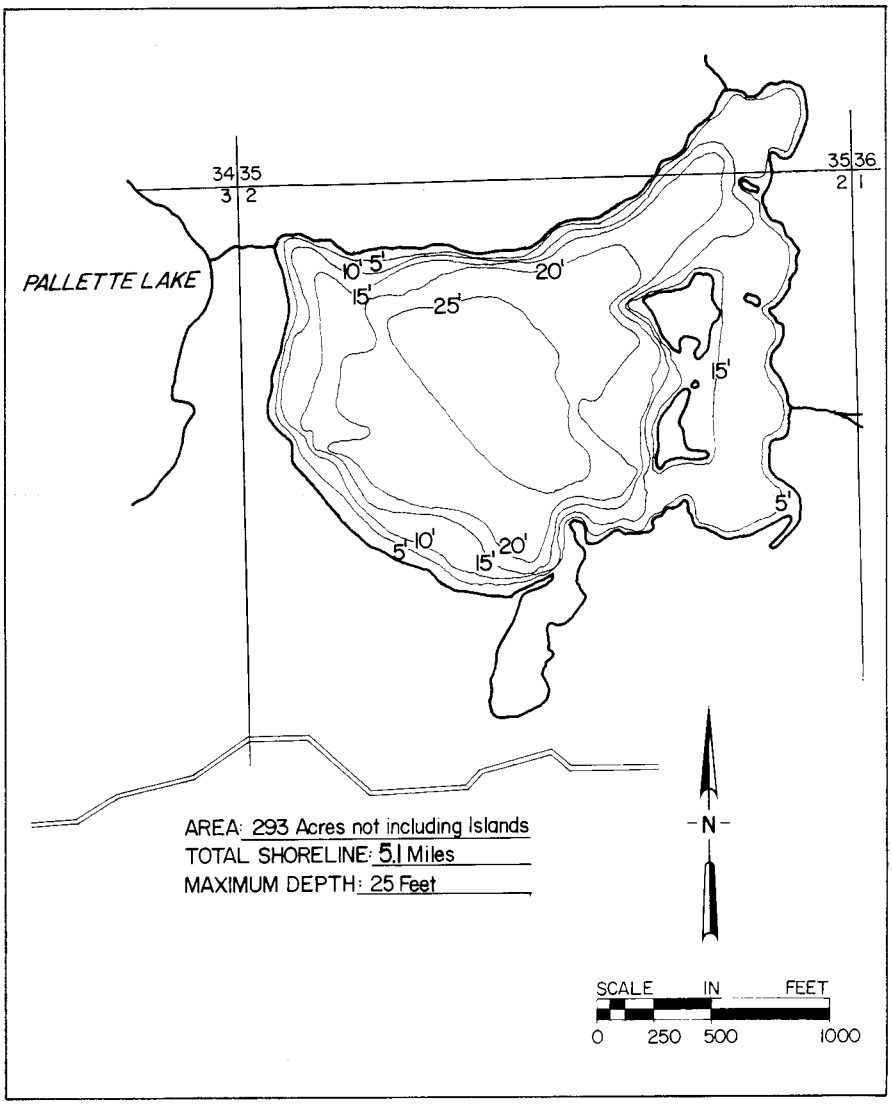


FIGURE 2. *Contour map of Escanaba Lake.*

area, developing a phytoplankton bloom in summer. Vegetation is abundant in the shallow areas.

Although the maximum depth is only 25 ft, no evidence of winterkill has been detected in 24 years of observation. Oxygen concentrations in the shallower areas may decrease in winter to levels that would not support fish; this also occurs in the deepest water during the summer. However, there is always an adequate supply of oxygenated water.

Twenty-four fish species are known to be present in Escanaba Lake; however, no systematic study of minnows or darters has been made, so additional species may be present (Appendix A). The major species of importance to the sport fishery include the walleye, northern pike, muskellunge, smallmouth bass, largemouth bass, yellow perch, pumpkinseed, bluegill, rock bass and black crappie. The walleye and northern pike are not known to be native to the lake. Stocking records show that approximately 5 million walleye fry were stocked in the ten years between 1933 and 1942. Between 1937 and 1941, one-half million northern pike fry were stocked. One or more of these fry stockings resulted in the establishment of the walleye and northern pike population. The only stockings since 1946 have been experimental plants of marked walleye fingerlings and muskellunge fingerlings and yearlings (Appendix B).

METHODS

CREEL CENSUS

The creel census on Escanaba Lake was a complete compulsory permit system. Permits were issued without charge at a checking station located at the only landing on the lake. At the end of each angler's fishing trip, the catch was inspected by Department personnel. Numbers of each species were recorded. All game fish and most panfish were measured to the nearest 0.1 inch (total length) and weighed to the nearest 0.01 lb. Scale samples from all game fish and from periodic stratified samples of panfish were taken for age determination. Data were recorded in code and transferred to punch cards for processing.

The fishing year was considered to begin and end with the disappearance of ice cover in the spring, usually between 15 and 30 April and therefore consisted of a season of open water fishing plus the winter fishing season immediately following. Ages of fish were recorded in the same way; each fish was credited with a "birthday" at the time of ice breakup rather than on the conventional 1 January date.

POPULATION ESTIMATES

Annual population estimates were made during varying periods of years

The Northern Highland Fishery Research Area was established by the Wisconsin Conservation Commission in 1946 to study primarily the effect of liberalized fishing regulations.

The checking station is located at the only landing on Escanaba Lake. Through a compulsory free permit and reporting system, data on fishing pressure, harvest, population estimates and exploitation rates are obtained.

for the following species above the total length in inches indicated: walleye (11.0), northern pike (12.0), muskellunge (18.0), yellow perch (6.0), pumpkinseed (4.5), rock bass (4.0), bluegill (4.0), and black crappie (6.0). Fish were collected with fyke nets or ac electroshockers during the spawning season and marked either with a tag or fin clip. Size of the population was estimated from the proportion of marked fish in the anglers' catch by the Petersen formula. Fish captured during the marking period were not weighed. Estimates were converted to poundage by multiplying by the average species' weight in that year's harvest as determined from checking station records.

Walleye estimates were made by year class since all walleyes were aged. Very few walleyes younger than age III appeared in the nets at spawning time, so the number of walleyes in this age range could not be estimated by the previously described method. A minimum estimate of each year class at age II was made by adding the harvest of age II fish to the estimate of the same year class at age III. This makes no allowance for natural mortality and underestimates the 2-year-old population by that amount. Similarly, the ratio of the age II harvest to this estimate gives a maximum estimate of the rate of exploitation at this age.

Because of gear limitations, panfish below the indicated minimal size were not captured during marking which was done as early as possible in the year. Large numbers of panfish below the minimal size at the time of marking grow into the catchable size range during the season and may contribute greatly to the season's harvest. In fact, it is quite possible for the annual angler harvest of a species to exceed the number of harvestable fish present at the beginning of the season (Cooper 1953). To avoid distortion of the estimate by these fish, the estimate is based on a recovery period of about 4 weeks immediately following marking and includes only those fish over the established minimal size at the time of marking.

These population estimates are of course subject to sampling error and are reliable only within their confidence limits. In the tables and text, the value used is the point estimate rounded, usually to the nearest 100. Any one estimate could differ from the true value by an amount dependent on the size of the sample used. However, when a number of independent estimates give consistent results, they may be considered reliable.

EXPLOITATION

Ricker (1958) defines rate of exploitation as "the fraction by number of the fish in a population at a given time, which is caught and killed by man during a specified time interval immediately following". The percentage of marked fish recovered by anglers in the year after marking is a direct estimate of the annual rate of exploitation of the species in the size or age range marked. This is calculated by year classes for walleyes and for total harvestable populations of walleyes and all other species.

In the case of centrarchids, a considerable part of the harvest is taken before the fish are marked. This has been partially corrected by multiplying the rate of exploitation by the ratio (P+B)/P, where P is the estimated population of harvestable fish at the date of marking and B is the angler's catch prior to that date.

Fish were captured for marking during the spawning season using (A) fyke nets and (B) a 230-volt, 3,000-watt, ac boom shocker. Population estimates and exploitation rates were determined from angler-caught fish through the complete creel census.

Panfish were marked by removal of a fin.

FINDINGS

The dynamics of a fish population are quite complex and difficult to assess. The age composition, spawning success, and survival of year classes of the abundant species do not remain constant but vary from year to year (Table 4). Annual estimates of sport fishes available to the angler indicated that the spring standing crops at Escanaba Lake from 1956 through 1969 varied from 19 lb/acre in 1968 to 117 lb/acre in 1958, with an average of 67 lb/acre.

Considerable variation in population size of the various species occurred during the years of the study. The bulk of the population, as estimated by weight of the anglers' catch and spring population estimates, was composed of the ten species listed in the section entitled, Study Area. These were considered as the influential species in the lake and the variation in their abundance probably affected the entire fish population. Although other species also varied in abundance, most of them were not abundant enough to have had more than minor roles in the ecology of the lake.

Before 1946, Escanaba Lake was not heavily fished. Fishing was mostly for bass in summer and yellow perch in winter. With the start of the research project, access to the lake was improved, a boat livery was established, and the liberalized regulations drew larger numbers of fishermen. From 1946 through 1969, 100,858 anglers fished 455,610 hours on Escanaba Lake and caught 381,425 fish weighing 138,303 lb (Table 1). The annual average catch was 15,893 fish weighing 5,763 lb.

WALLEYE

During the 1947 netting period, 100 walleyes were captured; aging of scales indicated that 25% of these were from the 1943 year class, the first known natural reproduction. In 1947, a native year class was produced that contributed heavily to the fishery in later years. From 1956 through 1969, walleyes in age group II and older accounted for 3 to 98% by number of the spring standing crop of sport fishes available to the angler (Table 3) and 11 to 94% by weight (Table 4). During this same period, the number of walleyes per acre varied from 15 to 36 fish except in 1963 when the spring standing crop estimate was only 6 fish per acre (Table 3).

The walleye fishing began in 1946 when 4 walleyes were harvested by anglers (Table 7). The number rose to 47 the next year and surged in 1948 to 4,313 walleyes (mostly yearlings) weighing 2,179 lb. Annual walleye harvest since 1948 varied from 1,010

to 5,887 or 3 to 20 fish per acre and averaged 10 fish per acre. Annual weight harvested since 1948 has varied from 900 to 6,720 lb or 3 to 23 lb/acre and averaged 8 lb/acre. During the 24-year period, 1946-69, walleyes ranked first in weight with 51,263 lb harvested and third in number with 63,029 caught (Table 2). Fish stocked in 1954 made up 6,500 of this total and weighed 4,300 lb. Since 1948, walleyes comprised 3 to 95% of the total number of fish caught annually (Table 5) and 9 to 92% of the annual weight harvested (Table 6). The average size of all walleyes taken by anglers from 1953 through 1969 was 12.9 inches in open water and 13.6 inches through the ice (Table 7). Average annual size did not vary significantly during the years, 11.4-14.2 inches during the open water season and 12.3-15.4 inches through the ice.

The adult walleye population in Escanaba Lake was first estimated in 1951 by Patterson (1953) at 9,100. Estimates in 1953, and every year since, indicated populations ranging from 1,600 to 6,600, or 5 to 23 fish per acre for age group III and older (Table 8). During this period, the annual rate of exploitation varied from .13 to .42 for these age groups.

The history of individual walleye year classes was traced for a large part of their lives. In the absence of a size limit, a walleye year class enters the fishery in significant numbers in its third year as age II fish (Table 9). The harvest of age II fish of a given year class may be nearly as great and sometimes exceeds the estimated abundance of the same year class at age III. Adding this harvest to the estimate at age III, it is possible to arrive at a minimum estimate of the population at age II and from this, a maximum estimate of the rate of exploitation at age II which varied from .07 to .53 (Table 9). Cumulative harvests of each year class, between ages III and VII, ranged between .26 and .89 of the age III estimate.

