LONG-TERM CHANGES IN THE LAKE WINNIBIGOSHISH WALLEYE SPORT FISHERY[1]

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ABSTRACT

Increased fishing pressure between 1958 and 1977 on Lake Winnibigoshish was associated with marked changes in the character of the walleye sport fishery. These changes were similar in direction to those observed between 1939 and 1958. Walleye yields have increased, the age and size structure of the catch has changed and the average size of the harvested walleye has declined. Fishing pressure increased by more than 700% from 1939 to 1977 while walleye yields increased 150%. The average weight of harvested walleye declined from 1.0 kg in 1939 to 0.6 kg in the 1950's and 0.5 kg in the 1970's. The major cause of this decline in average size was an increased harvest of immature walleye. The harvest of walleye less than age V increased by 130% between the 1950's and 1970's. The rate of exploitation of marked adult walleye increased between the two most recent studies. Since the estimated harvest of adults was similar in the two periods, this indicates a decline in abundance of adults. A comparison of length frequencies from spawning runs

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and the angling harvest indicates that anglers were harvesting adult walleye more nearly in proportion to their abundance in the 1970's than in the 1950's. At current levels of exploitation, Lake Winnibigoshish will probably continue to yield harvests similar to those observed during this study. If increasing fishing pressure leads to a more unstable fishery, stringent regulations will have to be applied to reduce harvest. Northern pike and yellow perch are the only other species that contributed significantly to the sport fishery. The northern pike fishery has changed little since 1939 while the summer yield of yellow perch has increased substantially since the 1950's. During the late winter of 1977-78, the harvest of yellow perch was 3.7 kg/ha, nearly twice the estimated harvest from mid-May through 15 February. Continued harvests of yellow perch at these levels could significantly alter the community dynamics of Lake Winnibigoshish.

INTRODUCTION

Lake Winnibigoshish and the connected Big and Little Cutfoot Sioux lakes are among Minnesota's prime walleye (Stizostedion vitreum vitreum) waters. These lakes provided a unique opportunity to examine long-term changes in a walleye sport fishery. Detailed studies of the sport fishery on this lake complex were completed in 1939 (Stoudt 1939; Stoudt and Eddy 1939) and in 1957-58 (Johnson and Johnson 1971). The latter investigators found that fishing pressure on the Lake Winnibigoshish complex increased five-fold and harvest of walleye by number more than two-fold, while walleye catch per manhour declined 50% between 1939 and 1957-58. In the same time frame, the mean weight of harvested walleye declined from 1.0 to 0.64 kg. Since then, fishing pressure has continued to increase and there has been a steady improvement in boats, motors, and fishing tackle and wider dissemination of knowledge of fish behavior that has enhanced an angler's opportunities and abilities to catch walleye.

Although fishing pressure has increased and anglers may be more effective, Minnesota's catch regulations for walleye have remained unchanged since 1956 when the bag limit was reduced from eight to six. A closed season on walleye and northern pike (Esox lucius) is in effect from 16 February to the Saturday nearest 15 May each year. To evaluate the suitability of long established catch regulations for managing our present walleye stocks requires current knowledge of the status of these stocks and the effects of fishing on them.

The objectives of this study were: 1) to specify for Lake Winnibigoshish and connected waters the amount of fishing effort and the yield, catch rate and age-size distribution for principal species in the catch; 2) to estimate the rate of exploitation for walleye; and 3) to document changes in these parameters over a period of nearly 40 years.

STUDY AREA

The study lakes were described in detail by Johnson (1969). Lake Winnibigoshish and the Cutfoot Sioux lakes are part of a system of reservoirs in north central Minnesota retaining water for navigation on the upper Mississippi River (Fig. 1).

Lake Winnibigoshish is shallow with a regular sandy shoreline and gently sloping bottom. The maximum depth is 21.3 m but very little of the lake exceeds 12.2 m. Mean depth is 4.6 m and more than 38% of the lake is shallower than the mean depth.

The Cutfoot Sioux lakes are more diverse with bottom contours being steeper and the shoreline more irregular. Shoreline soil types are mainly rock or muck with relatively little sand being present. The waters are bogstained, particularly at the upper end of the drainage.

Water levels are controlled by the U.S. Army Corps of Engineers. These lakes and broadly connected flowage areas, totaling 25,030 ha, were included in the study area. For purposes of this study, the surface area of Lake Winnibigoshish was considered to be 23,692 ha and that of the Cutfoot Sioux lakes 1,338 ha[1]. This represents 94.4% of the total reservoir storage area of 26,527 ha.

Water levels are controlled by a dam on the Mississippi River outlet of Lake Winnibigoshish. Before 1975, standard operations allowed water level fluctuations of 0.76 m but because of shoreline erosion, the summer high was reduced and current operating ranges provide for annual fluctuations no greater than 0.6 m. The U.S. Army Corps of Engineers, Office of Water Control, St. Paul, MN calculate that the Winnibigoshish

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[1] Johnson and Johnson (1971) used a value of 30,149 ha as the area of the reservoir, assigning 28,256 to Winnibigoshish and 1,853 to the Cutfoot Sioux lakes.

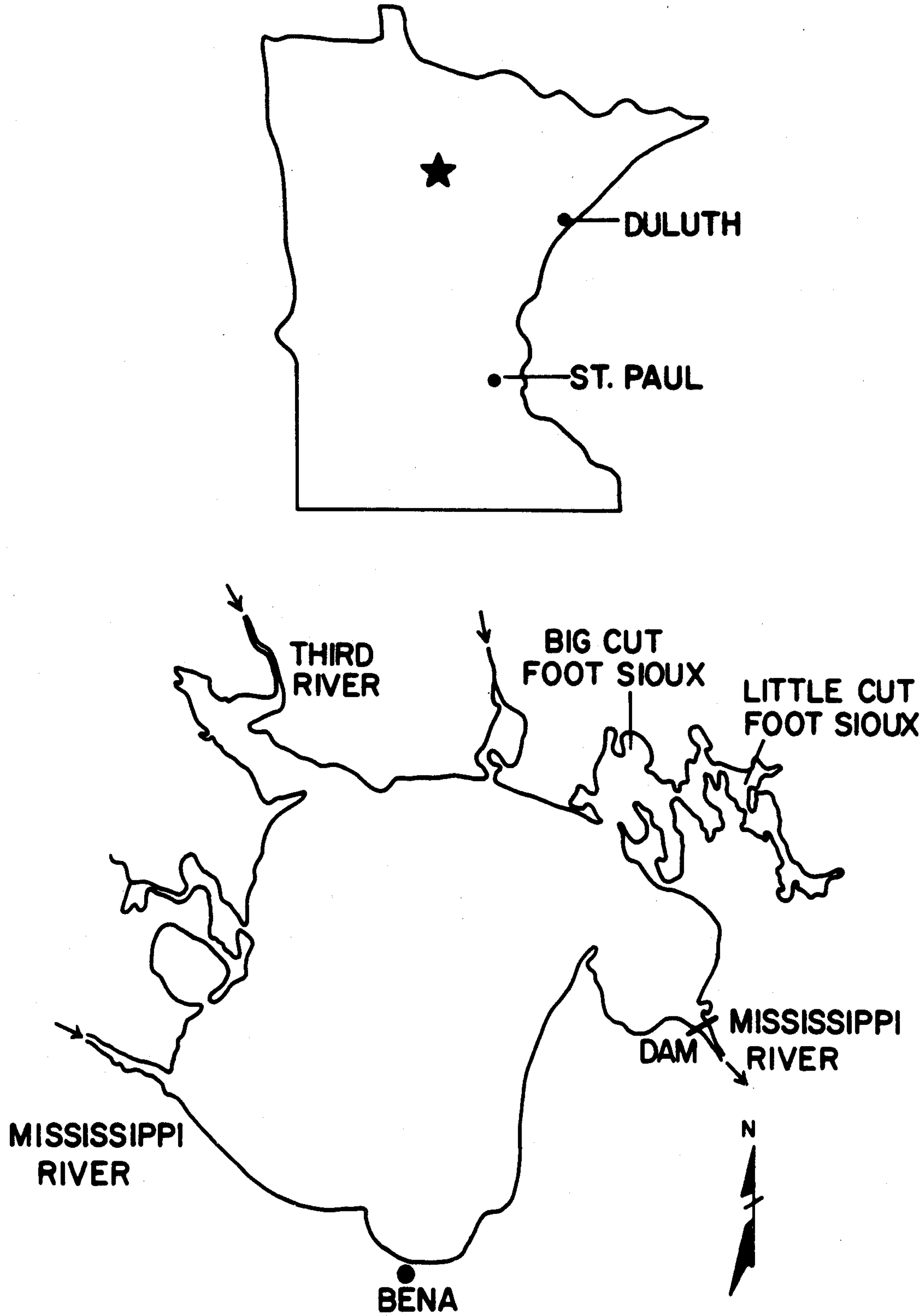

Figure 1. Lake Winnibigoshish and connected waters.

Reservoir contains 28,652 ha at a gauge reading of 3.05 m. Dam operation before 1975 had an overwinter drawdown to 2.44 m and a summer high of 3.2 m. Since 1975, operating levels have ranged from a low of 2.44 to a high of 2.9 m and the areas flooded at these readings are 25,374 and 27,681 ha, respectively.

Lake Winnibigoshish is moderately fertile with secchi disc readings in mid-summer of 2.0-2.6 m. Total alkalinity ranged from 147 to 170 mg/1, Kjeldahl nitrogen from 0.42-0.74 mg/1 and total phosphorus from 0.02-0.16 mg/1. The morphoedaphic index (Ryder 1965) is 45 and the potential fish yield estimated from this index is 6.9 kg/ha.

METHODS

Similar procedures were used in this study as in the previous studies - adult walleye in spawning runs were marked and a creel census was conducted.