TABLE 1. Total Angler Harvest on Escanaba Lake, 1946–1969

Year	No. Anglers	Hours		Fish (Numbers)			Fish (Weight)		
		Total	Per Acre	Total	No./Acre	No./Hr.	Total	Lb/Acre	Lb/Hr
1946	1,700	9,386	32	9,982	34	1.06	3,371	11	0.36
1947	1,259	6,295	21	7,058	24	1.12	2,625	9	0.42
1948	2,505	12,776	44	14,048	48	1.10	5,764	20	0.45
1949	3,868	19,332	66	10,224	35	0.53	5,038	17	0.26
1950	7,314	35,862	122	7,924	27	0.22	7,797	27	0.22
1951	4,416	21,874	74	3,821	13	0.17	3,455	12	0.16
1952	5,164	25,702	88	5,226	18	0.20	5,062	17	0.20
1953	5,159	28,862	99	8,184	28	0.28	5,084	17	0.18
1954	3,661	17,965	61	6,408	22	0.36	3,135	11	0.17
1955	5,164	23,403	80	24,629	84	1.05	8,018	27	0.34
1956	5,308	24,412	83	28,902	99	1.18	8,506	29	0.35
1957	5,778	24,775	85	34,796	119	1.40	9,751	33	0.39
1958	6,310	26,368	90	43,241	148	1.64	12,027	41	0.46
1959	5,222	21,979	75	37,703	129	1.72	10,861	37	0.49
1960	5,113	22,214	76	38,013	130	1.71	10,435	36	0.47
1961	4,406	18,497	63	24,708	84	1.33	7,043	24	0.38
1962	5,268	22,367	76	26,391	90	1.18	8,660	30	0.39
1963	4,999	20,796	71	22,616	77	1.08	6,573	22	0.31
1964	3,169	12,769	44	12,162	42	0.95	3,852	13	0.30
1965	2,821	10,775	37	5,535	19	0.51	2,541	9	0.24
1966	3,371	13,716	47	3,252	11	0.24	2,796	10	0.20
1967	3,668	14,437	49	3,551	12	0.25	2,844	10	0.20
1968	2,520	9,898	34	1,354	5	0.14	1,288	4	0.13
1969	2,695	11,150	38	1,697	6	0.15	1,777	6	0.16
Total	100,858	455,610	1,555	381,425	1,302	-	138,303	472	-
Avg.	4,202	18,983	65	15,893	54	0.84	5,763	20	0.30

TABLE 2. The Anglers' Harvest From Escanaba Lake, 1946-1969

	24-Year Total	Percent of Total	Annual Average
Number of Anglers	100,858	-	4,202
Number of Hours	455,610	-	18,983
Hours per Acre	1,553	-	65
Walleye			
Number	63,029	16.5	2,626
Pounds	51,263	37.1	2,136
Northern Pike			
Number	4,233	1.1	176
Pounds	7,327	5.3	305
Muskellunge			
Number	550	0.1	23
Pounds	2,604	1.9	108
Largemouth Bass			
Number	2,271	0.6	95
Pounds	2,611	1.9	109
Smallmouth Bass			
Number	4,397	1.2	183
Pounds	2,189	1.6	91
Yellow Perch			
Number	138,962	36.4	5,790
Pounds	36,914	26.6	1,538
Pumpkinseed			
Number	138,338	36.3	5,764
Pounds	24,559	17.8	1,023
Rockbass			
Number	13,171	3.4	549
Pounds	3,652	2.6	152
Bluegill			
Number	8,992	2.4	375
Pounds	1,845	1.3	77
Black Crappie			
Number	7,482	2.0	312
Pounds	5,339	3.9	222
Total			
Number	381,425	-	15,893
Pounds	138,303	-	5,763
Fish per Hour	-	-	0.8
Pounds per Hour	-	-	0.3
Fish per Acre	1,302	-	54
Pounds per Acre	472	-	20

TABLE 3. Estimated Species Composition of the Spring Standing Crop of Sport Fishes Available to the Angler in Escanaba Lake, 1956–1969 (Number Per Acre)

	Walleye**		Northern Pike[1]		Muskellunge		Yellow Perch		Pumpkinseed		Rock Bass		Bluegill		Black Crappie		Total	
Year	No./ Acre	Per-cent	No./ Acre	Per-cent	No./ Acre	Per-cent	No./ Acre	Per-cent	No./ Acre	Per-cent	No./ Acre	Per-cent	No./ Acre	Per-cent	No./ Acre	Per-cent	Number	No./ Acre
1956	36	11	-	-	*	*	184	59	58	19	17	5	4	1	14	4	91,510	312
1957	33	10	-	-	*	*	191	56	85	24	13	4	5	1	12	4	99,120	338
1958	19	5	7	2	*	*	225	64	65	19	11	3	6	2	18	5	102,760	351
1959	19	6	5	1	*	*	116	34	177	52	13	4	4	1	7	2	100,170	342
1960	16	7	2	1	*	*	120	49	89	37	3	1	8	3	5	2	71,200	243
1961	33	8	1	*	*	*	184	47	160	41	8	2	6	1	5	1	116,380	397
1962	20	5	4	1	*	*	232	53	150	34	19	4	6	1	6	1	128,220	438
1963	6	3	2	1	1	*	126	57	75	34	6	3	1	1	3	1	64,870	221
1964	15	10	*	*	1	*	99	67	31	21	-	-	1	1	-	-	43,050	147
1965	18	25	*	*	1	1	38	52	11	14	-	-	1	1	4	6	21,190	72
1966	32	60	*	1	*	1	20	38	-	-	-	-	-	-	-	-	15,580	53
1967	28	98	*	1	*	1	-	-	-	-	-	-	-	-	-	-	8,400	29
1968	17	94	1	4	*	2	-	-	-	-	-	-	-	-	-	-	5,210	18
1969	22	26	1	1	*	1	63	72	-	-	-	-	-	-	-	-	24,900	85

*Less than 1.

**Age II and older.

[1] 22-inch size limit became effective in 1964, estimated population of fish 22 inches and larger only.

TABLE 4. Estimated Species Composition of the Spring Standing Crop of Sport Fishes Available to the Angler in Escanaba Lake, 1956–1969 (Pounds Per Acre)

Year	Walleye**		Northern Pike[1]		Muskellunge		Yellow Perch		Pumpkinseed		Rock Bass		Bluegill		Black Crappie		Total	
	Lb / Acre	Per-cent	Lb / Acre	Per-cent	Lb / Acre	Per-cent	Lb / Acre	Per-cent	Lb / Acre	Per-cent	Lb / Acre	Per-cent	Lb / Acre	Per-cent	Lb / Acre	Per-cent	Pounds	Lb / Acre
1956	20	22	-	-	*	*	43	51	11	12	4	5	1	1	6	9	26,300	85
1957	22	22	-	-	*	*	48	50	14	14	3	3	1	1	9	9	28,270	96
1958	18	15	7	6	1	1	66	56	11	9	2	2	1	1	11	9	34,250	117
1959	19	18	9	8	*	*	38	36	29	28	4	4	1	1	6	6	30,960	106
1960	14	20	5	8	1	1	27	39	15	22	1	1	1	2	4	6	20,300	69
1961	18	19	2	2	*	*	41	43	28	29	2	2	1	1	4	4	28,460	97
1962	18	16	7	6	1	1	49	43	28	24	4	4	1	1	5	5	33,490	114
1963	6	11	3	6	2	3	25	46	14	26	2	3	*	1	3	5	16,020	55
1964	11	25	1	2	3	7	22	51	6	13	-	-	*	1	-	-	12,540	43
1965	14	42	1	2	2	7	10	32	2	7	-	-	*	1	3	8	9,480	32
1966	26	68	1	4	3	8	7	20	-	-	-	-	-	-	-	-	10,800	37
1967	22	94	*	2	1	4	-	-	-	-	-	-	-	-	-	-	6,750	23
1968	16	85	2	9	1	6	-	-	-	-	-	-	-	-	-	-	5,450	19
1969	16	41	3	7	2	4	18	48	-	-	-	-	-	-	-	-	11,250	38

*Less than 1.
**Age II and older.
[1] 22-inch size limit became effective in 1964, estimated population of fish 22 inches and larger only.

TABLE 5. Species Composition of the Anglers' Harvest as the Percent by Number of Fish From Escanaba Lake, 1946–1969

Year	Walleye	Northern Pike	Muskellunge	Largemouth Bass	Smallmouth Bass	Yellow Perch	Pumpkinseed	Rock Bass	Bluegill	Black Crappie	Total Number
1946	*	*	*	2	6	88	1	2	*	*	9,982
1947	1	-	*	1	6	87	1	4	*	*	7,058
1948	31	*	*	*	3	64	*	2	*	*	14,048
1949	22	*	*	1	5	69	1	2	*	*	10,224
1950	74	*	*	1	2	15	2	5	*	*	7,924
1951	59	*	1	1	1	22	4	9	2	*	3,821
1952	73	-	1	2	3	8	6	7	1	*	5,226
1953	57	-	*	1	8	9	3	19	3	*	8,184
1954	36	*	*	1	7	32	6	15	2	*	6,408
1955	21	*	*	1	1	37	37	5	2	*	24,629
1956	18	-	*	1	*	36	35	6	2	2	28,902
1957	10	*	*	1	*	42	35	6	3	3	34,796
1958	3	2	*	1	*	36	50	2	2	4	43,241
1959	3	2	*	*	*	19	68	2	2	3	37,703
1960	7	*	*	*	*	32	50	2	5	3	38,013
1961	15	1	*	*	*	31	44	2	5	1	24,708
1962	9	3	*	1	*	45	35	3	3	1	26,391
1963	6	3	*	1	*	36	49	1	2	2	22,616
1964	14	1	*	1	*	32	48	1	2	*	12,162
1965	28	1	*	2	*	18	45	1	4	2	5,535
1966	86	2	1	1	-	9	1	*	*	1	3,252
1967	95	1	1	*	-	4	*	*	-	*	3,551
1968	74	6	2	*	*	13	2	*	1	*	1,354
1969	62	14	2	-	*	18	2	1	*	*	1,697

*Less than 1%.

TABLE 6. Species Composition of the Anglers' Harvest as the Percent of Pounds From Escanaba Lake, 1946–1969

Year	Walleye	Northern Pike	Muskellunge	Largemouth Bass	Smallmouth Bass	Yellow Perch	Pumpkinseed	Rock Bass	Bluegill	Black Crappie	Total Pounds
1946	*	*	3	6	10	77	1	2	*	*	3,371
1947	2	-	3	3	11	75	1	5	*	1	2,625
1948	38	*	1	1	5	54	*	1	*	*	5,764
1949	47	*	1	4	4	41	1	1	*	*	5,038
1950	86	*	3	2	1	5	*	1	*	*	7,797
1951	79	*	2	1	2	10	1	3	1	*	3,455
1952	83	-	4	2	2	4	2	2	*	*	5,062
1953	72	-	4	2	4	7	2	8	2	*	5,084
1954	55	*	4	2	7	16	4	11	2	*	3,135
1955	42	*	*	1	2	28	19	5	1	*	8,018
1956	34	-	*	2	*	31	23	6	1	4	8,506
1957	24	1	1	2	*	37	21	4	2	7	9,751
1958	9	8	1	2	*	38	31	1	2	9	12,027
1959	9	15	*	1	*	22	39	2	1	9	10,861
1960	20	4	1	1	*	27	32	2	3	10	10,435
1961	29	8	1	2	*	24	27	2	4	3	7,043
1962	26	14	2	2	*	28	20	2	2	4	8,660
1963	19	13	3	2	*	24	32	1	1	5	6,573
1964	34	5	3	4	*	22	29	1	2	*	3,852
1965	45	8	4	5	*	11	21	1	2	3	2,541
1966	81	7	5	1	-	3	*	*	-	1	2,796
1967	92	3	4	*	-	1	-	*	-	*	2,844
1968	74	16	6	*	*	2	1	*	*	*	1,288
1969	51	34	8	-	*	5	1	*	*	*	1,777

*Less than 1%.

TABLE 7. The Walleye Harvest From Escanaba Lake, 1946–1969

Year	Total Harvest				Average Total Length (Inches)	
	Number	Pounds	No./Acre	Lb /Acre	Open Water	Ice
1946	4	12	-	-	-	-
1947	47	59	-	-	-	-
1948	4,313	2,179	15	7	-	-
1949	2,199	2,370	8	8	-	-
1950	5,887	6,720	20	23	-	-
1951	2,267	2,732	8	9	-	-
1952	3,791	4,189	13	14	-	-
1953	4,683	3,740	16	13	12.8	13.8
1954	2,292	1,714	8	6	12.8	13.3
1955	5,227	3,342	18	11	12.1	12.3
1956	5,096	2,863	17	10	11.7	12.3
1957	3,624	2,341	12	8	12.4	12.7
1958	1,178	1,115	4	4	13.9	14.8
1959	1,010	1,017	3	3	14.2	14.1
1960	2,469	2,094	8	7	11.7	14.0
1961	3,593	2,033	12	7	11.4	12.5
1962	2,490	2,278	8	8	13.5	15.4
1963	1,352	1,281	5	4	13.4	14.6
1964	1,758	1,292	6	4	12.7	12.8
1965	1,532	1,136	5	4	12.8	13.6
1966	2,789	2,279	10	8	12.9	14.6
1967	3,362	2,620	11	9	13.3	14.6
1968	1,028	957	3	3	14.1	13.8
1969	1,044	900	4	3	13.7	12.5
Total	63,035	51,263	215	175		
Average	2,865	2,330	10	8	12.9	13.6

TABLE 8. Estimated Population and Rate of Exploitation of Walleyes (Age Group III and Older) in Escanaba Lake, 1953–1969

Year	Estimated Population		Rate of Exploitation
	Number	No./Acre	
1953	6,500	22	.35
1954	4,900	17	.32
1955	4,900	17	.40
1956	3,500	12	.42
1957	5,600	19	.37
1958	5,500	19	.22
1959	5,500	19	.13
1960	3,600	12	.31
1961	3,600	12	.22
1962	6,600	23	.37
1963	1,900	6	.31
1964	1,600	5	.18
1965	3,500	12	.19
1966	3,200	11	.27
1967	6,400	22	.42
1968	3,500	12	.17
1969	5,300	18	.15

TABLE 9. Harvest and Size of Individual Year Classes of Walleyes in Escanaba Lake 1951–1967

Year Class	Estimated Number Present		Utilization by Anglers			
			Age II–Age III (1 year)		Age III–Age VII (4 years)	
	At Age II (Minimum)*	At Age III	Harvest	Fraction of Age II Estimate*	Harvest	Fraction of Age III Estimate
1951	5,100	2,800	2,300	.45	2,490	.89
1952	2,000	1,400	643	.32	1,164	.83
1953	2,000	900	1,065	.53	702	.78
1954						
Native	1,700	1,000	728	.43	500	.50
Stocked	5,300	3,200	2,148	.40	2,599	-
1955	4,100	2,800	1,327	.32	1,686	.60
1956	100	100	18	.18	96	-
1957	200	200	36	.18	126	-
1958	1,200	600	564	.47	326	.53
1959	6,000	3,200	2,778	.46	2,332	.73
1960	-	-	39	-	-	-
1961	200	150	30	.15	-	-
1962	2,800	1,800	977	.35	1,218	.68
1963	1,800	1,300	495	.28	838	.66
1964	6,100	4,400	1,740	.28	2,895**	.64
1965	1,900	1,500	391	.21	395**	.26
1966	2,200	2,000	163	.07	329**	.26
1967	-	-	177	-	-	-

*The age II estimate is derived by adding the age II harvest to the age III estimate. This is a minimum, since there is no allowance for natural mortality. The estimate of the fraction harvested at this age is correspondingly high.

**Less than 4 years.

NORTHERN PIKE

During the first 11 years of creel census, only 11 northern pike were taken by anglers (Table 10). No evidence of reproduction was found until 1957 when anglers caught a combination of 71 fingerlings and yearlings out of a total harvest of 72 northern pike that year. Sufficient fish were netted in 1958 to make the first population estimate. Since that time, the northern pike spring standing crop available to the angler ranged from less than 1 to 7 fish per acre or less than 1 to 9 lb/acre, making up only 2 to 9% by weight of the total spring standing crop of sport fish available to the angler (Table 4).

Since 1946, 4,233 northern pike weighing 7,327 lb were caught by anglers (Table 2). Northern pike comprised 1.1% of the total number of fish and 5.3% of the total weight harvested. After establishment of this species in the lake and with no restrictive regulations (1958-63), the annual harvest ranged from 152 to 935 fish or 3 fish or less per acre. Northern pike never comprised more than 3% of the total fish harvested annually from 1958 to 1963 (Table 5); however, they accounted for as high as 15% of the annual harvest by weight (Table 6). Annually the harvest of northern pike varied from 2 to 6 lb/acre, 1958-63.

In 1964, a size limit of 22 inches was placed on northern pike. The annual harvest from 1964 through 1969 varied from 31 to 239 fish and 83 to 615 lb and comprised 1 to 14% of the total annual harvest during that period. They accounted for 3 to 34% of the total weight harvested annually during the 6-year period. With no size limit, the average total length of northern pike caught by anglers was 19.0 inches. With a 22-inch size limit, the average size was 23.3 inches. During the period in which the size limit was in effect (1964-69), the average annual catch declined 85% numerically and 70% in weight.

The age II and older northern pike population with no restrictive regulations in effect ranged from 250 to 2,000 fish. Since the 22-inch size limit went into effect (1964), the exploitable population ranged from 40 to 300 fish. The annual rate of exploitation by anglers varied from .27 to .64 with no restrictive regulations in effect and from .31 to .56 with a 22-inch size limit imposed on the population. The average annual rate of exploitation was .46 of all fish available to the angler and did not change after the size limit went into effect.

TABLE 10. Harvest, Estimated Population and Exploitation Rate of Northern Pike in Escanaba Lake, 1946–1969

	Harvest					Estimated Population				
Year	Number	Pounds	Avg. Total Length	No./ Acre	Lb / Acre	Number	Pounds	No./ Acre	Lb / Acre	Rate of Exploitation
1946	3	7	-	*	*					
1947	-	-	-	-	-					
1948	1	4	-	*	*					
1949	2	10	-	*	*					
1950	1	4	-	*	*					
1951	2	4	-	*	*					
1952	-	-	-	-	-					
1953	-	-	-	-	-					
1954	1	2	-	*	*					
1955	1	3	-	*	*					
1956	-	-	-	-	-					
1957	72	108	18.3	*	*					
1958	935	928	16.0	3	3	2,000	2,000	7	7	.50
1959	882	1,680	19.8	3	6	1,350	2,600	5	9	.64
1960	152	446	22.8	1	2	550	1,600	2	5	.27
1961	294	582	19.3	1	2	250	500	1	2	.44
1962	691	1,219	19.6	2	4	1,200	2,100	4	7	.49
1963	638	834	17.5	2	3	700	900	2	3	.45
1964	** 64	197	23.4	*	1	** 80	250	*	1	.40
1965	73	202	23.3	*	1	70	200	*	1	.53
1966	70	194	23.5	*	1	140	400	*	1	.56
1967	31	83	23.1	*	*	40	100	*	*	.42
1968	81	205	22.9	*	1	200	500	1	2	.31
1969	239	615	23.4	1	2	300	800	1	3	.53

*Less than 1.

**22-inch size limit became effective, estimated population of fish 22 inches and larger only.

MUSKELLUNGE

The muskellunge is thought to be native to Escanaba Lake; however, 309,000 muskellunge fry were stocked in the 5 years between 1937 and 1941. Experimental plants of marked yearlings and/or fingerlings were made in 1961, 1965, and 1966 to study survival and yield to the angler. Muskellunge populations from 1956 through 1969 never exceeded 2% of the spring standing crop of sport fishes available to the angler (Table 3). The muskellunge population remained more stable throughout the study period than those of the other fish species.

During the period, 1946-69, with no size limit in effect, anglers harvested 550 muskellunge that weighed 2,604 lb (Table 2). Muskellunge comprised 0.1% of the total catch and 1.9% of the total weight harvested by anglers. From 1954 through 1969, the average annual size varied from 21.5 to 29.2 inches (Table 11) and during this period, 27% of those caught were 30 inches (minimum size limit on other state inland waters) or larger.

With no size limit, the stocking of yearling muskellunge in 1961 resulted in an increased harvest in 1962 and 1963. After stocking, 1961 through 1969, 22.1% of the 299 muskellunge caught by anglers were stocked fish from the 1961 yearling and fingerling plant. From the 1961 stocking of 197 yearlings, anglers caught 55 (27.9%) through 1969. The same year, 291 fingerlings were stocked and through 1969, only 11 (3.8%) were caught by anglers. None of the 301 fingerlings stocked in 1965 or the 155 yearlings stocked in 1966 were caught by anglers through 1969.

An attempt has been made to estimate the muskellunge population each year since 1954; however, because of the small number of fish involved, these are only rough approximations. Nevertheless, the general consistency of the estimates indicate that they are of the correct order of magnitude. Estimates have ranged from 10 to 60 before yearlings and fingerlings were stocked (1954-61) to 50 to 170 after stocking. The exploitation rate has ranged from .12 to .50 before stocking and .13 to .54 after stocking.

SMALLMOUTH BASS

Prior to the establishment of the walleye population, Escanaba Lake was highly regarded for its smallmouth bass fishing. Since 1956, when population estimates were first attempted, smallmouth bass have never been sufficiently numerous in the lake to allow population estimates. During 1965-69, only 5 smallmouth bass were caught by anglers and presently only a remnant population remains (Table 12).

During the 24 years of creel census, 4,397 smallmouth were caught weighing 2,189 lb (Table 2). From 1946 to 1955, smallmouth bass comprised 1 to 8% of the total annual catch and since 1956 less than 1% of the total annual catch (Table 5). In the early years, smallmouth bass accounted for 1 to 11% of the annual total weight harvested by anglers, but in recent years it has amounted to less than 1% (Table 6).

LARGEMOUTH BASS

The only index of largemouth bass abundance is the anglers' harvest, since largemouth bass were never numerous enough in the lake to allow a population estimate. At present, only a remnant population exists; only 2 largemouth bass were caught during the 1967-69 angling years.

From 1946 through 1969, anglers caught 2,271 largemouth bass weighing 2,611 lb (Table 2). This species never provided more than 2% of the total annual catch (Table 5) and never more than 6% of the total annual weight harvested (Table 6). The annual harvest reached a maximum in 1957 when 283 largemouth bass were caught that averaged 10.9 inches (Table 12).

TABLE 11. Harvest, Estimated Population and Rate of Exploitation of Muskellunge in Escanaba Lake, 1946–1969

	Harvest					Estimated Population				
Year	Number	Pounds	Lb / Acre	Percent Over 30 Inches	Percent Stocked	Avg. Total Length	Number	Pounds	Lb / Acre	Rate of Exploitation
1946	14	91	*							
1947	7	68	*							
1948	5	38	*							
1949	11	74	*							
1950	34	257	1							
1951	21	85	*							
1952	52	200	1							
1953	20	133	*							
1954	14	117	*	43		29.1	30	250	1	.25
1955	9	32	*	22		27.3	-	-	-	-
1956	6	30	*	33		26.0	10	50	*	.50
1957	13	78	*	38		26.7	20	120	*	.33
1958	16	80	*	31		24.8	60	300	1	.12
1959	11	45	*	18		25.0	20	60	*	.20
1960	18	90	*	28		26.4	50	250	1	.37
1961	24	86	*	21	17	21.5	30	110	*	.18
1962	74	207	1	12	18	22.3	120	340	1	.54
1963	57	173	1	11	35	23.0	170	520	2	.33
1964	22	131	*	36	25	28.7	150	890	3	.15
1965	23	112	*	35	26	25.6	140	680	2	.15
1966	22	153	*	50	27	29.2	130	900	3	.13
1967	21	105	*	33	14	25.3	50	250	1	.29
1968	24	76	*	8	8	23.7	110	350	1	.18
1969	32	143	1	23	19	25.9	100	450	2	.30

*Less than 1.

TABLE 12. Total Harvest of Bass From Escanaba Lake, 1946–1969

	Smallmouth					Largemouth				
Year	Number	Pounds	No./ Acre	Lb / Acre	Avg. Total Length	Number	Pounds	No./ Acre	Lb / Acre	Avg. Total Length
1946	635	324	2	1		167	218	1	1	
1947	421	278	1	1		52	85	*	*	
1948	385	264	1	1		53	65	*	*	
1949	540	185	2	1		62	183	*	1	
1950	191	116	1	*		49	121	*	*	
1951	57	61	*	*		21	46	*	*	
1952	156	113	1	*		90	118	*	*	
1953	636	225	2	1		47	61	*	*	
1954	447	207	2	1		68	64	*	*	
1955	329	164	1	1	9.9	146	106	1	*	10.5
1956	125	36	*	*	7.7	161	133	1	*	11.0
1957	90	41	*	*	9.1	283	227	1	1	10.9
1958	54	30	*	*	9.8	203	182	1	1	11.8
1959	130	49	*	*	8.8	101	111	*	*	12.3
1960	86	40	*	*	9.1	103	132	*	*	12.9
1961	66	30	*	*	9.0	72	113	*	*	13.6
1962	27	10	*	*	8.3	176	152	1	1	10.4
1963	10	6	*	*	10.3	172	152	1	1	10.8
1964	7	3	*	*	8.8	137	160	1	1	12.2
1965	3	4	*	*	13.6	81	137	*	1	13.8
1966	-	-	-	-	-	25	39	*	*	14.4
1967	-	-	-	-	-	1	2	*	*	14.5
1968	1	1	*	*	11.0	1	4	*	*	17.9
1969	1	2	*	*	15.8	-	-	-	-	-

*Less than 1.

YELLOW PERCH

Before the project began in 1946, yellow perch were present in sufficient numbers to attract anglers, especially during the ice fishing season. From 1956 through 1969, the yellow perch accounted numerically for 34 to 72% of the spring standing crop of sport fishes available to the angler except in 1967 and 1968 when they were not numerous enough to permit estimation of population size (Table 3). The perch population has shown more extreme fluctuations in numbers than any other fish population in the lake.

During the 1946-69 period, anglers caught 138,962 perch weighing 36,914 lb (Table 2). They ranked first in number of fish caught, comprising 36.4% of the total. The average annual catch was 5,790 fish with annual harvest varying from 126 to 15,738 (Table 13). Perch ranked second in weight harvested, comprising 26.6% of the total weight harvested. The first 4 years of the project (1946-49), perch comprised 88, 87, 64, and 69% respectively of the total annual catch (Table 5).

Since 1956, the population of yellow perch 6.0 inches and larger ranged from 68,000 to a population too few to estimate. The rate of exploitation ranged from .02 to .34.

PUMPKINSEED

The history of the pumpkinseed has been as erratic as that of the yellow perch. They were harvested in negligible numbers every year until 1955 when the harvest rose abruptly from 376 in 1954 to 8,109 in 1955. The population reached a maximum in 1959 and then declined to virtually nothing from 1966 through 1969 (Table 14). From 1956 through 1965, pumpkinseed comprised 14 to 52% of the spring standing crop of sport fishes available to the angler and after 1965, the population of pumpkinseed was unmeasurable (Table 3).

The total harvest during the 24 years of creel census was 138,338 fish weighing 24,559 lb (Table 2). Pumpkinseed ranked second in number of fish caught, comprising 36.3% of the total catch and ranked third in total poundage, comprising 17.8% of the total.

The pumpkinseed population based on fish 4.5 inches and larger was estimated to range from 52,000 in 1959 to a population too few to estimate in 1966 through 1969. The rate of exploitation varied from .13 to .41.

ROCK BASS

Like the pumpkinseed, rock bass populations fluctuated extremely. Annual harvest from 1946 through 1952 never exceeded 1 fish per acre, indicating small population size. Although rock bass made up 5% or less of the spring standing crop of sport fishes available to the angler, from 1956 through 1963, their numbers had increased sufficiently to make a population estimate. From 1964 through 1969, the population declined so that a population estimate could not be made in those years.

During the 24 years of creel census, 13,171 rock bass weighing 3,652 lb were caught by anglers. They represented 3.4% of the total numbers of fish taken during this period (Table 2). The greatest annual harvest was 7 per acre, taken in 1957.

The estimated population based on fish 4.0 inches and larger varied annually from 1,000 to 5,600 from 1956 through 1963 (Table 15). During this period, the rate of exploitation ranged from .05 to .44.