The summer creel census used a modification of Schupp (1964). All completed boat trips landing at 25 sampling stations (access points) were counted during a 2-h period. In 1975, all areas were sampled equally but hours of the day were sampled based on the probability of a boat landing within a given 8-h period. These probabilities were derived from a similar census conducted at Leech Lake (Schupp 1972).

In 1976 and 1977, the census was further modified to use probability sampling procedures developed by Fleener (1971). Clusters of two to five sampling stations were established. Probabilities of a boat landing were established for clusters, stations within clusters, hour of the day, type of day (weekend or weekday) for boats and for charter launches based on 1975 data.

Four census clerks worked during the May opening weekend, three clerks during the rest of May and on June weekends and two clerks on June weekdays and the rest of the season. Census clerks recorded all completed trips landing in a sample area by method of fishing and interviewed as many fishermen as time permitted. All data were identified by grid area (Fig. 2). Length and weight were measured for as many fish as possible and scale samples were taken.

The winter creel census was conducted using a roving probability census similar to that of Malvestuto, Davies and Shelton (1978). The lake was divided into distinct sampling areas where roads were maintained on the ice to facilitate counts and interviews. Access to sampling areas varied from winter to winter because of variations in snowfall and resulted in the need to adjust area boundaries annually and sometimes seasonally.

Walleye Tagging

Walleye were marked with tags during the spring and summer 1976 to estimate exploitation rates. Mature walleye caught in spawning run traps at Little Cutfoot Sioux Lake during the spring 1975 and 1976 were marked with serially numbered Floy FD 67B tags. In 1975, tags were inserted with either an interneural or skin anchor while in 1976 all were anchored in interneural bones. No difference in the rate of return was observed between anchoring methods. Twenty-five marked walleye were held overnight on each tagging date with no observed mortality. A fish-kill caused by Columnaris spp. occurred after the spawning run in Little Cutfoot Sioux Lake in 1976 which affected an unknown number of marked and unmarked fish. Tags applied in 1976 were defective as the tubing containing the tag number and legend was missing from several tagged walleye subsequently recaptured.

In the spring of 1977, walleye caught in a spawning trap in the Third River Flowage between Lake Winnibigoshish and Dixon Lake were marked with serially numbered disc-dangler tags. The tags were attached through the posterior musculature beneath the dorsal fin with stainless steel surgical

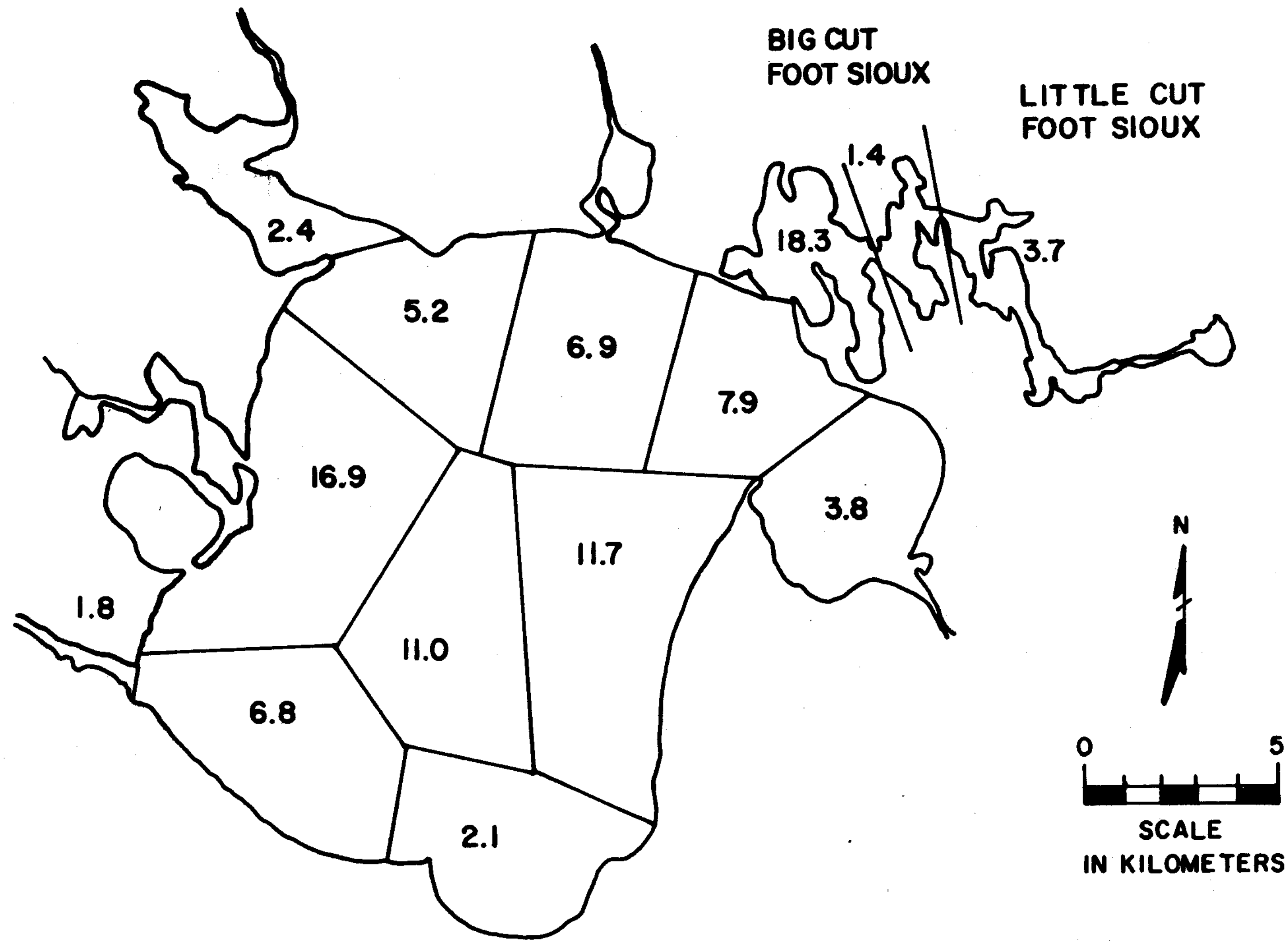

Figure 2. Mean percent fishing effort by grid location, Lake Winnibigoshish, 1975-1977.

wire. In all spring tagging, the sex and total length (TL) of tagged fish were recorded. Scale samples were taken from up to 20 fish of each sex for each 25 mm size-group.

Walleye $\geq$ 254 mm total length (TL) caught by trawling in Lake Winnibigoshish were marked with the disc-dangler tags in the summers of 1975 and 1976. Most were immature fish. Trawling stations varied from year to year but covered nearly the entire shoreline of the lake. All marked walleye were measured, weighed and scale samples were taken from a representative group.

Tag returns were solicited through local newspaper and radio press releases, posters at access points and invitations to resorters to assist in recording returns. Information recorded for each caught tagged fish included the tag number, date caught, location caught, method of reporting and the angler's home address.

RESULTS

The study lakes were fished for approximately 10 months each year with little or no fishing occurring for about a month just prior to freezeup in the fall and during the spring breakup. Most of the fishing pressure occurred during the open-water season from the season opening in mid-May through October (Table 1). The average annual summer fishing pressure was 29.9 manhours/ha (Table 2) or 93.4% of the total effort. This was similar to summer fishing pressure at Cass Lake but over 50% higher than at Leech and Mille Lacs lakes (Table 3).

Summer fishing effort was not uniformly distributed throughout the system. The center portion of Lake Winnibigoshish, on an east-west axis, received nearly 40% of the fishing effort though easy access is available on all shores of the lake. The smaller Cutfoot Sioux lakes received about 5.4 times more effort per unit area than Lake Winnibigoshish. This distribution

Table 1. Estimated number of sport fishing boat trips per day and the standard error of the estimates by sampling period, Lake Winnibigoshish, 1976 and 1977.

		1976			1977		
Sampling Period	Days in period	Boat trips	S.E.	No. of estimates	Boat trips	S.E.	No. of estimates
Opening weekend	(2)	1,512	167	(32)	1,571	181	(42)
Other May weekends	(5)	1,016	75	(72)	1,235	116	(82)
May weekdays	(10)	294	32	(65)	377	45	(86)
June weekends	(8)	510	56	(102)	464	48	(97)
June weekdays	(22)	433	35	(123)	379	36	(142)
July weekends	(10)	386	43	(72)	350	55	(64)
July weekdays	(21)	288	26	(91)	255	24	(116)
August weekends	(9)	338	61	(48)	325	50	(56)
August weekdays	(22)	369	37	(108)	302	34	(122)
September weekends	(9)	496	45	(72)	437	60	(72)
September weekdays	(21)	253	28	(92)	280	33	(97)
October	(15)	Season Closed - Fire Danger			194	44	(73)

of fishing effort was consistent from year to year and probably reflects walleye availability to anglers.

Summer angling on the study lakes was of three types - small sport fishing boats, charter launches and shore fishermen. The majority of sport fishing originated from small boats on each lake, averaging over 90% of all fishing on the Cutfoot Sioux lakes and over 80% of all fishing on Lake Winnibigoshish. Launch fishing was significant on Lake Winnibigoshish, averaging 16.3% of fishing effort for the 3 years but launches rarely fished the Cutfoot Sioux lakes. Fishing from shore averaged 7.2% of all fishing

Table 2. Estimated annual fishing pressure in total manhours, manhours/ha and percent of total by different fishing methods for Lake Winnibigoshish and the Cutfoot Sioux lakes, 1975-78.