TABLE 13. Harvest, Estimated Population and Rate of Exploitation of Yellow Perch in Escanaba Lake, 1946–1969

	Total Harvest				Estimated Population (6 inches +)				Rate of
Year	Number	Pounds	No./ Acre	Lb / Acre	Number	Pounds	No./ Acre	Lb / Acre	Exploitation
1946	8,803	2,592	30	9					
1947	6,121	1,958	21	7					
1948	9,026	3,121	31	11					
1949	7,028	2,097	24	7					
1950	1,210	409	4	1					
1951	843	349	3	1					
1952	393	190	1	1					
1953	728	340	2	1					
1954	2,072	488	7	2					
1955	9,006	2,256	31	8					
1956	10,251	2,613	35	9	54,000	13,800	184	47	.18
1957	14,612	3,697	50	13	56,000	14,200	191	48	.21
1958	15,738	4,577	54	16	66,000	19,200	225	66	.25
1959	7,293	2,371	25	8	34,000	11,000	116	38	.19
1960	12,225	2,780	42	10	35,000	8,000	120	27	.34
1961	7,699	1,705	26	6	54,000	12,100	184	41	.07
1962	11,935	2,449	41	9	68,000	14,300	232	49	.18
1963	8,182	1,549	28	5	37,000	7,300	126	25	.13
1964	3,926	859	13	3	29,000	6,400	99	22	.10
1965	981	268	3	1	11,000	3,000	38	10	.07
1966	286	97	1	*	6,000	2,000	20	7	.05
1967	126	27	*	*	**				
1968	170	31	*	*	**				
1969	308	91	1	*	18,000	5,400	63	18	.02

*Less than 1 fish or 0.1 lb.
**Too few to estimate.

TABLE 14. Harvest, Estimated Population and Rate of Exploitation of Pumpkinseed in Escanaba Lake, 1946–1969

	Total Harvest				Estimated Population (4.5 inches+)				Rate of
Year	Number	Pounds	No./ Acre	Lb / Acre	Number	Pounds	No./ Acre	Lb / Acre	Exploi-tation
1946	81	28	*	*					
1947	46	15	*	*					
1948	18	4	*	*					
1949	95	32	*	*					
1950	121	26	*	*					
1951	159	32	*	*					
1952	302	99	1	*					
1953	273	91	1	*					
1954	376	134	1	*					
1955	8,109	1,560	28	5					
1956	10,199	1,928	35	7	17,000	3,200	58	11	.27
1957	12,131	1,985	41	7	24,000	4,000	82	14	.26
1958	21,740	3,677	74	13	19,000	3,200	65	11	.41
1959	25,792	4,253	88	15	52,000	8,600	177	29	.32
1960	19,164	3,340	65	11	26,000	4,500	89	15	.35
1961	10,958	1,897	37	6	47,000	8,200	160	28	.15
1962	9,189	1,698	31	6	44,000	8,200	150	28	.13
1963	11,170	2,075	38	7	22,000	4,100	75	14	.33
1964	5,839	1,108	20	4	9,000	1,700	31	6	.35
1965	2,463	544	8	2	3,100	700	11	2	.32
1966	38	13	*	*	**				
1967	1	*	*	*	**				
1968	32	7	*	*	**				
1969	42	13	*	*	**				

*Less than 1.
**Too few to estimate.

TABLE 15. Harvest, Estimated Population and Rate of Exploitation of Rock Bass in Escanaba Lake, 1946–1969

	Total Harvest				Estimated Population (4 inches+)				Rate of
Year	Number	Pounds	No./ Acre	Lb / Acre	Number	Pounds	No./ Acre	Lb / Acre	Exploi-tation
1946	240	82	1	*					
1947	306	122	1	*					
1948	224	70	1	*					
1949	235	67	1	*					
1950	380	108	1	*					
1951	343	109	1	*					
1952	366	121	1	*					
1953	1,563	406	5	1					
1954	986	343	3	1					
1955	1,191	418	4	1					
1956	1,844	477	6	2	4,900	1,300	17	4	.33
1957	1,914	409	7	1	3,700	800	13	3	.33
1958	668	166	2	1	3,300	800	11	3	.17
1959	597	177	2	1	3,900	1,200	13	4	.16
1960	700	184	2	1	1,000	300	3	1	.44
1961	493	114	2	*	2,400	600	8	2	.08
1962	736	172	3	1	5,600	1,300	19	4	.10
1963	211	55	1	*	1,800	500	6	2	.05
1964	76	22	*	*	**				
1965	68	20	*	*	**				
1966	3	1	*	*	**				
1967	5	2	*	*	**				
1968	5	2	*	*	**				
1969	17	5	*	*	**				

*Less than 1.
**Too few to estimate.

BLUEGILL

From 1956 through 1969, bluegills, made up 3% or less of the available spring standing crop of sport fishes (Table 3). The bluegill population never did attain the population size of pumpkinseed; however, like other centrachid species, the bluegill population declined sharply during the period from 1963 to 1966.

Anglers harvested 8,992 bluegills weighing 1,845 lb from 1946 through 1969 which represents only 2.4% of the total number of fish caught (Table 2). The annual harvest from 1946 through 1952 ranged from 7 to 95 fish, followed by an annual harvest of 144 to 1,876 fish from 1953 through 1965 (Table 16). From 1966 through 1969, only 16 bluegills were caught.

The bluegill population estimate for fish 4.0 inches and larger from 1956 through 1965 varied from 300 to 2,400. After 1966, the population was too small to estimate. The rate of exploitation varied from .30 to .64.

BLACK CRAPPIE

The black crappie never exceeded 6% of the spring standing crop of sport fishes available to the angler from 1956 through 1969 (Table 3). During the same period in which the other centrarchid populations declined, it also decreased and remained low.

During the 24-year creel census period, 7,482 black crappies weighing 5,339 lb were caught by anglers. This represents 2.0% of the total number caught and 3.9% of the total weight harvested (Table 2). From 1946 through 1955, the annual harvest ranged from 5 to 63 fish (Table 17). In 1956, the harvest began to increase, so that by 1958, anglers caught 1,782 fish. The harvest then began to decline, so that during 1967-69, only 15 black crappies were caught.

The estimated population for fish 6.0 inches and larger from 1956 through 1965 ranged from 900 to 5,300. No estimate could be made from 1966 to 1969 because of a sharp decline in numbers. The rate of exploitation during the 1956-65 period varied from .09 to .50.

OTHER SPECIES

No quantitative studies were attempted on nongame species during the course of the project. It was observed from net catches, however, that white suckers were very numerous from 1958 through 1962 when the panfish populations were abundant. The white sucker population, even though it was not exploited, declined just prior to the panfish population decline and remained low.

TABLE 16. Harvest, Estimated Population and Rate of Exploitation of Bluegills in Escanaba Lake, 1946–1969

	Total Harvest				Estimated Population (4 inches+)				Rate of
Year	Number	Pounds	No./ Acre	Lb / Acre	Number	Pounds	No./ Acre	Lb / Acre	Exploitation
1946	26	10	*	*					
1947	31	9	*	*					
1948	7	3	*	*					
1949	40	14	*	*					
1950	33	6	*	*					
1951	95	30	*	*					
1952	71	23	*	*					
1953	224	78	1	*					
1954	144	57	1	*					
1955	548	112	2	*					
1956	575	121	2	*	1,300	250	4	1	.42
1957	885	151	2	1	1,400	250	5	1	.40
1958	927	197	3	1	1,600	350	5	1	.43
1959	587	130	2	*	1,300	300	4	1	.38
1960	1,876	295	6	1	2,400	350	8	1	.34
1961	1,244	255	4	1	1,700	350	6	1	.51
1962	730	144	3	1	1,800	350	6	1	.34
1963	430	96	2	*	400	100	1	*	.64
1964	300	61	1	*	400	100	1	*	.30
1965	203	50	1	*	300	100	1	*	-
1966	1	-	*	*	**				
1967	-	-	-	-	**				
1968	9	2	*	*	**				
1969	6	1	*	*	**				

*Less than 1.
**Too few to estimate.

TABLE 17. Harvest, Estimated Population and Rate of Exploitation of Black Crappies in Escanaba Lake, 1946–1969

Year	Total Harvest				Estimated Population (6 inches+)				Rate of Exploitation
	Number	Pounds	No./ Acre	Lb / Acre	Number	Pounds	No./ Acre	Lb / Acre	
1946	9	7	*	*					
1947	27	31	*	*					
1948	16	16	*	*					
1949	12	6	*	*					
1950	18	30	*	*					
1951	13	7	*	*					
1952	5	9	*	*					
1953	10	10	*	*					
1954	8	9	*	*					
1955	63	25	*	*					
1956	645	305	2	1	3,800	1,800	13	6	.14
1957	1,172	714	4	2	4,300	2,600	15	9	.22
1958	1,782	1,075	6	4	5,300	3,200	18	11	.27
1959	1,300	1,028	4	4	2,100	1,700	7	6	.39
1960	1,220	1,034	4	4	1,400	1,200	5	4	.50
1961	265	228	1	1	1,400	1,200	5	4	.17
1962	343	331	1	1	1,600	1,500	5	5	.30
1963	394	352	1	1	900	800	3	3	.25
1964	33	19	*	*	**	-	-	-	-
1965	108	68	*	*	1,300	800	4	3	.09
1966	24	20	*	*	**				
1967	4	5	*	*	**				
1968	3	3	*	*	**				
1969	8	7	*	*	**				

*Less than 1.
**Too few to estimate.

DISCUSSION

POPULATION LEVELS

The history of the population composition in Escanaba Lake since observations began in 1946 has been one of constant change. We have no way of knowing how stable populations may have been before the beginning of the project nor do we know if an equilibrium condition will occur at some future date. We do know that since 1956, the estimated species composition of the spring standing crop of fishes available to the angler has changed. Prior to 1956, these changes were detected indirectly from variations in the recorded harvest. From 1956 on, changes were documented more precisely by comparison of spring standing crop estimates. During the 1956-63 period, the spring standing crop of fishes available to the angler varied annually from 55 to 117 lb/acre of which panfish, mainly yellow perch and pumpkinseed, comprised 61 to 72 percent. There was a steady decline in the standing crop from 114 lb/acre in 1962 to a low of 19 lb/acre in 1968, with an increase to 38 lb/acre in 1969 (Table 4 and Fig. 3). In a broader time reference, the average spring standing crop skidded from 101 lb/acre in the late 1950's to 76 lb/acre in the early 1960's and to 30 lb/acre in the late 1960's.

This change is directly traceable to the decline and virtual disappearance of panfish, since in those time periods

stated above, the only other abundant recorded species, the walleye, accounted for 20, 13, and 19 lb/acre, respectively. While the average standing crop in the late 1960's was only 30 percent of that recorded in the late 1950's, the pounds per acre of walleyes during those two periods were approximately the same. On the same period basis, the number of walleyes available to the angler in the spring also remained relatively stable, with the average number in the final period of the study approximating that in the late 1950's; i.e., 23 and 27 fish per acre, respectively. These estimates are comparable to those reported for Spirit Lake, Iowa (Rose 1949; Rose 1955); Many Point Lake, Minnesota (Olson 1958); Clear Lake, Iowa (Whitney 1958); and Oneida Lake, New York (Forney 1967) (Table 18).

The adult walleye population (age III and older) was also characterized by relative numerical stability in the face of strong fluctuations in the panfish population. The numerical standing crop of adult walleyes during the 1953-69 period averaged 15 per acre; that of the first 5-year period being 17 and that of the last, 15. Numbers of adults in 2 of the last 5 years exceeded the average and in one of those two years (1967), the record of 22 adults per acre, attained only twice previously, was tied. In 1964, the adult walleye population reached its lowest level, 5 fish per acre. It is of special note that this smallest adult population produced the largest year class on record for Escanaba Lake, 108 fall fingerlings per acre (Kempinger and Churchill 1972). Three years later, this year class comprised 69 percent of the adult walleyes then present.

The abrupt rise of the northern pike in the late 1950's paralleled that of the walleye earlier, both emanating from hitherto straggling populations. From a level too low to estimate in 1957, the spring population jumped to 7 fish per acre in 1958 and averaged 4 fish and 6 lb/acre during the 1958-63 period. During the 1964-69 period when a minimum size limit of 22 inches was being tested, the average number of northern pike per acre rose to 5 of which in any one year, no more than 1 per acre was 22 inches or over (Kempinger, unpubl.).

From 1954 to 1962, the muskellunge population never exceeded 1 lb/acre. During the next 7-year period, the population twice attained a level of 3 lb/acre, directly attributable to the 1961 stocking.

At the time this study was initiated, Escanaba Lake was known as a "good" smallmouth bass lake. We have no population data on this species, but the harvest records suggest an abundance early in the study period. These records also indicate that the population began a steady decline in the mid-1950's leading to the virtual disappearance of the species by the mid-1960's. This decline is attributed to the establishment of the walleye population, similar to that described by Eschmeyer (1950) in Gogebic Lake, Michigan.

The greatest change in species composition in this multispecies lake occurred in the panfish population. Within that group, the fluctuation of the yellow perch population was the most pronounced.

During the late 1940's, the perch harvest, roughly indicative of the population level, ranged from 7 to 11 lb/acre. This catch approximated that of 1956, when the population was estimated at 47 lb/acre. The catch dropped to about 1 lb/acre in each year of the period, 1950-53. The perch fishery of the late 1940's was supported primarily by the 1944 and 1945 year classes (Threinen 1951) and their disappearance in 1950 was marked by the sharp drop in the catch. The 1950-53 low was followed by a rise in catch to 2 and 8 lb/acre in 1954 and 1955, respectively, and to 9 lb/acre in 1956—in that year the population was estimated to be 47 lb/acre. The population rise continued in 1957 and peaked in 1958 at 66 lb/acre, from which point the second decline began. By 1967 and again in 1968, the perch population level was too low to estimate. A resurgence, to 18 lb/acre, was recorded in 1969.

The initial increase of the perch population in the mid-1950's was no doubt composed of one or more year classes which originated during the 1950-53 period. At that time, the perch population was low and the angling pressure was high—at 96 hours per acre (range of 74 to 121), well above the average of 65 for the entire study period; i.e., the population rose in spite of the high angling pressure. Further, in the three years preceding the 1967 crash of the perch population, angling pressure averaged only 43 hours per acre, approximating that preceding the first decline in the perch population in the early 1950's; i.e., the population declined in the face of low angling pressure. The one apparent and two demonstrated population highs interspersed by two lows in the perch population clearly support the earlier conclusion of Threinen (1951) that the "no bag limit" regulation did not jeopardize the perch population in Escanaba Lake.

The harvest record of the pumpkinseed indicated a low population level from 1946 to 1954, with a sharp rise in 1955. The increase continued through the late 1950's and peaked in 1959 at an estimated 29 lb/acre. From that same approximate level in 1962, the population level fell off sharply to 2 lb/acre in 1965 followed by four years during which numbers were too low to permit estimation. Unlike the upswing demonstrated by the perch population, as of 1969 there was no indication of recovery of the pumpkinseed population.

The population levels of the three other panfish species of record—rock bass, bluegill, and black crappie—followed the same general pattern. Harvest records and population estimates indicate a low level through the early 1950's, followed by a rise in the mid- and late 1950's to a peak in the late 1950's or early 1960's. This was followed by a decline in numbers of each species in the early and mid-1960's to levels which, by 1966, were too low to permit estimation. Although at lower population levels, the history of these three species closely parallels that of the major centrarchid panfish species, the pumpkinseed. That common thread provides grounds for speculation on the rise and fall of the centrarchids collectively, but lack of adequate concurrent measurements, especially of environmental characteristics, precludes such analysis.

While the virtual disappearance of panfish in the mid-1960's cannot be fully explained, the increasing predator population in the late 1950's and early 1960's warrants consideration as a possible factor.

Strong yellow perch year classes of 1944 and 1945 supported the Escanaba Lake perch fishing through 1950 (Threinen 1951) but due to year class failures in the late 1940's, perch virtually disappeared from the catch during the 1951-53 period. Strong walleye year classes occurred during 1946, 1947, and 1949 (Patterson 1953) and the conclusion that the resulting surge of the walleye population during that period was primarily responsible for suppressing any oncoming perch year

classes is inescapable, especially in view of the fact that no other panfish species were then present in any appreciable numbers. Patterson (1953) reported the walleye population as of May 1951 to be 8,000-11,000 fish of spawning size; our data indicate an adult walleye population of 6,500 in the spring of 1953. If in fact the walleye population was previously able to suppress oncoming perch year classes, the post-1951 population apparently could not, since the perch reappeared in the 1955 catch in appreciable numbers. Their reappearance may have been aided by the apparent simultaneous increase of the pumpkinseed during the early 1950's as indicated by later catch records (Table 5), thus expanding the prey species base.

As indicated earlier, the perch and the pumpkinseed population continued to rise, peaking in 1958 and 1959, respectively, at which time both began a gradual decline, culminating in virtual disappearance in the mid-1960's. During this period, the walleye population was holding relatively steady and seemingly could not alone have been responsible for the panfish decline. However, the appearance of the northern pike in 1957, adding appreciably to the predator component of the total fish population, cannot be ignored as a possible contributing factor.

Johnson (1949) suggested that the northern pike could achieve dominance or control of fish populations when its weight comprises 25 to 30 percent of the total fish weight present. In contrast, the walleye would have to constitute 45 to 50 percent of all fish weight present to achieve dominance; i.e., the northern pike had essentially a predator rating twice that of the walleye.

In both 1956 and 1957, the walleye in Escanaba Lake accounted for 22 percent of the total measurable fish weight. By attributing a predator rating to the northern pike double that of the walleye, the combined walleye predator equivalency in terms of percent total weight would have been 27, 34, and 36 percent in 1958, 1959, and 1960, respectively, with a period average of 32 percent. The average on that same basis for the 1958-62 period would have been 30 percent. The increasing weight of the muskellunge in 1961 and 1962 would have been an additive factor. While this does not equal the level stated by Johnson (1949), it does constitute a 45 to 55 percent increase in the percentage of the predator component which conceivably could have been sufficient to suppress oncoming year classes of panfish during that period. There would have been, of course, a time lag in the effect on the catch; i.e., the effect of missing or reduced year classes from the late 1950's and early 1960's would have been most noticeable during the early and mid-1960's. We suggest that Ricker's (1952) type A predation was operating in that the predators of any given abundance take a fixed number of prey, enough to satiate them, and the surplus escapes. As the level of predator abundance rises, so does the amount of prey consumed. As stated by Ricker (1952), "If a type A situation persisted for long, it would come to an abrupt end with the extermination of the prey." While extermination did not occur in Escanaba Lake, the prey species were reduced to immeasurable levels.

Fishing for panfish is preferred by most Wisconsin anglers. When the yellow perch, along with other panfish species, declined in Escanaba Lake, so did the fishing pressure.

FISHING PRESSURE

Even with no closed season on any species, annual fishing pressure on Escanaba Lake never exceeded 122 hours per acre and averaged only 65 (Table 1). By contrast La Faunce, Kimsey, and Chadwick (1964) reported pressure up to 460 hours per acre in limited seasons on Sutherland Reservoir, California. More comparable are figures for 12 Michigan lakes (Christensen 1953) and 12 Minnesota lakes (Moyle and Franklin

Muskellunge comprised 0.1% of the total number of fish caught and 2% of the total weight harvested during the 24-year study.

1955) where annual fishing pressure averaged 120 and 33 hours per acre, respectively. Churchill and Snow (1964) concluded that the location of Escanaba Lake, over 200 miles from any large center of population, was an important factor in limiting the fishing pressure. However, factors other than distance influenced the fishing pressure at Escanaba Lake since the range was 21 to 121 hours per acre and a general decline in pressure during the study period is evident. From an average high of 89 hours per acre in the early 1950's, pressure fell to 83 in the late 1950's, to 66 in the early 1960's, and to 41 hours per acre in the late 1960's.

An analysis of angler motivation was not part of the study design and any comment on factors bearing on the decline of fishing pressure must here remain largely speculative. However, the heavy fishing pressure during the early years was very probably due to the quality fishing offered by the new burgeoning walleye population and perhaps, in part, to the novelty of the situation where size, seasons or bag limits were not in effect. That fishing pressure continued relatively high in the late 1950's is probably a reflection of the average fishing success during this period, the highest during the study period in terms of both numbers (1.40 fish per hour) and weight (0.41 pounds per hour), due primarily to the high population level of panfish. The appearance of the northern pike during this period also offered added interest.

The sharp decline in fishing pressure during the early 1960's is mirrored by the decline of the panfish during this period which, as indicated above, led to their virtual disappearance in the late 1960's. Since panfish have been shown to lead the fish species preference list of Wisconsin anglers by a large margin (DNR mimeographed survey report, April 26, 1965), it follows that absence of these species in Escanaba Lake would tend to reduce angling pressure.

HARVEST

Fishing success during the 1946-69 period varied from 0.14 to 1.72 fish per hour and averaged 0.84. Annual yields ranged from 5 to 41 and averaged 20 lb/acre. Comparable data reported from other midwestern lakes by Bennett (1954), Hansen (1966), Christensen (1953), Patriarche (1960), Olson (1958), and Moyle and Franklin (1955) suggest that Escanaba Lake is intermediate among these with respect to fish caught per hour and high in regard to average annual harvest of pounds per acre (Table 19). However, Churchill (1957) pointed out that over half of the game fish taken in Escanaba Lake during the first ten years of this study would have been illegal under the regulations then in force elsewhere in the state.

The most remarkable feature of the Escanaba Lake harvest has been the continuous change in the proportion of species harvested. The lake contains all of the warm water species common in that part of the state, but their relative numbers and importance in the harvest have varied to such a degree as to completely change the appearance of the harvest from time to time (Fig. 4). The fishery has been dominated in turn by yellow perch, walleye, and pumpkinseed. Prior to the walleye, the smallmouth bass was the dominant game fish species. Some of the changes were due to the establishment of new species, walleye and northern pike. Others resulted from changes in the proportion of already established species. All changes occurred progressively over a period of several years, and included a nongame fish species, white suckers, which were not utilized by anglers.

Northern pike, muskellunge, smallmouth bass, largemouth bass, rock bass, bluegill, and black crappie comprised only 18 percent of the total weight harvested. The history of the harvest is illustrated in Figures 4 and 5. Analysis of these annual harvest changes shows that muskellunge and northern pike remained most constant of all species. The smallmouth bass harvest indicates only a remnant population while the harvest of the walleye, largemouth bass, rock bass, bluegill and black crappie varied. The yellow perch and pumpkinseed harvest fluctuated the most drastically.

Part of the annual fluctuation in the harvest is of course due to variation in the fishing pressure. When the harvest is expressed as pound per unit of effort, the remaining variation is much less and suggests a cyclical, rather than random, change in fishing conditions. When a single separation is made between larger predators and panfishes, it is clear that most of the fluctuation in fishing success was related to the availability of the latter. Harvest of predators per unit effort varied relatively little over the 24-year period (Table 20, Fig. 6).

The species composition of the harvest shows enough agreement with that of the standing crop for the same year to confirm our assumption that the harvest is a reasonably good index of the population levels (Fig. 7). This parallel between the species composition of the harvest and that of the population is only approximate because different species are harvested at different rates.

The exploitation rate for each species varied greatly from year to year, but the mean which was established over a number of years is characteristic for each species (Table 21). Annual rate of exploitation of the walleye population in Escanaba Lake has varied from .13 to .42. Other investigations (Table 18) have estimated exploitation rates for walleye from .10 to .47. Olson (1958) with a nearly complete creel census, reported returns of .21 to .33 from Many Point Lake, Minnesota. Mraz (1968) reported voluntary returns of .19 to .24 in Pike Lake, Washington County in southeastern Wisconsin. Forney (1967), from independently conducted creel census and population estimates, calculated the rate of return at .10 to .47 in Oneida Lake, New York.

Northern pike (.46) and bluegill (.42) were the most heavily exploited of the Escanaba Lake species but both accounted for only a minor fraction of the total catch; neither species ever comprised more than 9 percent of the total annual standing crop of fish. Yellow perch was the most lightly

TABLE 18. Harvest, Population Estimates and Rate of Exploitation Data for Walleye Lakes in the United States

Lake	Size (Acres)	Years	Harvest			Population Estimate (No./Acre)	Minimum Age or Length	Rate of Exploitation	
			Catch/ Hour	No./ Acre	Lb / Acre			Range	Avg.
Spirit, Iowa	5,684								
(Rose, 1949)		1947		1.7		5	13 inches		.29
(Rose, 1955)		1954		1.1		8	12 inches		
Many Point, Minnesota (Olson, 1958)	1,716	1955–1957	0.11–0.16	2.0–2.9	2.5–3.7	7–11	III	.21–.33	.27
Clear, Iowa (Whitney, 1958)	3,643	1953				9	12 inches		
Oneida, New York (Forney, 1967)	51,000	1957–1963	0.10–0.71	0.8–9.1		5–20	IV	.10–.47*	.24
Pike, Wisconsin (Mraz, 1968)	522	1959–1960					10 inches	.19–.24	.22
Present Study	293	1946–1969	0.04–0.34	3–20	3–23	5–22	III	.13–.42	.29

*Exploitation only for 3 years, 1957–1959.

TABLE 19. Fishing Pressure, Yield and Fishing Success on Lakes in Midwestern United States

Investigator	Years of Observation	Lake and State	Acres	Hours/ Acre	Fish/ Hour	Pounds/ Acre
Present Study	1946–1969	Escanaba, Wis.	293	65	0.84	20
Wis. Department of Natural Resources*	1967	10 Lakes, Racine County, Wis.	3,529	93	0.87	
Bennett (1954)	1942–1950	Ridge Lake, Ill.	18	187	0.48	30
Hansen (1966)	1943–1950	Glendale Lake, Ill.	82	61	.62	10
Christensen (1953)	1946–1950	12 Lakes, Mich.	4,506	120	1.25	
Patriarche (1960)	1946–1956	4 Lakes, Ogemaw County, Mich.	255	23	.75	4.4
Moyle & Franklin (1955)	1952–1954	12 Lakes, Minn.	15,136	33	.83	16
Olson (1958)	1955–1957	Many Point Lake, Minn.	1,716	17	.54	7.5

*Data from a survey of the Fox River Watershed in cooperation with the Southeastern Wisconsin Regional Planning Commission.