		Manhours/ha				
Lake and year	Total manhours	Total	Summer angling	Winter angling	Darkhouse spearing	Spring[a] ice-angling
Winnibigoshish						
1975-76	517,547	22.1	20.8	0.1	1.2	-
1976-77	657,768	27.9	25.9	0.5	1.5	-
1977-78	669,765[b]	28.4	26.5	0.7	1.2	
Mean	615,027	26.1	24.4	0.4	1.3	
Cutfoot Sioux lakes						
1975-76	185,961	138.6	133.4	1.5	3.7	-
1976-77	172,662	129.0	121.8	5.2	2.0	-
1977-78	204,640[b]	153.0	135.9	7.2	9.9	-
Mean	187,754	140.2	130.4	4.6	5.2	
All lakes combined						
1975-76	703,508	28.2	26.8	0.2	1.2	-
1976-77	830,430	33.1	30.9	0.7	1.5	-
1977-78	966,596[c]	38.5[c]	32.1	1.0	1.7	3.7
Annual mean, all lakes[d]	802,781	32.0	29.9	0.6	1.5	-

[a] Angling through the ice after 15 February was censused only in 1978.
[b] Value does not include 92,191 manhours of ice-angling after 15 February.
[c] Values include estimated 92,191 manhours of ice-angling after 15 February.
[d] Annual averages do not include ice-angling after 15 February.

effort on the Cutfoot Sioux lakes but only 1.5% on Lake Winnibigoshish.

The most intensive fishing effort occurred during the first six weeks of the season. Nearly 50% of the open water fishing trips were made from the season opening (mid-May) through June (Table 4). This was similar to observations at Leech Lake (Schupp 1972) and Cass Lake (Strand 1980).

The winter sport fishery was of two types through 15 February, angling through the ice and darkhouse spearing. Winter angling comprised 1.9% and darkhouse spearing 4.7% of the annual fishing effort. The average winter angling pressure was higher than at Cass and Leech lakes but was only 2% of

Table 3. Comparative census statistics for summer and for the full year from recently censused large lakes.

Lake	Area(ha)	Years censused	Fishing pressure, manhours/ha[a]		Yield (kg/ha) Total		Walleye		N. pike		Y. perch		Walleye catch/manhour	
			Summer	Tot	Summer	Tot	Summer	Tot	Summer	Tot	Summer	Tot	Summer	Winter
Cass (Strand 1980)	7,350	1971-75	34.1	36.6	6.9	7.7	2.4	2.4	1.5	1.8	2.9	2.9	0.17	0.00
Kabetogama[b] (Ernst & Osborn 1980)	10,425	1977-78	50.7	-	9.9	-	5.6	-	3.0	-	0.3	-	0.20	-
Leech (Schupp 1972)	45,123	1965-67	18.5	19.8	4.5	4.8	2.1	2.1	1.5	1.6	0.8	0.8	0.18	0.03
Mille Lacs[c] (Maloney 1978)	53,626	1976-77	20.0	51.9	3.7	6.1	3.1	4.5	0.2	0.3	-	1.2	0.22	0.08
Red, Upper (Close 1978)	19,425	1976	11.1	13.8	3.4	4.3	2.8	3.7	TR	<0.2	TR	<0.2	0.85	1.09
Winnibigoshish[e]	25,030	1975-78	29.9	32.0	6.9	7.6	3.6	3.6	1.9	2.2	1.2	1.5	0.23	0.03

[a] Includes darkhouse spearing.
[b] No winter creel census.
[c] Calculated from two summer seasons and one winter season.
[d] The total area of Upper and Lower Red Lake is 19,425 ha but only Upper Red Lake is open to non-Indian fishermen.
[e] Does not include spring fishery.

Table 4. Percentage distribution of summer angling effort through the season on Lake Winnibigoshish and connected waters.

Year	15 May-30 June	1 July-15 August	16 August-31 October
1975	49	24	27
1976	44	30	26[a]
1977	52	24	24[b]

[a] Season closed 30 September due to fire danger emergency.
[b] Census terminated 14 October.

that at Mille Lacs Lake in the winter of 1976-77. Darkhouse spearing pressure was similar to that at Cass and Leech lakes but was 15 times higher than at Mille Lacs Lake.

The winter sport fishery changed markedly during the study period. Darkhouse spearing and angling pressure increased throughout the study but angling increased more rapidly. Darkhouse spearing accounted for 86% of the fishing effort in the winter of 1975-76. During the next 3 years, spearing effort increased by 42% while winter angling effort increased by over 500% (Table 2). Total fishing effort during the winter nearly doubled and by 1977-78 darkhouse spearing accounted for 63% of the winter fishing effort.

Most of the increased angling effort was directed at yellow perch (Perca flavescens). This shift was first observed during the winter of 1976-77 and indicated a change in the character of winter angling. The primary cause of this change was an influx of Wisconsin residents who comprised 48% of the winter anglers in contrast to only 9% during the following summer.

Winter spearing effort in all three winters was concentrated during the first two weeks of the season. An average of 58% of all winter spearing was expended from 1-15 December. The same pattern was not evident for angling.

The increased angling effort noted before 15 February 1977 continued through the early spring. There had been a relatively small late-winter sport fishery for yellow perch for a number of years but it had not been large enough to warrant a census. The winter census was extended to cover this period in 1978 following observations of increased effort the previous year. An estimated 3.7 manhours/ha was expended between mid-February and early April 1978. This effort exceeded the three-year average for winter angling from 1 December through 15 February by 500% and comprised 10% of the total effort from May 1977 through April 1978. Wisconsin residents exerted 80% of this fishing pressure.

Fishing Success

Each of the various fishing methods used at Lake Winnibigoshish was directed mainly at walleye but estimated catch-rates were based on all fishing effort. Winter angling before 15 February was mainly for yellow perch but there was some angling for walleye. Most summer angling was for walleye though northern pike and yellow perch were sometimes sought.

Within the summer fishing season, walleye catch rates were generally highest in May and lowest in August. The low mid-summer catch rate, characteristic for summer angling in other Minnesota walleye lakes, was evident in 1975 and 1977 but not in 1976, a year in which the catch rate was relatively consistent from spring to fall. The peak monthly catch rate was 0.47/hour in May 1977 while the lowest catch rate was 0.08/hour in August 1975. The observed walleye catch rates were similar to those at Mille Lacs Lake and somewhat higher than those from Leech and Cass lakes (Table 3) but lower than those at Upper Red Lake and Lake of the Woods (Schupp 1974).

Winter catch rates for walleye were relatively low with the highest rate (0.05/manhour) occurring in winter 1976-77 (Table 5). This is below the lowest rate observed at Mille Lacs in three winters of census (Maloney 1978).

Summer catch rates for northern pike varied little from year to year and the three-year average for angling from boats was 0.05 fish/manhour (Table 5). Catch rates within the season also varied little, though there was a tendency for higher rates in mid- and late summer. This may be a result of more fishing directed at northern pike when walleye fishing is relatively poor. Catch rates for shore anglers were lower than for boat anglers in two of the three years but the highest catch rate recorded was for shore anglers in 1977. Northern pike are usually incidental in the catch from launches so estimated catch rates were low. Summer catch rates at Lake Winnibigoshish were near the average observed for lakes in Minnesota.

Northern pike comprised a small part of the winter angling catch but contributed substantially to the darkhouse spearing fishery. Catch rates for northern pike by winter angling were low when compared to other lakes. Darkhouse spearing catch rates were the highest observed from large walleye lakes though lower than the average for all censused Minnesota lakes.

Interest in catching and keeping yellow perch as well as catch rates appeared to be increasing during the study period (Table 5). The peak summer monthly catch rate was 0.47 fish/hr in August 1976 with a low of 0.07 fish/hour in June 1976. The apparent increased interest in yellow perch angling was also noted at Mille Lacs Lake (Maloney 1978). Winter catch rates for yellow perch were considerably higher than those at Mille Lacs Lake and Leech Lake (Schupp 1972).

Table 5. Fishing success for walleye, northern pike and yellow perch expressed as numbers and kg of fish caught per manhour by method and season, Lake Winnibigoshish and connected waters, 1975-78.

	Numbers/manhour				Weight (kg)/manhour			
	1975-76	1976-77	1977-78	Mean	1975-65	1976-77	1977-78	Mean
Northern pike								
Summer								
Boat	0.05	0.06	0.05	0.05	0.07	0.07	0.07	0.07
Launch	0.02	0.01	0.02	0.02	0.03	0.01	0.03	0.02
Shore	0.04	0.02	0.19	0.08	0.05	0.03	0.26	0.11
Winter								
Angling	0.04	0.04	0.02	0.03	0.04	0.05	0.02	0.04
Darkhouse spearing	0.12	0.12	0.12	0.12	0.23	0.21	0.22	0.22
Total	0.27	0.25	0.40	0.30	0.42	0.37	0.60	0.46
Yellow perch								
Summer								
Boat	0.11	0.25	0.26	0.21	0.02	0.06	0.05	0.04
Launch	0.18	0.27	0.19	0.21	0.03	0.06	0.04	0.05
Shore	0.35	0.42	0.18	0.32	0.06	0.10	0.02	0.06
Winter								
Before 15 February	2.00	0.42	4.01	2.14	0.42	0.08	0.78	0.43
After 15 February	-	-	5.15	-	-	-	1.08	-
Total	2.64	1.36	9.79	4.60	0.53	0.30	1.97	0.93
Walleye								
Summer								
Boat	0.15	0.25	0.24	0.21	0.09	0.13	0.12	0.11
Launch	0.22	0.41	0.30	0.31	0.13	0.20	0.15	0.16
Shore	0.05	0.15	0.22	0.14	0.03	0.08	0.11	0.07
Winter								
Angling	0.03	0.05	0.01	0.03	0.03	0.02	0.01	0.02
Total	0.45	0.86	0.77	0.69	0.28	0.43	0.39	0.36

Fishing Yield

The mean annual yield to sport fishing from Lake Winnibigoshish was the second highest recorded from large walleye lakes (> 6,000 ha) censused in Minnesota (Table 3). The 7.6 kg/ha mean yield was dominated by walleye (47%), northern pike (29%) and yellow perch (20%) (Table 6). By number, walleye comprised 40%, northern pike 10% and yellow perch 46% of the annual harvest. These values do not include the late-winter sport fishery censused in 1978. The yield for the 1977-78 season was 13.0 kg/ha, 28% of which was harvested after 15 February. The summer yield of 6.9 kg/ha comprised 91% of the total annual yield (average of 1975-77) and was exceeded only by the yield from Kabetogama Lake in 1979. Walleye comprised 51% of the summer yield, northern pike 27% and yellow perch 18%. By number, walleye comprised 44%, northern pike 10% and yellow perch 42% of the total summer harvest. The mean summer yield of walleye and northern pike was exceeded only at Kabetogama Lake while the summer yield of yellow perch was exceeded only at Cass Lake (Ernst and Osborn 1980; Strand 1980).