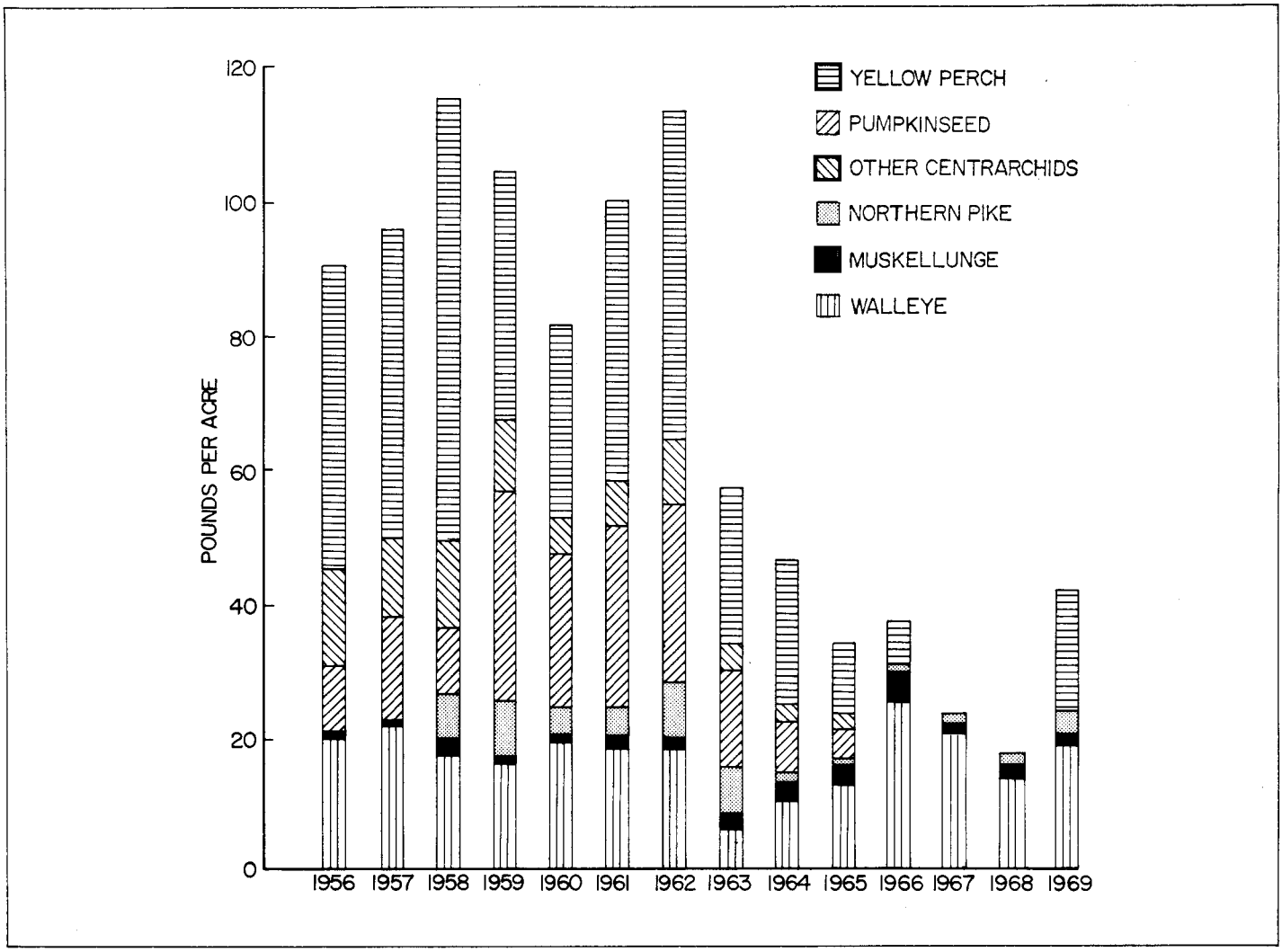


FIGURE 3

The estimated populations of sport fishes available to the angler in Escanaba Lake, 1956-69 (bass omitted).

TABLE 20. Anglers' Catch (Pounds) per 100 Hours Fishing in Escanaba Lake

Year	Predator Fishes	Panfishes	Total
1946	6.9	29.0	35.9
1947	7.8	33.9	41.7
1948	20.0	25.5	45.5
1949	14.5	11.5	26.0
1950	20.1	1.6	21.7
1951	13.4	2.4	15.8
1952	18.0	1.7	19.7
1953	14.4	3.2	17.6
1954	11.7	5.8	17.5
1955	15.6	18.7	34.3
1956	12.5	22.3	34.8
1957	11.3	27.3	38.6
1958	8.8	36.8	45.6
1959	13.2	36.2	49.4
1960	12.6	34.4	47.0
1961	15.4	22.6	38.0
1962	17.6	21.1	38.7
1963	11.8	19.8	31.6
1964	14.0	16.3	30.3
1965	14.7	8.8	23.5
1966	19.5	0.9	20.4
1967	19.5	0.2	19.7
1968	13.5	0.9	14.4
1969	15.7	0.2	15.9

(.15) exploited species. As a result of these high and low exploitation rates, the northern pike and bluegill made up a larger part of the harvest than they did of the estimated population, while the yellow perch was just the opposite.

The reason for these specific differences appears to relate to their food habits and general behavior. The walleye, for instance, is considered by most anglers to be a more desirable fish than the northern pike; however, the northern pike was more heavily exploited when both were present. Similarly, the yellow perch and pumpkinseed were abundant in the same years and were taken with the same gear and bait. But the proportion of the pumpkinseed population harvested by anglers was twice that of the yellow perch. The more pelagic habits of the walleye and yellow perch may reduce their vulnerability to fishing, but this would not explain the difference between exploitation rates of bluegills (.42) and pumpkinseed (.29), both of which inhabit the littoral area.

Annual variation of the rate of exploitation of a species is much greater than can be accounted for by sampling error. The vulnerability of a species to fishing is apparently influenced by environmental factors in the lake that have not yet been identified. The rate of exploitation, of course, cannot be entirely independent of fishing pressure, but in most cases this effect is not evident. A significant correlation between fishing pressure and rate of exploitation can be demonstrated only in the case of yellow perch ($r = .80$, 10 df) and juvenile (age II) walleye ($r = .73$, 11 df). Similarly, no relation is apparent between rate of exploitation and abundance, or between the exploitation rates of different species.

The most probable cause of var-

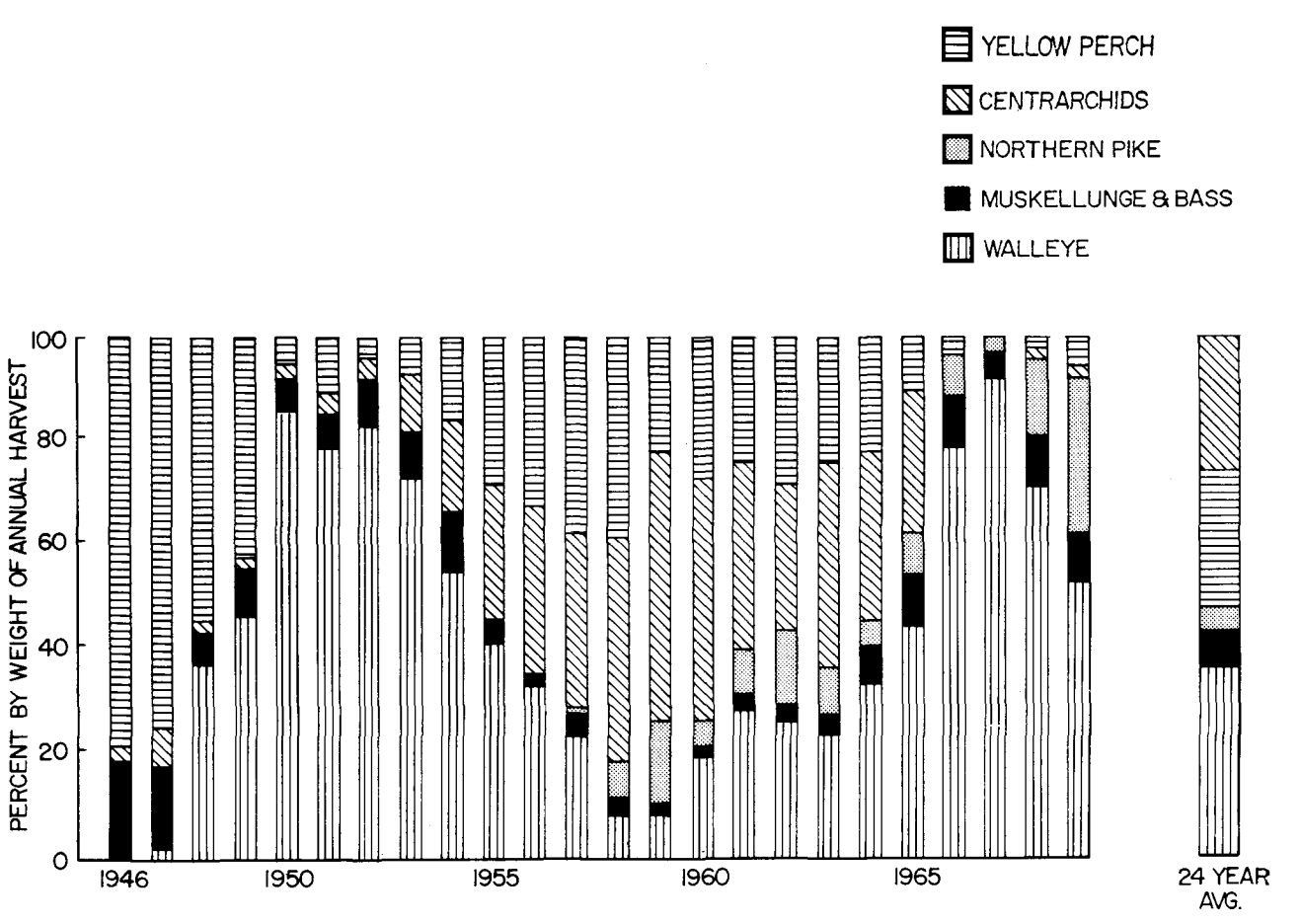


FIGURE 4

Species composition of the annual harvest from Escanaba Lake, 1946-69.

TABLE 21. Annual Rate of Exploitation of Fishes in Escanaba Lake*

Year	Walleye	Northern Pike	Muskellunge	Yellow Perch	Pumpkinseed	Rock Bass	Bluegill	Black Crappie
1953	.35							
1954	.32		.25					
1955	.40							
1956	.42		.50	.18	.27	.33	.42	.14
1957	.37		.33	.21	.26	.33	.40	.22
1958	.22	.50	.12	.25	.41	.17	.43	.27
1959	.13	.64	.20	.19	.32	.16	.38	.39
1960	.31	.27	.37	.34	.35	.44	.34	.50
1961	.22	.44	.18	.07	.15	.08	.51	.17
1962	.37	.49	.54	.18	.13	.10	.34	.30
1963	.31	.45	.33	.13	.33	.05	.64	.25
1964	.18	.40	.15	..10	.35		.30	
1965	.19	.53	.15	.07	.32			.09
1966	.27	.56	.13	.05				
1967	.42	.42	.29					
1968	.17	.31	.18					
1969	.15	.53	.30	.02				
Avg.	.29	.46	.27	.15	.29	.21	.42	.26

*Rate of return of marked fish corrected for catch prior to time of marking.

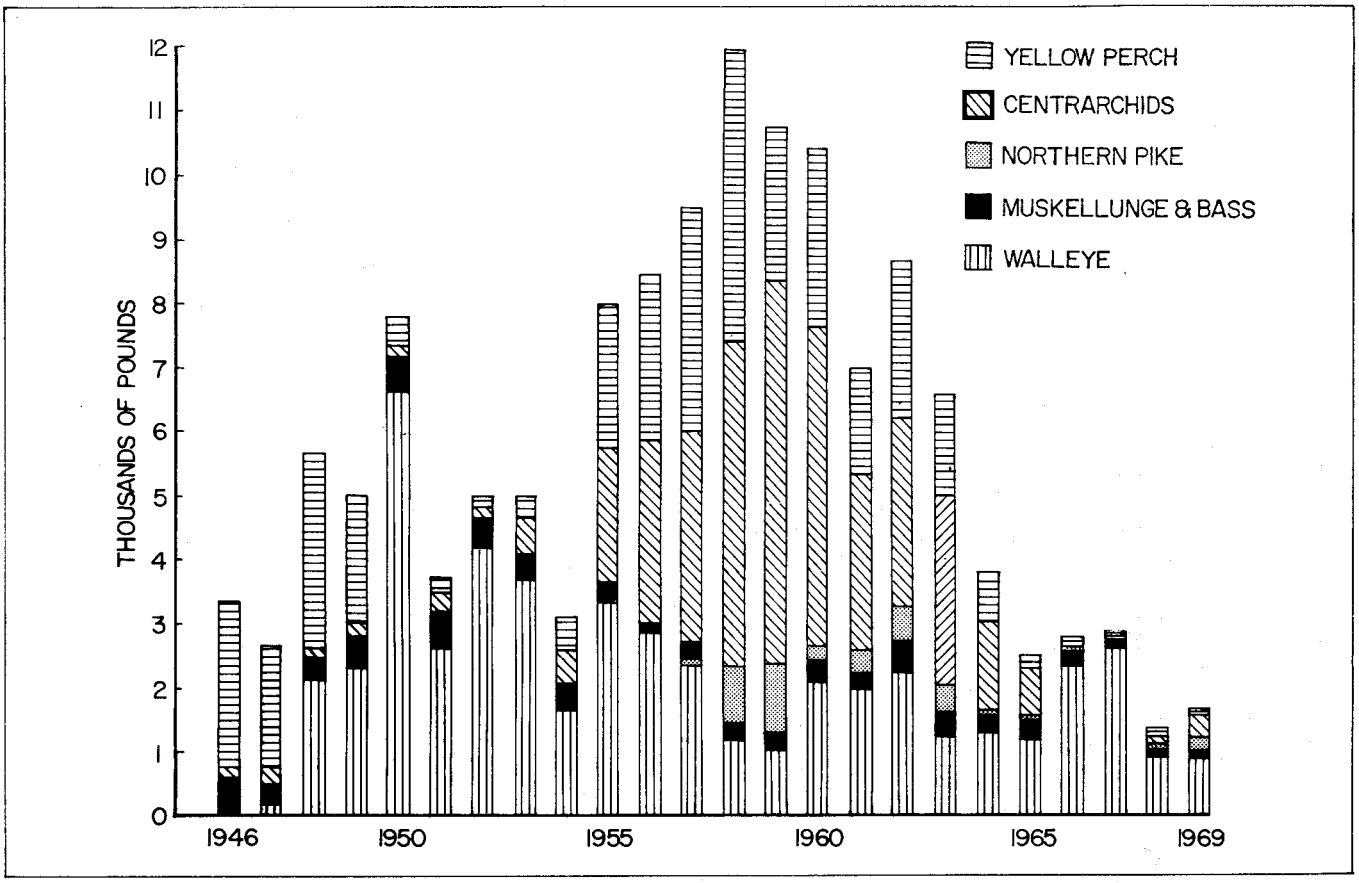
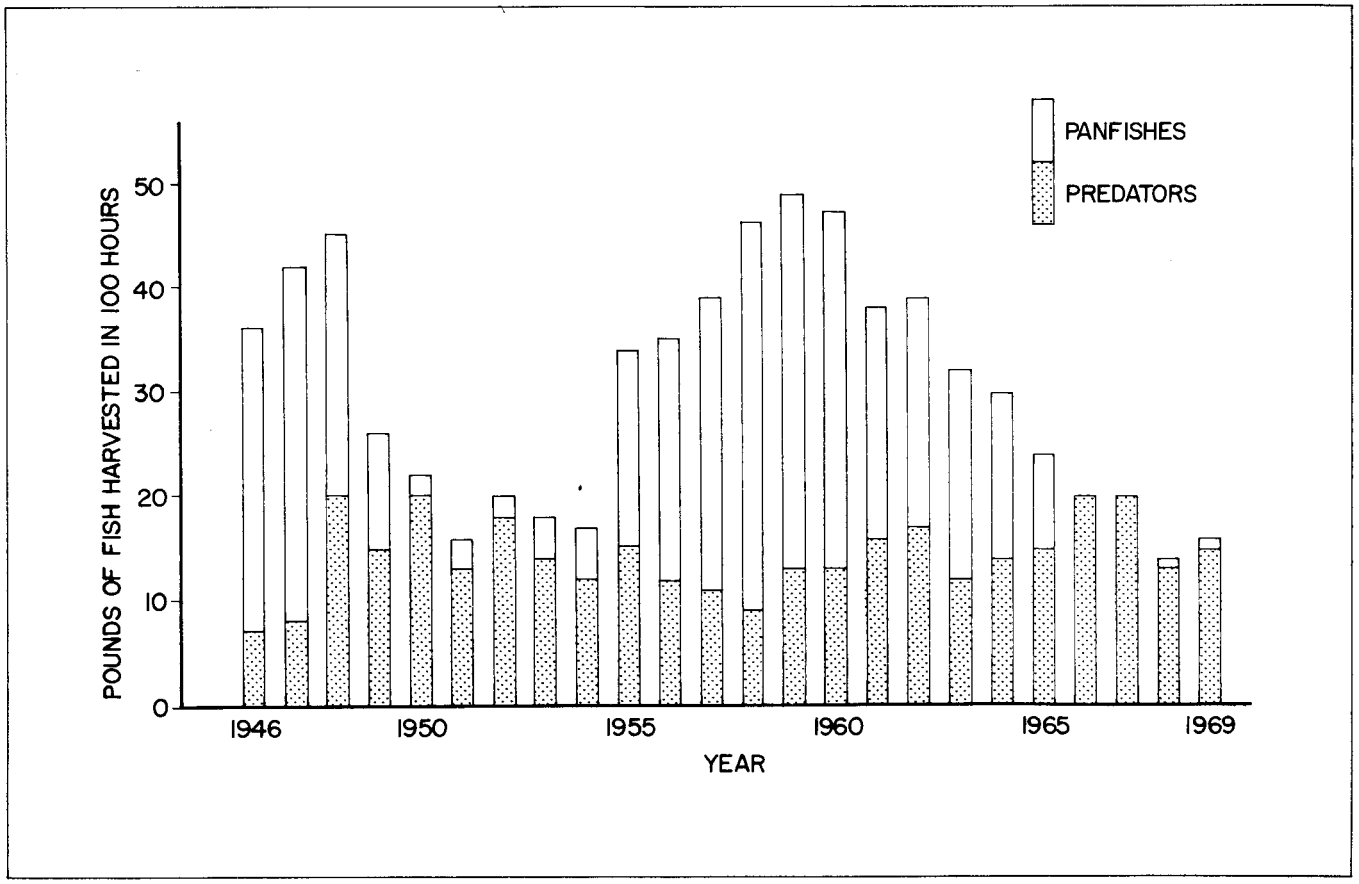