The seasonal distribution of catch varied among the three principal species. An average of 57% (range 42-67%) of the walleye harvest occurred in May and June and 8-15% of the harvest was made the first two days of the season. Maximum monthly catches of northern pike occurred in May and August each year and month-to-month fluctuations were not as great as for walleye. Catches of yellow perch tended to be highest from July through September but in 1975 the early season catch was also high.

The winter harvest at Lake Winnibigoshish changed substantially during the study. The predominance of darkhouse spearing through the winter of 1975-76 was reflected in northern pike dominating the catch (Table 7). Northern pike comprised 32% of the 1975-76 catch by number and 81% by weight with more than 95% of these totals taken by spearing.

Table 6. Estimated summer sport fishing catch in numbers and kilograms, Lake Winnibigoshish and connected waters, 1975-77.

	1975		1976		1977		3-year average	
	Total	Catch/ ha	Total	Catch/ ha	Total	Catch/ ha	Total	Catch/ ha
Catch (numbers)								
Northern pike	28,486	1.1	39,998	1.6	40,978	1.6	36,487	1.5
Muskellunge	34	<0.2	129	<0.2	17	<0.2	60	<0.2
Bullhead	3,381	<0.2	1,787	<0.2	8,376	0.3	4,515	<0.2
Rock bass	4,296	<0.2	4,981	0.2	5,000	0.2	4,759	<0.2
Sunfish	3,194	<0.2	2,532	<0.2	3,231	0.2	2,986	<0.2
Black crappie	7,094	0.3	845	0.2	2,915	<0.2	3,618	<0.2
Yellow perch	82,364	3.3	197,271	7.9	197,780	7.9	159,138	6.4
Walleye	104,002	4.2	206,953	8.3	198,168	7.9	169,708	6.8
Other species[a]	0	0.0	184	<0.2	35	0.2	73	<0.2
Catch (kg)								
Northern pike	39,570	1.6	46,485	1.9	56,670	2.2	47,575	1.9
Muskellunge	127	<0.1	714	<0.1	66	<0.1	302	<0.1
Bullhead	1,227	<0.1	308	<0.1	2,131	<0.1	1,222	<0.1
Rock bass	1,242	<0.1	1,765	0.1	1,786	<0.1	1,598	<0.1
Sunfish	1,560	0.1	528	<0.1	1,271	<0.1	1,120	<0.1
Black crappie	1,865	0.1	261	<0.1	1,271	<0.1	1,132	<0.1
Yellow perch	14,530	0.6	41,442	1.7	38,338	1.6	31,437	1.2
Walleye	62,158	2.5	104,431	4.1	100,601	4.0	89,063	3.6
Other species[a]	0	0.0	305	<0.1	33	<0.1	113	<0.1
TOTAL (kg)	122,279	4.9	196,239	8.0	202,167	8.1	173,562	6.9

[a] Other species include white suckers, burbot, whitefish and largemouth bass.

Increased angling pressure, first noted in the winter of 1976-77, was accompanied by a shift to yellow perch as the predominant fish in the winter harvest. Through the end of the sport fishing season of 1977-78 (15 February), yellow perch comprised 94% of the harvest by number and 64% by weight. During the three years of winter census, northern pike harvests also increased. The harvest of walleye was estimated to be less than 1,000 fish each winter. The annual winter yield for all species increased from 0.3 to 1.2 kg/ha as a result of the increased angling for yellow perch.

Table 7. Estimated winter sport fishing catch from 1 December through 15 February in number and kilograms, Lake Winnibigoshish and connected waters, 1976-78.

	1975-76		1976-77		1977-78		3-year average	
	Total	Catch/ ha	Total	Catch/ ha	Total	Catch/ ha	Total	Catch/ ha
Catch (numbers)								
Northern pike	3,886	0.2	5,122	0.2	5,988	0.2	4,999	0.2
Angling	135	<0.1	611	<0.1	542	<0.1	429	<0.1
Spearing	3,751	<0.1	4,511	0.2	5,446	0.2	4,570	0.2
Black crappie	243	<0.1	1,080	<0.1	405	<0.1	576	<0.1
Yellow perch	7,766	0.3	7,409	0.3	99,301	4.0	38,159	1.5
Walleye	127	<0.1	835	<0.1	235	<0.1	399	<0.1
Catch (kg)								
Northern pike	7,418	0.3	8,773	0.3	10,782	0.4	8,991	0.3
Angling	132	<0.1	934	<0.1	595	<0.1	554	<0.1
Spearing	7,285	0.3	7,839	0.3	10,187	0.4	8,437	0.3
Black crappie	55	<0.1	309	<0.1	116	<0.1	160	<0.1
Yellow perch	1,621	<0.1	1,463	<0.1	19,373	0.8	7,486	0.3
Walleye	97	<0.1	410	<0.1	221	<0.1	243	<0.1
TOTAL (kg)	9,191	0.3	10,955	0.4	30,492	1.2	16,880	0.7

The increased harvest of yellow perch by winter anglers was the most significant change observed at Lake Winnibigoshish during the study. The total estimated harvest of perch, before 15 February, increased over 1,000% from 1976 to 1978. The late winter fishery in 1978 harvested an estimated 470,362 perch weighing 92,191 kg (3.7 kg/ha) from 16 February through 31 March (Table 8). This was 1.6 times the estimated perch harvest from mid-May 1977 through 15 February 1978. The addition of the late winter harvest in 1978 accounted for about 28% of the total 1977-78 harvest and was 48% of the estimated average annual harvest, excluding this late fishery.

Walleye Fishery

Age-classes III through VI typically compose the majority of the walleye catch in Minnesota lakes. These four age-classes comprised an

Table 8. Comparison of the harvest of yellow perch and all other species from mid-May through 15 February 1975-78 to the harvest of yellow perch from 15 February through 31 March 1978, expressed as total kilograms and kilograms/hectare, Lake Winnibigoshish and connected waters.

	Mid-May through 15 February						15 February through 31 March	
	Yellow perch		All other species		Total		Yellow perch	
Year	Total (kg)	kg/ha	Total (kg)	kg/ha	Total (kg)	kg/ha	Total (kg)	kg/ha
1975-76	16,151	0.6	115,319	4.6	131,470	5.3	-	-
1976-77	42,905	1.7	164,289	6.6	207,194	8.3	-	-
1977-78	57,711	2.3	174,948	7.0	232,659	9.3	92,191	3.7
3-year average	38,922	1.6	151,519	6.0	190,441	7.6	-	-

average of 78% of the catch from 1975-77 (Table 9). This is similar to the contribution reported for Lake Winnibigoshish in an earlier study (Johnson and Johnson 1971) and for Leech Lake (Schupp 1972).

The walleye fishery was dominated by a strong year-class in each of the study years. The 1971 year-class comprised 42% of the catch in 1975 and the 1973 year-class comprised 62% and 50% of the catch in 1976 and 1977, respectively. Walleye less than age V contributed an average of 65% to the catch (Table 9). This value is intermediate between the 43% observed at Mille Lacs in 1976-77 (Maloney 1978) and 76% at Rainy Lake in 1977-78 (Ernst and Osborn 1980) for lakes censused since 1965.

There was a periodicity in the contribution of age classes within the fishing season (Table 10). Mature walleye (VI+) contributed about 40% of the harvest in May and June, about 14% in July and August and about 20% of the September-October harvest. Newly recruited age II and III walleye dominated the catch from July through October.

Table 9. Percentage age-class distribution of the walleye harvest from Lake Winnibigoshish and connecting waters, 1975-1977.

	Age-class								
Year	II	III	IV	V	VI	VII	VIII	IX	X+
1975	7.4	4.2	42.0	15.3	11.2	3.3	5.6	6.0	6.0
1976	2.0	62.1	2.8	14.4	7.7	4.2	2.3	0.9	3.6
1977	8.0	15.6	50.3	2.9	6.5	4.2	3.5	1.7	7.3

Table 10. Mean percentage of harvest by month for various age groups of walleye, Lake Winnibigoshish and connecting waters, 1975-77.

Age groups	May	June	July	Aug.	Sept.-Oct.	Mean
Age II-III	10.5	12.8	44.2	57.9	42.3	33.0
Age IV-V	50.9	47.7	42.3	28.4	37.4	42.5
Age VI+	38.6	39.5	13.5	13.7	20.3	24.5

The dominance of the 1973 year-class, and demonstrated difficulties in aging older Lake Winnibigoshish walleye (Olson 1980), precluded estimating total mortality from a simple catch curve based on age-frequency of the angler's catch as used by Johnson and Johnson (1971). Total mortality was estimated to be 0.44 for age V+ walleye (Robson and Chapman 1961) with age VII and older walleye combined.

Only minimum rates of exploitation could be estimated for this study. A tag loss of unknown magnitude occurred among Floy-tagged walleye marked in the spring spawning runs at Cutfoot Sioux Lake in 1975 and 1976. Estimated losses of Floy-tags from walleye were 15.2% in the St. Louis River during a one-year period (T.C. Osborn, unpublished data). The first-year rate of return for Floy-tagged walleye was 33% lower than for fish marked with disc-dangler tags the following year. Too few tagged fish were seen in the creel census to reliably estimate the true percentage of marked fish. The average rate of exploitation estimated for trawl-tagged walleye was 0.252 (Table 11). This is nearly identical to the average value at Cass Lake (0.246) (Strand 1980). The exploitation rate for fish tagged in the spawning run at Third River was 0.296. Floy-tagged fish marked in the Cutfoot Sioux spawning run were returned at a similar rate in 1975 but at a much lower rate in 1976 though fishing success was substantially higher in 1976 (Tables 5 and 6).

No consistent differences in the rate of return for male and female walleye could be detected. There was some evidence of an inverse relationship between size and rate of exploitation. The percentage of tags returned declined with increasing size of adult walleye tagged in spawning runs for both sexes in all years (Table 12). Only one of the slopes (1975 females) differed significantly from zero but all were negative. These results are similar to those reported by Serns (1981). No significant differences among the slopes could be detected. The average rate of return declined by 0.9% for each 25 mm increase in length.

The timing of spawning runs in relation to the legal opening date of the season had a pronounced effect on the exploitation of adult fish. The Little Cutfoot Sioux Lake spawning run was completed only four days prior to the fishing season in 1975 and Little Cutfoot Sioux Lake was closed to fishing during the first week of the 1975 season. In 1976, the run was completed several weeks before the season opened.

Tag returns in 1976 indicated a wider dispersal of adult walleye by mid-May than in 1975 (Fig. 3). Johnson and Johnson (1971) reported that males tended to remain in Little Cutfoot Sioux Lake for two to three weeks after spawning while most females apparently emigrated back to Big Cutfoot

Table 11. Minimum rates of exploitation estimated for various groups of tagged walleye the first year after tagging, Lake Winnibigoshish and connecting waters, 1975-77.

Tagging site	Year	Sex	Type of tag	Rate of exploitation
Cutfoot Sioux Lake	1975	M	Floy dart	0.225
		F	Floy dart	0.320
Cutfoot Sioux Lake	1976	M	Floy dart	0.175
		F	Floy dart	0.139
Third River	1977	M	Disc-dangler	0.293
		F	Disc-dangler	0.326
Winnibigoshish Lake (Trawl)	1975	Both	Disc-dangler	0.235
Winnibigoshish Lake (Trawl)	1976	Both	Disc-dangler	0.269
Unweighted average		Both	Disc-dangler	0.268
		Both	Floy dart	0.179

Table 12. Summary of linear regressions of percentage of tags returned on total length for walleye tagged in spawning runs, Lake Winnibigoshish and connecting waters, 1975-77.

Year	Spawning run	Sex	No. of fish tagged	b	a	r
1975	Cutfoot Sioux Lake	M	693	-0.0195	0.4980	-0.594[a]
		F	125	-0.0281	0.8094	-0.650[a]
1976	Cutfoot Sioux Lake	M	938	-0.0107	0.3370	-0.465
		F	988	-0.0052	0.2298	-0.342
1977	Third River	M	468	-0.0125	0.4596	-0.292
		F	46	-0.0160	0.5492	-0.190

[a] $P < 0.05$.

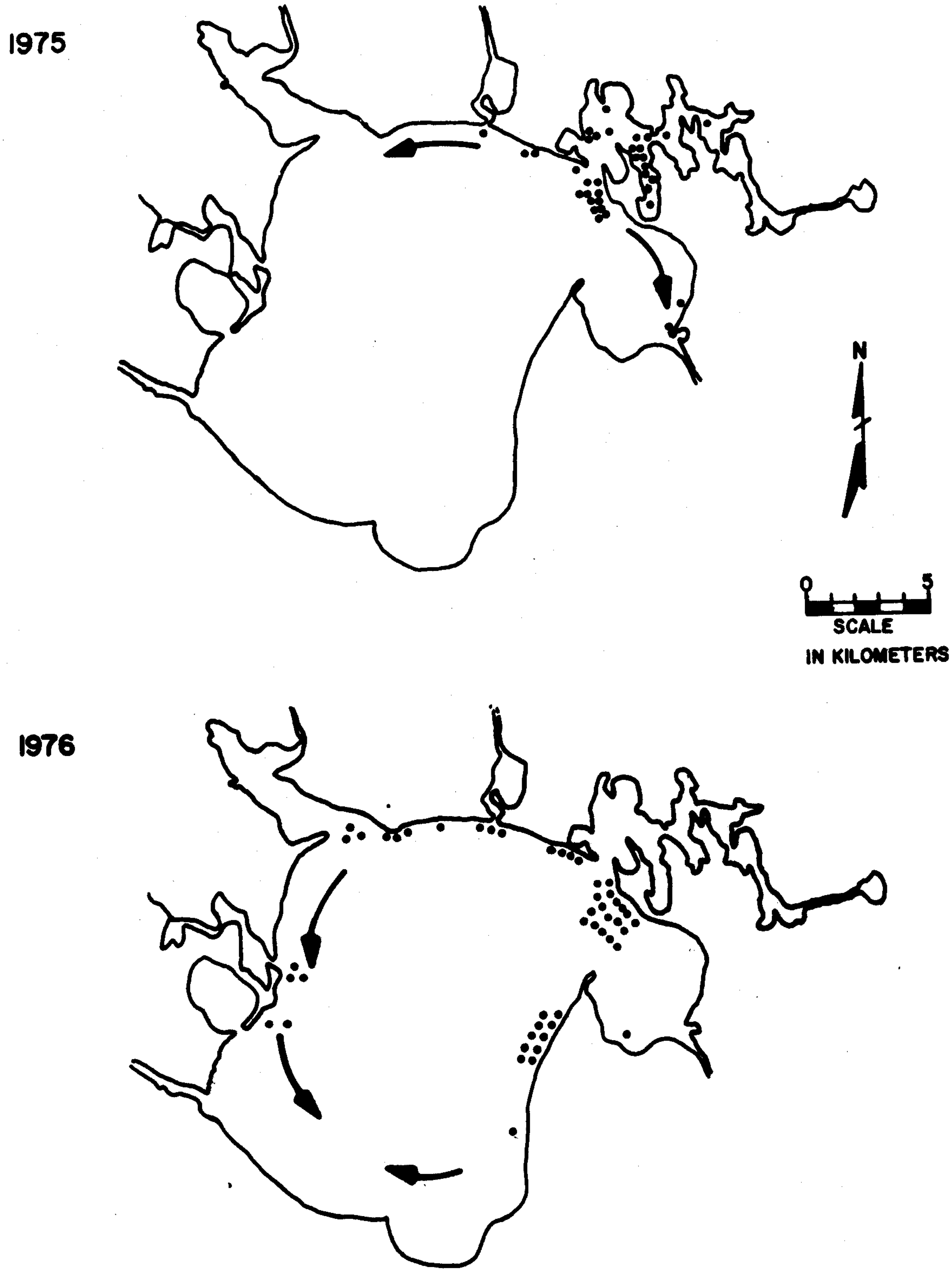

Figure 3. Reported tag returns of walleye marked in the Little Cutfoot Sioux Lake spawning run and caught the first weekend of the fishing season in Lake Winnibigoshish and connected waters, 1975 and 1976.

Sioux and Winnibigoshish lakes. During the first week of the 1975 season, tag returns from females were reported at a higher rate than males (X^2 = 13.05, P < 0.005) while in 1976 males were reported at higher rate than females (X^2 = 6.38, P < 0.025) (Table 13). This suggests that the rate of exploitation for females may be much higher when spawning occurs late in spring. More than 50% the tag returns from females were reported during the first week of the 1975 season compared to 31% of those from males. There were no significant differences in tag returns between sexes after 21 May during either season.

An earlier tagging study suggested that walleye in the Little Cutfoot Sioux spawning run were mainly from Lake Winnibigoshish that migrated through Big Cutfoot Sioux Lake and were vulnerable to angling in the latter lake only during the return migration (Johnson and Johnson 1971). During June and July, 86% of the walleye tagged in the 1975 and 1976 spawning runs and caught were reported from Lake Winnibigoshish (Table 14). This is identical to the value reported for marked male walleye caught after May in 1957-58.

In this study, there was evidence of a return of marked adult walleye to Big Cutfoot Sioux Lake from Winnibigoshish Lake beginning in August (Table 14). The ratio of fish reported from the two lakes differed significantly between May and June-July (X^2 = 17.78, P < 0.01) and between June-July and August through winter. Thus, mature walleye appear to begin assembling in Big Cutfoot Sioux Lake in the fall. At spawning time, these fish move upstream into Little Cutfoot Sioux Lake. Following spawning, a fairly rapid exit of fish (particularly females) occurs back through Big Cutfoot Sioux Lake into Lake Winnibigoshish. As they enter Lake Winnibigoshish, they tend to follow the shoreline in either direction until they reach their summer range, often associating with offshore reefs.

Table 13. Numbers of adult walleye tagged at the Little Cutfoot Sioux Lake spawning trap and reported caught by anglers in Cutfoot Sioux (CS) and Winnibigoshish (W) lakes at various times of the year, summer 1975 and 1976. Numbers in parentheses indicates the number tagged.

Number tagged	1975 Male (693)		1975 Female (125)		1976 Male (938)		1976 Female (988)	
	CS	W	CS	W	CS	W	CS	W
Tag returns								
May 15-21	21	27	10	12	39	35	21	28
May 22 - June 15	31	50	1	10	10	39	7	38
June 16 - August 31	3	16	0	7	8	12	4	15
Sept. 1 - Oct. 31	3	2	0	0	4	9	4	4
Total	58	95	11	29	61	95	32	85

Table 14. Distribution of tag returns reported by anglers by month and lake for walleye of both sexes tagged in the Little Cutfoot Sioux Lake spawning run, Lake Winnibigoshish and connecting waters, 1975 and 1976.