FIGURE 5
Annual harvest (weight) from Escanaba Lake, 1946-69.

FIGURE 6
Fishing success on Escanaba Lake, 1946-69.



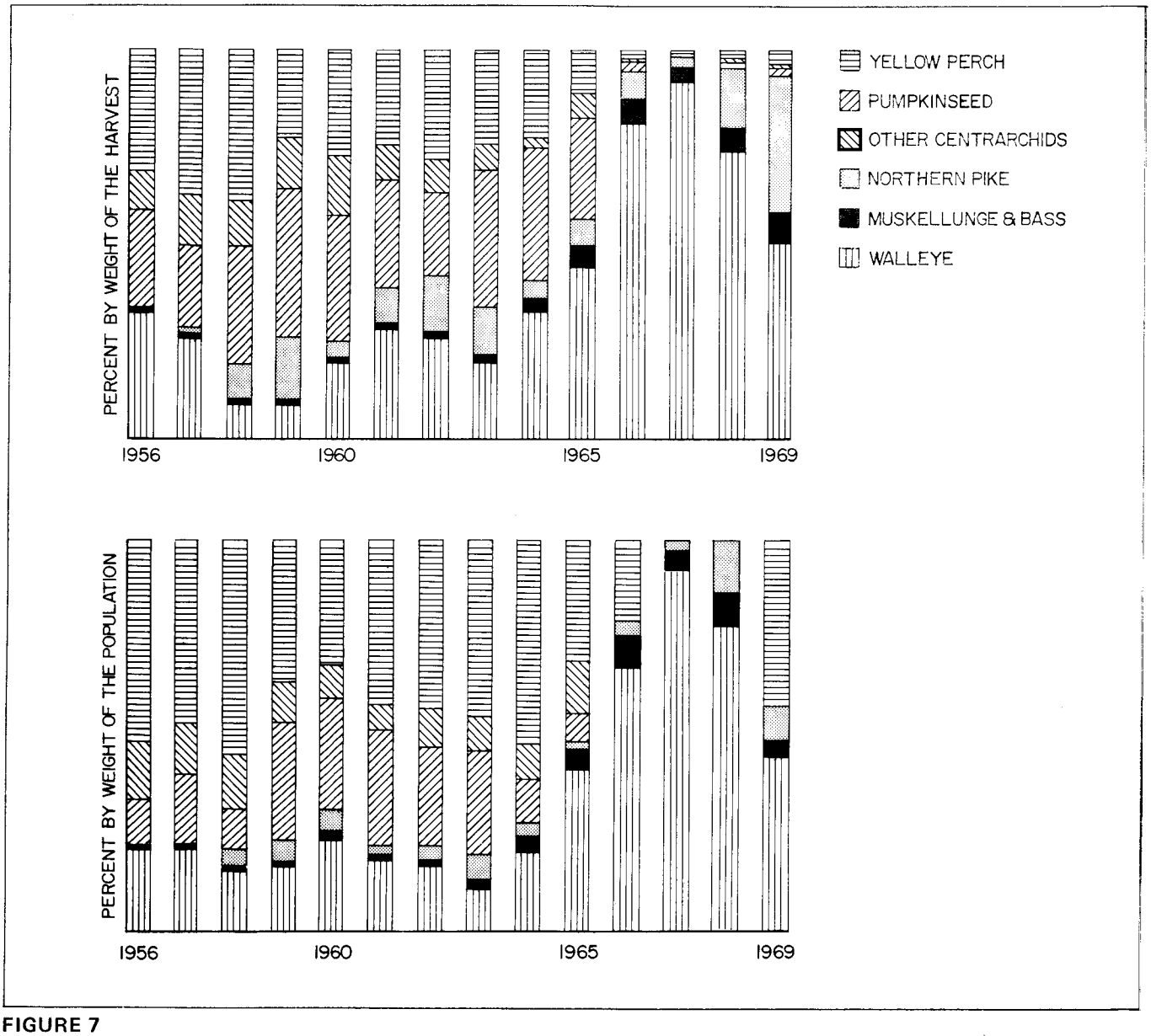


FIGURE 7

Species composition of the population of harvestable sport fishes available to the angler in Escanaba Lake, 1956-69 compared to that of the harvest for the same period.

iation in vulnerability to fishing is the state of the natural food supply. Thuemler (1969) and Morsell (1970), studying food habits of walleyes in Escanaba Lake from 1964 to 1968, found definite differences in the walleye's diet between years which seem to agree with differences in the rate of exploitation. During the summer of 1967 (.42 exploitation rate), Thuemler found that large numbers of crayfish, but only a small amount of yellow perch fry and fingerling, were consumed. In 1968 (.17 exploitation rate), the opposite condition was observed when numerous yellow perch fry and fingerlings, but only a few crayfish, were found in the stomach contents. Morsell reported that he found only 3 percent of the fingerling walleyes to be eating young-of-the-year yellow perch during 1967, whereas from 1964 through 1966, young-of-the-year yellow perch were contributing from 52 to 94 percent of the food eaten by young-of-the-year walleyes. Yellow perch fingerlings, which are a preferred food of walleyes, were scarce in 1967 which may have caused the high exploitation rate of walleyes.

One might expect from this that growth rate and condition, which are also dependent on food supply, would be correlated with rate of exploitation. In Escanaba Lake, the average weight of 14-inch walleye in August shows a significant negative correlation with the exploitation rate for the same year (Fig. 8). Forney (1967) found an inverse relationship between the estimated minimum rate of exploitation and the annual growth increment of walleye in Oneida Lake, New York. He concluded that both growth and catchability are largely determined by the forage supply.

EFFECTS OF LIBERALIZED REGULATIONS

References have already been made to some findings pertaining to the original overall objective of the project, the determination of the effects of liberalized regulations on the fish populations. Prior conclusions emanating from this study were that after 5 years

the "no bag limit" did not jeopardize the perch population in Escanaba Lake (Threinen 1951) and that there was no evidence of depletion after 10 years of unrestricted fishing (Churchill 1957). Oehmcke and Waggoner (1956), independently analyzing Churchill's data, also concluded that there was no evidence of damage to the fish population of Escanaba Lake after 10 years of unrestricted fishing.

Conclusions in each of those papers were based solely on harvest data. The present report has the advantage of a 24-year perspective, with harvest data for the entire period and population estimates from 1956 on.

On the same basis of average annual harvest data only, we can compare the first 10-year period with the following 9-year period. Average angling pressure remained about the same—69 and 74 hours per acre; the numerical catch jumped from 0.61 to 1.36 fish per hour; and the weight harvested rose from 0.28 to 0.39 lb/hour. For the last year of that 9-year period, the numerical catch per hour was 0.95, well above the 0.84 average of the 24-year period and the pounds caught per hour equalled the average for the entire study period. On that generalized basis, one can easily conclude that 19 years of liberalized fishing did not deplete the fish population of Escanaba Lake.

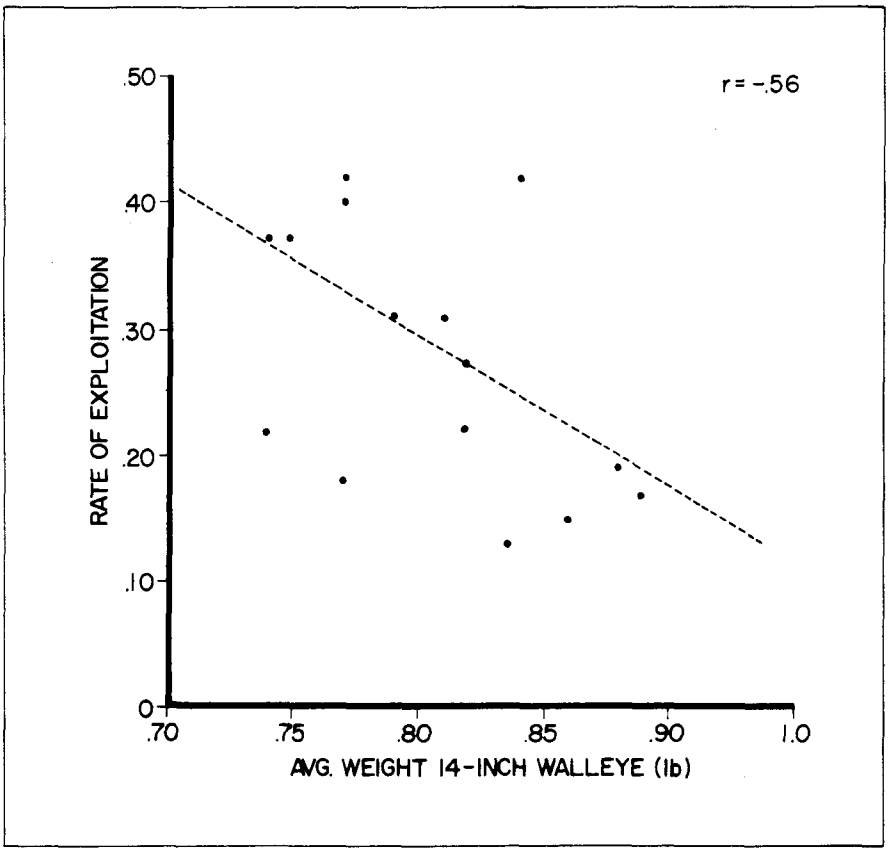


FIGURE 8
Relation of rate of exploitation to condition of Escanaba Lake walleye.

The catch decline in the last 5-year period of this study was a direct reflection of the decline of the panfish population just before and during that period. This was exemplified by the two dominant panfish species, the perch which dropped from 22 lb/acre in 1964 to a level in both 1967 and 1968 too low to estimate and the pumpkinseed, from 14 lb/acre in 1963 to 6 lb/acre in 1964 to indeterminable levels in 1966-69.