Month	Cutfoot Sioux Lake Number	Cutfoot Sioux Lake %	Winnibigoshish Lake Number	Winnibigoshish Lake %
May	81	34.8	152	65.2
June	18	14.1	110	85.9
July	3	13.0	20	87.0
August	9	64.3	5	35.7
September/October	8	36.4	14	63.6
Winter	2	28.6	5	71.4

LONG-TERM CHANGES IN THE SPORT FISHERY

Fishing Pressure

Fishing pressure by all methods increased by 60% from the late 1950's to the 1970's with summer angling accounting for most of the increased fishing effort (Table 15). Summer fishing pressure increased by more than 440% from 1939 to the 1950's and by 61% from the 1950's to the 1970's.

Table 15. Changes in sport fishing pressure mean annual manhours/ha, Lake Winnibigoshish and connected waters (range in parentheses), 1939 to 1977.

	1939[a]	1957-58	1975-78
Summer angling	3.43	18.56 (16.70-20.39)	29.90 (26.7-32.1)
Winter angling	-	0.25 (0.12-0.37)	0.59 (0.15-0.95)
Darkhouse spearing	-	1.09 (0.96-1.21)	1.47 (1.19-1.71)
Late winter angling		-	3.68[b]
TOTALS	3.43	19.90 (17.78-21.97)	31.96 (35.64)[b] (26.7-32.1)

[a] Data for summer angling only.
[b] Angling through the ice after 15 February, censused only in 1978.

Since 1939, fishing pressure has increased 771%. The average rate of increase between the earlier periods was 23% while between the later periods it was 2.5%.

The increase in fishing effort on the lake complex since 1957-58 has been focused on Lake Winnibigoshish. Mean annual summer fishing pressure was 12.6 manhours/ha in 1957-58 and increased by 94% to 24.4 manhours/ha during 1975-77. Summer fishing pressure on the Cutfoot Sioux lakes decreased 9% during the same period.

The distribution of effort within the season has changed little since 1939. Between 40 and 50% of summer fishing pressure occurred during the first six weeks of the season while the rest was distributed evenly from July through October.

Winter sport fishing pressure has also increased since 1957-58. Darkhouse spearing pressure was 35% higher in the 1970's while winter angling pressure was 136% higher. The major increase in winter angling apparently occurred while this study was in progress. Winter angling pressure increased 400% from 1975-76 to 1977-78 for the period 1 December through 15 February. Most of this increase was the result of greater interest in yellow perch angling particularly by Wisconsin residents.

Increased angling for perch was also evident for the period after 15 February in 1976-77 and 1977-78. The estimated fishing pressure of 3.7 manhours/ha after 15 February 1978 was 10% of the total effort for the 1977-78 open-water and ice-fishing season. Winter fishing made up 7.0% of all effort in the 1950's but by the winter of 1977-78, fishing through the ice made up 17% of the total effort.

Total Harvest

Since 1939, the total catch has increased, the species composition of the catch has changed and winter fishing seasons have become increasingly important contributors to the annual harvest. Total yield increased by 67% between 1939 and the 1950's and 27% between the 1950's and the 1970's (Table 16).

The principal reason for the increased yields was a steady increase in the harvest of walleye and an abrupt increase in the harvest of yellow perch. The relative contribution of walleye to the total yield has changed little since 1939 (Fig. 4). The increased acceptance of perch by anglers has been the major change in the composition of the catch. In some years, perch may comprise more than 50% of the catch by number and the yield may equal or exceed those of walleye and northern pike. Maloney (1978) also noted an increased acceptance of yellow perch at Mille Lacs Lake since the early 1960's.

Table 16. Changes in sport fishing yields (kg/ha), Lake Winnibigoshish and connecting waters (range in parentheses), 1939 to 1977.

	1939[a]	1957-58	1975-77
Summer angling	3.6	5.6 (4.1-7.1)	6.9 (4.9-8.0)
Northern pike	2.0	2.6 (1.7-3.4)	1.9 (1.6-2.2)
Yellow perch	<0.1	0.3 (0.3-0.4)	1.2 (0.6-1.7)
Walleye	1.5	2.6 (2.0-3.1)	3.6 (2.4-4.1)
Other species	<0.1	0.1	0.2
Winter angling	-	<0.1	0.4
Northern pike	-	<0.1	<0.1
Yellow perch	-	<0.1	0.3 (0.1-0.7)
Walleye	-	<0.1	<0.1
Darkhouse spearing			
Northern pike	-	0.3 (0.2-0.3)	0.3(0.2-0.3)
Late winter angling[b]			
Yellow perch	-	-	3.7
All methods combined	3.6	6.0 (4.4-7.4)	7.6 (5.2-9.2)[c]
Northern pike	2.0	2.9 (2.0-3.8)	2.2 (1.9-2.7)
Yellow perch	<0.1	0.3 (0.3-0.4)	1.6 (0.7-2.4)[c]
Walleye	1.5	2.7 (2.0-3.1)	3.6 (2.4-4.1)
Other species	<0.1	0.1	0.2 (0.1-0.2)[c]

[a] Summer creel census only.
[b] Angling through the ice after 15 February 1978.
[c] Does not include harvest through the ice after 15 February.

Walleye Fishery

The changes in the walleye fishery between 1939 and 1958 (Johnson and Johnson 1971) have continued in the same direction over the last two decades. Walleye yields have increased, the age and size structure of the catch has changed and the average size of fish caught has declined. Catch rates were similar in the 1950's and the 1970's but this was mainly the result of an increased harvest of younger fish. From 1939 to the 1950's, the yield increased by 1.2 kg/ha and between the 1950's and the 1970's by 0.9 kg/ha. The average yield in the 1970's was 2.4 times that of 1939 (Table 16).

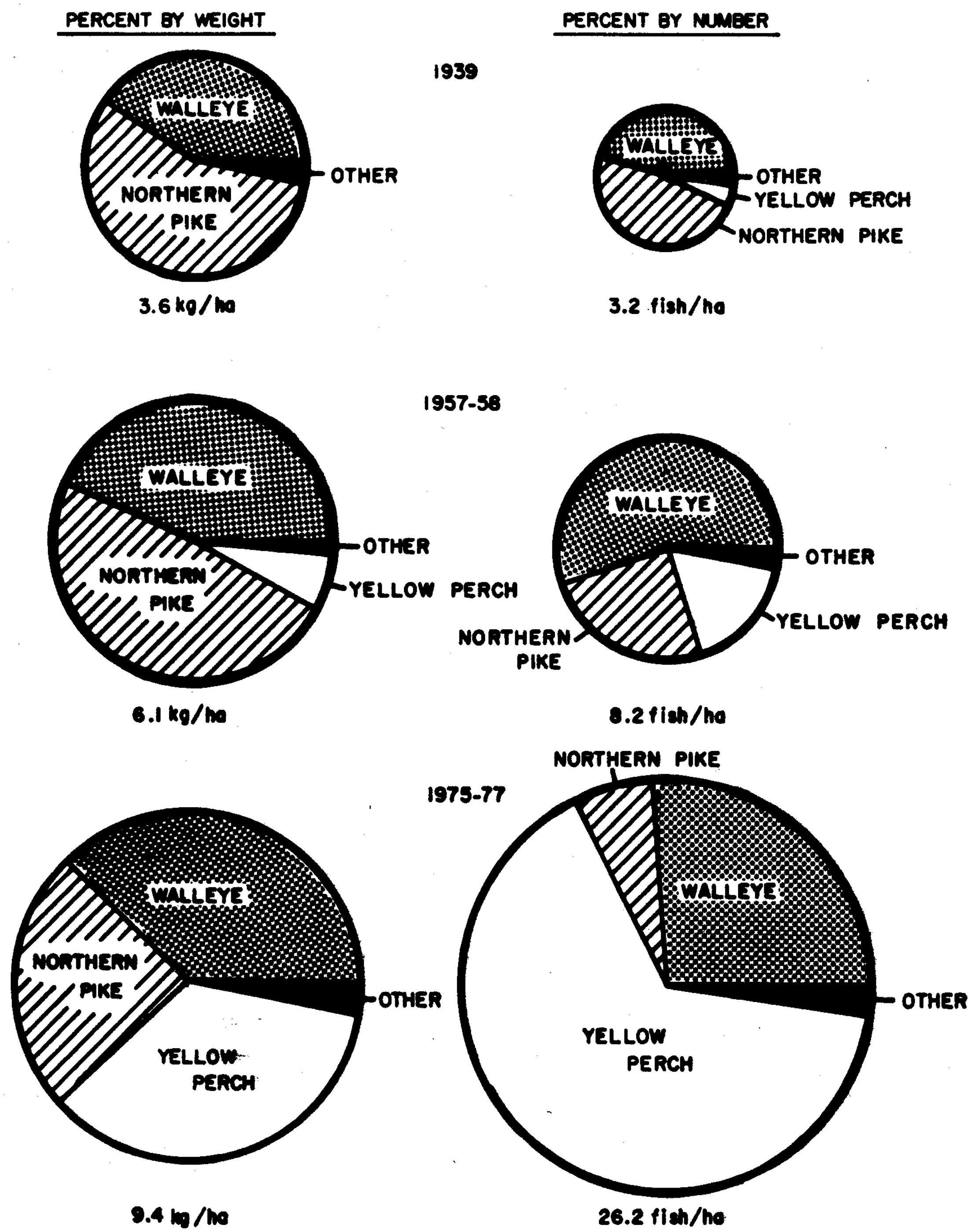

Figure 4. Composition (%) of the sport fishing catch in weight (kg) and numbers/hectare from Lake Winnibigoshish and connected waters, 1939, 1957-58 and 1976-77. Relative size of the diagram facilitates comparison of between year harvest.