It is to be noted that the earlier rise of those two species was preceded by periods of four or more years of apparent low population levels, that the increases were very abrupt, both appearing in 1955, and that the rise occurred during a period of high angling pressure. This suggests that the initial burst was due to appearance of a strong year class of both species. The less abrupt decline in both catch and standing crop in the early 1960's suggests an extended passage through the fishery of the last strong year class(es) with only weak oncoming year classes to support the fishery. The slightly greater average length of pumpkinseed spring-netted in 1965 compared to that for pumpkinseeds taken in 1964 (5.7 vs. 6.0 inches in total length), and even greater size differences for the rock bass (6.6 vs. 7.0 inches) and bluegill (5.6 vs. 6.3 inches) (Kempinger, unpubl.) lend credence to that view. The perch population experienced two alternating highs and lows during the course of this study and the 1969 population estimate hints of a third rise. Attributing the decline of panfish to the increase in the predator component of the population, as suggested earlier, might well be questioned; but in view of the prior 19-year record, ascribing that decline to overfishing is untenable.

The walleye harvest also declined in the later years of this study, but unlike the panfish, the drop was not due to a declining walleye population but rather to a lower exploitation rate; i.e., the fish were there but they were not caught. The spring standing crops of walleyes available to the angler in the late 1960's were essentially the same as those in the late 1950's, 19 and 20 lb/acre, respectively. During the 1953-69 period for which population estimates were available, the adult (age III and older) walleye population averaged 15 fish per acre; during 1965-69, the average was also 15 fish per acre, with the record for Escanaba Lake of 22 adults per acre being tied during that period. Certainly there is no indication of walleye depletion in these data.

During the last 5-year period of the study, the walleye alone accounted for an average of 66 percent (range of 41 to 94) of the total measurable weight of the fish population in Escanaba Lake, well above the dominance level indicated by Johnson (1949). Adding to that the weight of the northern pike population flourishing under the protection of a 22-inch minimum size limit and to a lesser extent the weight of the muskellunge stocked in 1961, resulted in a unique situation in 1967 and 1968 in that the predator component then accounted for virtually 100 percent of the measurable population. That predation was responsible during that period for con-

Escanaba Lake has offered year-round fishing opportunities through continuous open seasons in an area where the resort business is the leading industry.

tinuing suppression of the panfish population is not debatable.

In that regard, it is to be noted that the maintenance and increase of the predator level during the latter part of the study were aided and abetted by intentional experimental management practices entirely unrelated to the question of liberalized regulations. Had not studies of the 22-inch minimum size limit on northern pike and the experimental stocking of muskellunge been initiated, it is conceivable that another upswing in the panfish population similar to that experienced in the early 1950's might have occurred. That at least one successful year class of perch occurred during the period is indeed indicated by the 1969 population estimates.

It follows that the consideration of the effects of liberalized regulations must be confined to the early years of the study, essentially from 1946 to 1963. Consideration of that issue in the later years when other man-induced intentional changes were occurring is not germane.

In that perspective, we conclude that the liberalized angling regulations on Escanaba Lake, within the range of angling pressure applied, had no detrimental effect on the fish population. The panfish decline in the late 1950's and early 1960's is attributed primarily to the natural increase in the predator population, perhaps operating simultaneously with other unknown factors affecting strength of oncoming year classes. Continued suppression of panfish during the later years of the study was primarily due to man-induced buildup of the predator component of the population. Given the latter circumstances, it could be argued that "overfishing" and its implied suppression of predators might well have been the best management prescription for the panfish population in Escanaba Lake at that point in time.

SUMMARY

1. Variations in the fish population during a 24-year period were not attributable to liberalized angling regulations.
2. Liberalized regulations provided increased fishing opportunities (no closed seasons) and permitted greater utilization of a natural resource. Harvest averaged 20 lb/acre annually during 24 complete fishing seasons.
3. Panfish populations exhibited extreme fluctuations but there is no reason to believe that fishing mortality accounted for any of the declines. Fishing pressure and exploitation rates were just as high during the population increases as they were during the population declines. The white sucker, a nonfished species, declined to a low level like panfish.
4. The last panfish decline in the early and mid-1960's was probably due primarily to the natural buildup of the northern pike population in the late 1950's and to the relatively constant walleye predator component.
5. Continuing suppression of the panfish population in the late 1960's is attributed to the northern pike population thriving under a 22-inch minimum size limit, adding appreciably to the predator species component.
6. Unusually large yields of walleyes and northern pike occurred immediately after populations were established; however, they were followed by lower but fairly constant yields.
7. Total harvest of yellow perch and pumpkinseed, the dominant panfish in Escanaba Lake, was a reasonably good record of their representation in the fish population.
8. Predators, in contrast to panfish species, maintained a relatively stable population with liberalized regulations.
9. With a restrictive 22-inch size limit on northern pike, the average annual catch (6 years) of that species declined 85% and total pounds decreased 70%.
10. Each species had a characteristic mean rate of exploitation over a number of years.
11. There was no detectable relation between abundance of walleyes and their rate of exploitation. The vulnerability of walleyes to hook and line fishing is apparently influenced by environmental factors. The most probable limiting factor influencing catchability is availability of food.
12. Following two yearling and two fingerling releases, only the 1961 stockings of 197 yearling muskellunge substantially increased the harvest of that species, comprising 18.3 percent of the muskellunge caught after stocking, 1961-69.

APPENDIX A:
Known Fish Species Present in Escanaba Lake

UMBRIDAE–MUDMINNOW
Central mudminnow, *Umbra limi* (Kirtland)

ESOCIDAE–PIKE
Northern pike, *Esox lucius* Linnaeus
Muskellunge, *Esox masquinongy* Mitchill

CYPRINIDAE–MINNOWS AND CARP
Northern redbelly dace, *Phoxinus eos* (Cope)
Golden shiner, *Notemigonus crysoleucas* (Mitchill)
Common shiner, *Notropis cornutus* (Mitchill)
Bluntnose minnow, *Pimephales notatus* (Rafinesque)
Fathead minnow, *Pimephales promelas* Rafinesque

CATOSTOMIDAE–SUCKER
White sucker, *Catostomus commersoni* (Lacepede)

ICTALURIDAE–FRESHWATER CATFISH
Black bullhead, *Ictalurus melas* (Rafinesque)

GADIDAE–CODFISH
Burbot, *Lota lota* (Linnaeus)

GASTEROSTEIDAE–STICKLEBACK
Ninespine stickleback, *Pungitius pungitius* (Linnaeus)

CENTRARCHIDAE–SUNFISH
Rock bass, *Ambloplites rupestris* (Rafinesque)
Pumpkinseed, *Lepomis gibbosus* (Linnaeus)
Bluegill, *Lepomis macrochirus* Rafinesque
Smallmouth bass, *Micropterus dolomieui* Lacepede
Largemouth bass, *Micropterus salmoides* (Lacepede)
Black crappie, *Pomoxis nigromaculatus* (Lesueur)

PERCIDAE–PERCH
Iowa darter, *Etheostoma exile* (Girard)
Johnny darter, *Etheostoma nigrum* Rafinesque
Yellow perch, *Perca flavescens* (Mitchill)
Logperch, *Percina caprodes* (Rafinesque)
Walleye, *Stizostedion vitreum vitreum* (Mitchill)

COTTIDAE–SCULPIN
Mottled sculpin, *Cottus bairdi* Girard

APPENDIX B:
Fish Stocked in Escanaba Lake, 1933-66

Year	Species	Size	Number
1933	Walleye	Fry	103,000
1933	Largemouth bass	Fingerling	79
1934	Walleye	Fry	95,000
1935	Walleye	Fry	189,000
1936	Walleye	Fry	597,000
1936	Yellow Perch	Yearling	1,000
1936	Yellow Perch	Fingerling	5,000
1937	Walleye	Fry	496,000
1937	Muskellunge	Fry	114,000
1937	Northern pike	Fry	307,000
1937	Largemouth bass	Fingerling	750
1938	Walleye	Fry	525,000
1938	Muskellunge	Fry	39,000
1938	Northern pike	Fry	50,000
1939	Walleye	Fry	200,000
1939	Northern pike	Fry	90,000
1939	Muskellunge	Fry	86,000
1940	Walleye	Fry	1,628,000
1940	Northern pike	Fry	50,000
1940	Muskellunge	Fry	63,000
1941	Walleye	Fry	1,100,000
1941	Northern pike	Fry	50,000
1941	Muskellunge	Fry	7,000
1941	Shiners	Adult	300
1941	White sucker	Adult	2,500
1941	White sucker	Fry	500,000
1942	Walleye	Fry	128,000
1942	Largemouth bass	Fingerling	120
1943	Largemouth bass	Fingerling	400
1944	Largemouth bass	Fingerling	1,875
1945	Largemouth bass	Fingerling	300
1954*	Walleye	Fingerling	48,300
1958	Walleye	Fingerling	35,800
1959	Walleye	Fingerling	11,000
1961	Walleye	Fingerling	21,000
1961	Muskellunge	Fingerling	291
1961	Muskellunge	Yearling	197
1965	Muskellunge	Fingerling	301
1966	Muskellunge	Yearling	155

*Marked with fin removal for future identification, 1954–1966.

LITERATURE CITED

BENNETT, G. W.
1954. Largemouth bass in Ridge Lake, Coles County, Illinois. Ill. Nat. Hist. Surv. Bull. 26(2):217-276.

CHRISTENSEN, K. E.
1953. Fishing in twelve Michigan lakes under experimental regulations. Mich. Dep. Conserv. Inst. Fish. Res. Misc. Publ. No. 7. 46 pp.

CHURCHILL, W.
1957. Conclusions from a ten-year creel census on a lake with no angling restrictions. J. Widl. Manage. 21(2):182-188.

1970. A mail survey of open water fishing in Wisconsin, 1969. Wis. Dep. Nat. Resour. 6 pp. (mimeo).

CHURCHILL W. and H. SNOW
1964. Characteristics of the sport fishery in some northern Wisconsin lakes. Wis. Conserv. Dep. Tech. Bull. No. 32. 47 pp.

COOPER, G. P.
1953. Population estimates of fish in Sugarloaf Lake, Washtenaw County, Michigan, and their exploitation by anglers. Mich. Acad. Sci., Arts and Lett. 38(1952):163-186.

ESCHMEYER, P. H.
1950. The life history of the walleye, *Stizostedium vitreum vitreum* (Mitchill), in Michigan. Mich. Dep. Conserv. Bull. Inst. Fish. Res. No. 3. 99 pp.

FORNEY, J. L.
1967. Estimates of biomass and mortality rates in a walleye population. N. Y. Fish and Game J. 14(2):176-192.

HANSEN, D. F.
1966. Stocking and sport fishing at Lake Glendale (Illinois). Ill. Nat. Hist. Surv. Bull. 29(2):105-158.

JOHNSON, R. E.
1949. Maintenance of natural population balance. Proc. Int. Assoc. Game, Fish and Conserv. Comm. Conv. 38(1948):35-42.

KEMPINGER, J. J. and W. S. CHURCHILL
1972. Contribution of native and stocked walleye fingerlings to the anglers' catch, Escanaba Lake, Wisconsin. Trans. Am. Fish. Soc. 101:644-648.

LA FAUNCE, D. A., J. B. KIMSEY, and H. CHADWICK
1964. The fishery at Sutherland Reservoir, San Diego County, California. Calif. Fish and Game 50(4):271-291.

MORSELL, J. W.
1970. Food habits and growth of young-of-the-year walleyes from Escanaba Lake, Wis. Dep. Nat. Resour. Res. Rep. No. 56. 14 pp.

MOYLE, J. B. and D. R. FRANKLIN
1955. Creel census of 12 Minnesota lakes December 1, 1952 to December 1, 1954. Minn. Dep. Conserv. and Fish. Res. Invest. Rep. 159:1-35 (mimeo).

MRAZ, D.
1968. Recruitment, growth exploitation and management of walleyes in a southeastern Wisconsin lake. Wis. Dep. Nat. Resour. Tech. Bull. No. 40. 38 pp.

OEHMCKE, A. A. and D. W. WAGGONER
1956. How liberal can you get? Wis. Conserv. Bull. 21(5):12-15

OLSON, D. E.
1958. Statistics of a walleye sport fishery in a Minnesota lake. Trans. Am. Fish. Soc. 87:52-72.

PATRIARCHE, M. H.
1960. A twelve-year history of fishing in the lakes of the Rifle River area, Ogemaw County Michigan, 1945-1956. Mich. Dep. Conserv. Inst. Fish. Res. Misc. Publ. No. 13. 45 pp.

PATTERSON, D. L.
1953. The walleye population in Escanaba Lake, Vilas County, Wisconsin. Trans. Am. Fish. Soc. 82:34-41.

RICKER, W. E.
1952. Numerical relations between abundance of predators and survival of prey. Can. Fish. Cult. Issue 13. pp. 5-9.

1958. Handbook of computations for biological statistics of fish populations. Fish. Res. Board Can. Bull. No. 119. 300 pp.

ROSE, E. T.
1949. The population of yellow pike-perch *(Stizostedion v. vitreum)* in Spirit Lake, Iowa. Trans. Am. Fish Soc. 77:32-41.
1955. The fluctuation in abundance of walleyes in Spirit Lake, Iowa. Proc. Iowa Acad. Sci. 62:567-575.

THREINEN, C. W.
1951. Changes in the creel and fishing success as brought out in a five-year creel census. Wis. Conserv. Dep. Div. Fish Manage. Invest. Rep. No. 801. 11 pp.

THUEMLER, T. F.
1969. The food habits of the walleye, *Stizostedium vitreum vitreum* (Mitchill) in Escanaba Lake, Vilas County, Wisconsin. M.S. Thesis. Univ. of Wis., Milwaukee.

WHITNEY, R. R.
1958. Numbers of mature walleyes in Clear Lake, Iowa, 1952-3, as estimated by tagging. Iowa State Coll. J. Sci. 33(1):55-79.

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