An increase in the harvest of walleye younger than age V accounted for most of the increase in walleye yields since the 1950's (Table 17; Fig. 5). The estimated numbers of walleye harvested increased by 56% from the 1950's to the 1970's. The harvest of fish younger than age V more than doubled while the harvest of fish age V and older declined slightly. The change in harvest of older fish is probably not significant since sampling error is larger than the difference. Since 1939, the harvest of walleye of all sizes has increased 355%.

The increased harvest of younger fish has led to a continuing decline in the average size caught (Table 18). From 1939 to the 1950's, average weights of harvested walleye declined 39% and from the 1950's they declined 12%. The average weight of harvested walleye during the 1970's was 54% of that harvested during 1939.

Catch rates for walleye declined substantially between 1939 and the 1950's but were identical in the 1950's and 1970's (Table 19). The catch/manhour in the 1950's was 46% lower than in 1939. The increased harvest of younger fish was the principal reason that catch rates were similar in the two recent census periods. Since the 1950's, the catch rate of walleye less than age V increased 50% while the catch rate of walleye age V and older decreased 42% (Table 17).

The changes in the walleye population are more subtle than the changes in harvest. Johnson and Johnson (1971) estimated annual mortality from all causes to be 44% from a simple catch curve based on the age frequency of the angler's catch. This is identical to the value estimated for this study for age V and older walleye. The estimates for the 1957-58 study were recalculated using the Robson-Chapman method (Robson and Chapman 1961). The recalculated estimate for the 1950's was 41% which indicates that annual mortality has not appreciably changed.

Table 17. Changes in the estimated summer harvest and catch rate of walleye less than age V and age V and older between 1957-58 and 1975-77, Lake Winnibigoshish and connecting waters.

	1957-58 average	1975-77 average	Percent change
Estimated total harvest	108,942	169,708	55.8
Harvest, < age V	49,350	113,548	130.1
Harvest, age V and older	59,592	56,160	-5.8
Catch/manhour, < age V	0.10	0.15	50.0
Catch/manhour, age V and older	0.12	0.07	-41.7

Table 18. Mean weight (kg) of fish harvested from 1939 to 1978, Lake Winnibigoshish and connected waters (range in parentheses).

	1939[a]	1957-59	1975-78
Summer angling			
Northern pike	1.36	1.44 (1.27-1.54)	1.31 (1.21-1.39)
Yellow perch	0.37	0.27 (0.26-0.29)	0.20 (0.18-0.21)
Walleye	0.99	0.60 (0.59-0.62)	0.53 (0.50-0.60)
Winter angling			
Northern pike	-	1.71 (1.69-2.00)	1.29 (0.98-1.53)
Yellow perch	-	-	0.20 (0.20-0.21)
Walleye	-	0.92 (0.88-0.97)	0.61 (0.49-0.94)
Darkhouse spearing			
Northern pike	-	1.86 (1.78-1.93)	1.85 (1.74-1.94)
Spring angling[b]			
Yellow perch	-	-	0.20

[a] Summer creel census only.
[b] Angling through the ice after 15 February 1978.

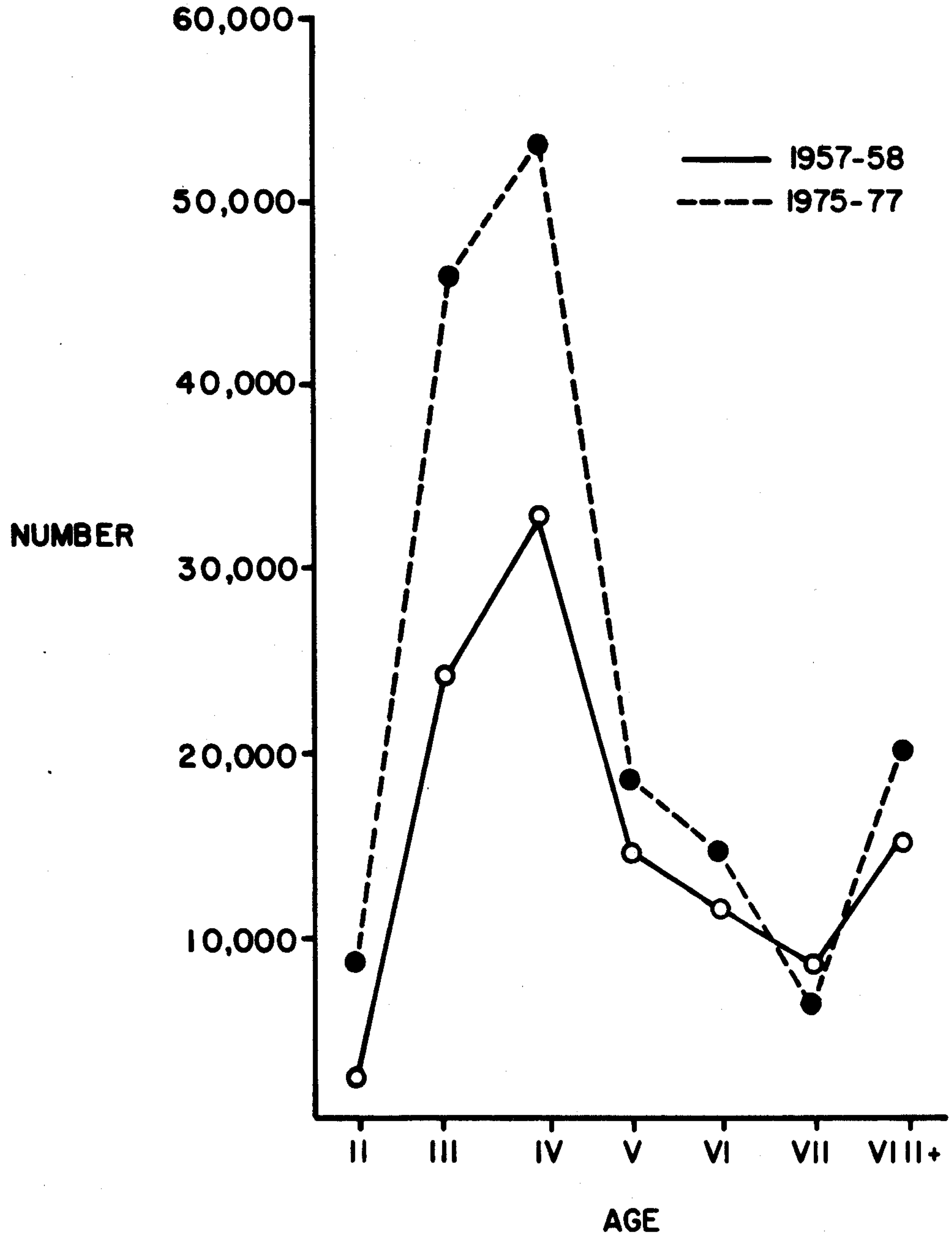

Figure 5. Comparative walleye harvest by age-class for 1975-77 (dashed line) and 1957-58 (solid line) for Lake Winnibigoshish and connected waters.

Table 19. Fishing success (catch per manhour) from 1939 to 1978, Lake Winnibigoshish and connected waters (range in parentheses).

	1939[a]	1957-59	1975-78
Summer angling			
Northern pike	0.41	0.09 (0.09-0.10)	0.06 (9.95-0.09)
Yellow perch	0.03	0.05 (0.03-0.07)	0.23 (0.13-0.30)
Walleye	0.41	0.22 (0.20-0.28)	0.22 (0.16-0.29)
Winter angling			
Northern pike	-	0.06 (0.02-0.08)	0.03 (0.02-0.03)
Yellow perch	-	-	2.47 (0.42-4.01)
Walleye	-	0.09 (0.06-0.15)	0.03 (0.01-0.05)
Darkhouse spearing			
Northern pike	-	0.15 (0.14-0.16)	0.12 (0.12-0.12)
Spring angling[b]			
Yellow perch	-	-	4.95

[a] Summer creel census only.
[b] Angling through the ice after 15 February 1978.

The rate of exploitation apparently increased at a far greater rate than total mortality. Minimum rates of exploitation estimated in the 1970's averaged 25% (Table 11) and ranged from 14 to 33%. Estimates of the true rate of exploitation in the 1950's were 11 and 22% in 1957 and 1958 (average 16.5%), respectively (Johnson and Johnson 1971). Stoudt and Eddy (1939) reported that 8% of the tagged walleye were caught from 1937 to 1939. Most of the walleye caught by mid-summer trawling and tagged in 1975 and 1976 were immature but rates of exploitation were similar to those for adult fish tagged from spawning runs.

Since exploitation has increased between the two most recent studies and the harvest of age V and older walleye has not significantly changed, the abundance of adult walleye must have declined since 1958. A minimum estimate of this decline is 38%. This value is similar to the estimated reduction in catch rate for older walleye (Table 17).

There is evidence that anglers have become more proficient at harvesting mature walleye during the 1970's. A comparison of catch curves based on length frequencies from spawning runs and the angler's catch for the two recent study periods indicated that anglers were catching adult walleye more nearly in proportion to their abundance in spawning runs during the 1970's. Analysis of covariance indicated that the $\log_{10}$ frequencies of walleye 432 mm TL and larger in the spawning runs differed significantly from the frequencies in the angler's catch during the 1950's but not during the 1970's (Table 20). There were no significant differences in the size frequencies of spawning males 381 mm TL and larger and females 457 mm TL and larger between the two periods.

Serns and Kempinger (1981) and Serns (1978) demonstrated that the rate of exploitation for walleye decreased with size and age in Escanaba Lake, Wisconsin. The analysis of length frequencies from the 1950's indicates that this was also the case at Lake Winnibigoshish but there has been a marked change since then. Larger walleye still appear to be slightly less vulnerable to angling at Lake Winnibigoshish. The mean length at tagging of walleye marked in spawning runs and caught by anglers the following summer was lower than the mean length of all fish tagged for both sexes and all three years of the recent study (Table 21). The differences were statistically significant ($P < 0.05$) when data for all years were combined.

Conclusive evidence of compensatory changes in the walleye population as a result of exploitation is lacking. Spangler et al. (1977) stated that the most conspicuous responses of percids to exploitation are increased growth rates, reduction in age of first spawning and increased variability of recruitment. Walleye growth rates in the 1970's were similar to those in the 1950's and there was no change in age of first spawning for either sex. The dominance of the 1973 year-class in the catches of 1976 and 1977

Table 20. Summary of covariance statistics of length frequencies ($\log_{10}$) for adult walleye in spawning runs and in the angler's catch, Lake Winnibigoshish and connecting waters.[a,b]

Comparison	Years	Regression statistics: Intercept a	slope b	Correlation coefficient r	F-test, slopes	d.F.	Probability of F occurring by chance
Spawning runs							
Male ≥ 381 mm TL	1951,57,58,69	2.9561	-0.2452	-0.938			
Male ≥ 381 mm TL	1975-77	2.9795	-0.2738	-0.994	0.64	1,14	0.439
Female ≥ 457 mm TL	1951,57,58,69	2.9015	-0.1908	-0.885			
Female ≥ 457 mm TL	1975-77	2.6264	-0.1580	-0.945	0.74	1,18	0.401
Both sexes ≥ 432 mm TL	1951,57,58,69	2.6206	-0.1430	-0.962			
Both sexes ≥ 432 mm TL	1975-77	2.6141	-0.1448	-0.982	0.01	1,18	0.917
Anglers catch							
≥ 432 mm TL	1957-58	2.8673	-0.2260	-0.982			
≥ 432 mm TL	1975-77	2.5774	-0.1448	-0.996	33.96	1,18	0.001
Spawning run ≥ 432 mm TL	1951,57,58,69	2.6206	-0.1430	-0.962			
Anglers catch ≥ 432 mm TL	1957-58	2.8673	-0.2260	-0.982	16.91	1,18	0.001
Spawning run ≥ 432 mm TL	1975-77	2.5774	-0.1448	-0.982			
Anglers catch ≥ 432 mm TL	1975-77	2.6147	-0.1366	-0.996	0.72	1,18	0.408

[a] Spawning run length frequencies for the earlier years are from Johnson (1971) and are a composite of length frequencies from the 1951, 57, 58 and 69 runs at Little Cutfoot Sioux Lake.

[b] Spawning run length frequencies for the later years are a composite from the 1975-77 runs at Little Cutfoot Sioux Lake.

Table 21. Mean total length (mm) at time of tagging of walleye marked and caught by anglers and of all walleye marked in the Little Cutfoot Sioux Lake and Third River spawning runs, Lake Winnibigoshish and connecting waters, 1975-77. Sample sizes in parentheses with standard deviation listed below the mean length.

	Males		Females	
Year	Tagged	Recaptured by anglers	Tagged	Recaptured by anglers
1975[a]	386(693) 41.4	381(135) 45.2	463(125) 62.0	450(40) 54.1
1976[a]	414(938) 47.8	407(162) 39.1	513(988) 67.8	505(135) 61.0
1977[b]	382(468) 43.4	379(137) 41.1	491(46) 59.4	490(15) 30.0
1957-77	398(2,099) 43.4	390(434) 39.6	507(1,159) 66.8	493(190) 57.9

[a] Little Cutfoot Sioux Lake
[b] Third River

may be a symptom of increased variability in recruitment, however, there are no comparable data series to indicate that the variability differed in the two recent study periods.

Northern Pike Fishery

Northern pike contributed a substantial portion of the total yield during all three studies (Fig. 4). They comprised 56, 48 and 29% of the yield during 1939, 1957-58 and 1975-77 studies, respectively. By number, they comprised 47, 33 and 10% of the catch, respectively.

The northern pike sport fishery has changed little since 1939. Annual yields have varied from 2.0 to 2.9 kg/ha and no trends in yield were evident (Table 16). The relative proportion of the catch taken by angling and by darkhouse spearing was also similar in the 1950's and the 1970's.

The average sizes of harvested northern pike were also similar for the three studies (Table 18). Northern pike caught by summer anglers averaged 1.4 kg and ranged from 1.3 to 1.4 kg. The average weights of pike harvested by darkhouse spearing were identical in the 1950's and the 1970's. Winter anglers in the 1970's harvested pike that were substantially smaller than those taken in the 1950's but only about one percent of the harvest was taken by this method.

The major change in the northern pike sport fishery was a decline in catch rates by angling (Table 19). This decline was roughly proportional to the increase in fishing pressure. The catch rate by darkhouse spearers was slightly lower during the 1970's than during the 1950's.

Yellow Perch Fishery

The phenomenal increase in the harvest of yellow perch during the course of this study was noted earlier but increasing interest in perch by anglers was already evident in the 1950's. The summer yield of perch has increased from less than 0.1 kg/ha to 1.2 kg/ha (Table 16). Since 1958, the yield of perch has increased 400% during the period mid-May to 15 February. The addition of the large, late-winter harvest in 1978 increased the 1977-78 yield compared to the 1939 summer yield by 370%. It is assumed that most of the harvest in the 1930's occurred in summer.

Catch rates for yellow perch have also increased dramatically. Between 1939 and the 1950's, summer catch rates increased 67% and they increased 360% between the 1950's and the 1970's (Table 19). The average size of harvested yellow perch has declined since 1939 (Table 18). The mean weight of perch caught and kept in the 1970's was 26% lower than in the 1950's and 46% lower than in 1939. The increased catch rates and smaller average size of retained fish is likely the result of increased angler acceptance.

DISCUSSION

Increased fishing pressure almost certainly caused the changes that have been observed in the walleye sport fishery at Lake Winnibigoshish in the last 40 years. The increase in effort was measured but anglers also have more sophisticated equipment and the knowledge of successful fishing techniques is more widely disseminated. Shoreline erosion may have damaged some walleye spawning areas but strong year-classes are still regularly produced. There were no other evident changes and the species composition of the sport fishing catch during the three studies suggests that there has been little change.

The most conspicuous responses of percids to exploitation are increases in growth rate, reduction in age of first spawning and changes in variability of recruitment (Spangler et al. 1977). Growth rates observed in this study were similar to those in the 1950's and age of first spawning for either sex did not change. The dominance of the 1973 year-class in the catch in 1976 and 1977 may be a symptom of increased variability in recruitment, however, there are no comparable data series to indicate that the 1950's and the 1970's differed. The nearly two-fold variation in annual walleye harvest during this study (Table 2) was the greatest observed for large walleye lakes censused in Minnesota but is small compared to the 11-fold variation observed at Lake Oneida, New York (Forney 1980). Greater fluctuations in commercial yields have also been noted at Red Lake, Minnesota (Smith 1977) and at Shoal Lake, Ontario (Schupp and Macins 1977).

The similarity of the harvests of walleye age five and older in the 1950's and 1970's, though exploitation rates have increased, indicates a marked decline in abundance of older fish. This is further corroborated by the evidence that anglers have become more proficient at catching adult walleye. The decrease in vulnerability with size and age noted by Serns (1981) is still evident at Lake Winnibigoshish but anglers were harvesting walleye >432 mm TL nearly in proportion to their abundance in the spawning runs in the 1970's. This is in sharp contrast to the 1950's.

Changes in the walleye sport fishery between 1939 and the 1950's (Johnson and Johnson 1971) continued between the 1950's and the 1970's. Yield increased and the average size harvested decreased. Catch rates in the 1950's and 1970's were similar only because of the huge increase in harvest of walleye age-classes III and IV. The decline in catch rate of walleye age V and older was almost inversely proportional to the increase in summer fishing pressure.

The northern pike yield exceeded that of walleye in 1939 but was relatively less important in the recent studies. The stability of the northern pike fishery since 1939 is probably the result of a pike harvest that is largely incidental to walleye fishing. Spawning habitat for pike is ample and so long as most fishing effort is directed at walleye the stable pike fishery should continue.

Continued intensive harvests of yellow perch, such as that in 1978, would substantially alter the community dynamics of Lake Winnibigoshish. Adult perch of the size taken by anglers are not particularly vulnerable to predation and are a resource that was previously under-utilized. A large reduction in abundance of adult perch should stimulate greater recruitment which in turn could influence the walleye fishery. Walleye in Lake Oneida, New York were most vulnerable to exploitation when perch abundance was low (Forney 1980). Continued high recruitment of perch could reduce walleye fishing success and contribute to faster walleye growth rates, thus mitigating to some extent the effects of high exploitation. Interest in yellow perch angling will likely continue to increase, however it is unlikely that the huge harvest of perch in late-winter 1978 will be annually repeated. Winter fishing pressure is dependent on the severity of the winter. When snowfall is high, travel on the lake is difficult and fishing pressure is low.

A continuation of the trends noted in the walleye fishery since 1939 can be expected if fishing pressure continues to increase. Greater variation in recruitment would likely occur, leading to wider oscillations in fishing success from year-to-year. The harvest of adult walleye more nearly in proportion to their abundance can also be expected to continue. Increases in growth rate and earlier age of spawning may compensate for some of the reduced abundance of adult walleye.

MANAGEMENT IMPLICATIONS

Forney (1980) pointed out that exploitation of walleye is difficult to control through regulations. At current levels of exploitation on Lake Winnibigoshish, the walleye fishery would probably continue to yield harvests similar to those observed from 1975 through 1977. Yearly monitoring is necessary to document any changes in exploitation or the population structure. If increased fishing pressure leads to a more unstable fishery, stringent regulations would have to be applied to reduce exploitation. Regulations tailored to Lake Winnibigoshish would be the most effective means of regulating the harvest.

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