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The Walleye Sport Fishery in Three Upper Mississippi Reservoir Lakes: Cass, Andrusia, and Big Wolf, 1971-75.[1/]

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The Walleye Sport Fishery in Three Upper Mississippi Reservoir Lakes: Cass, Andrusia, and Big Wolf, 1971-75

by

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ABSTRACT

The walleye sport fishery in the Upper Mississippi reservoir lakes of Cass, Andrusia, and Big Wolf is one of the most intensive in Minnesota. The annual mortality of walleye (0.59) was the highest observed in a sport fishery and voluntary tag returns suggest that fishing was the main cause of this mortality. Exploitation rates were higher for male and juvenile walleye than for females. Females tagged in three stream spawning runs were caught at higher rates in Cass Lake, the second lake downstream from each run, than in the first downstream lake. Walleye yields were within the ranges usually observed and were relatively stable from Cass Lake, but yields from Andrusia and Big Wolf lakes rose during the study. Most of the increase in yields was the result of recruitment of two strong year classes, but fishing pressure increased and there is some evidence that the rate of exploitation also rose. Mean age of harvest declined from 4.9 to less than 4.0 during the course of the study. Age classes III and IV made up 75% of the harvest from 1973 to 1975. The average weight of walleye harvested declined from 1.1 to 0.8 pounds. Walleye tagged in stream spawning runs were strongly associated with one lake in each case, but fish from all three runs were recaptured from each of the study lakes. Similarly, trawl-caught walleye tagged in summer tended to remain in the lake where tagged, but 20-30% of these fish moved to other study lakes. Numbers of walleye caught in stream spawning runs were near levels counted or estimated in the 1930's and 1940's and may account for 20-60% of all spawning walleye in the

system. Walleye spawning in the Mississippi River was unsuccessful. Currents drifted many eggs away from suitable substrates and heavy growths of filamentous algae and periphyton during the incubation period apparently impaired metabolism and killed those eggs that did settle on clean riffle areas. The study lakes can probably continue to support an intensive walleye fishery so long as spawning habitat is maintained and movement of brood stock is unimpeded.

INTRODUCTION

An important sport fishery for walleye (Stizostedion vitreum), northern pike (Esox lucius), and muskellunge (Esox masquinongy) exists in the Upper Mississippi reservoir lakes composed of Cass, Andrusia, and Big Wolf lakes and the connecting portions of the Mississippi River. These lakes have a combined area of approximately 30,000 acres and naturally reproducing fish populations that support a substantial resort industry, which places principal emphasis on the walleye as a sport fish.

The investigation reported here was conducted from 1971 through 1975 with the following objectives: (1) determine current status and yield of fish populations of the inter-connected lake complex composed of Cass, Andrusia, and Big Wolf lakes with particular emphasis on the walleye; (2) delineate the major walleye spawning groups within this lake-river complex and determine whether they were co-mingling or discrete populations; and (3) establish a data base from which to monitor changes in fish populations, resulting from or influenced by, accelerating eutrophication due to sewage effluent discharge into the Mississippi River above the study lakes.

Study Lakes

The study lakes are located in north central Minnesota, primarily in the southeast corner of Beltrami County, with portions of the lakes in northeastern Hubbard and northwestern Cass counties (Fig. 1). They lie in a glacial moraine area characterized by a relatively broad, flat highland covered by numerous lakes, swamps, and low hills. They are hardwater lakes with an average total alkalinity of 150 mg./L. All are easily accessible and shoreline development in the form of cottages and resorts is extensive.

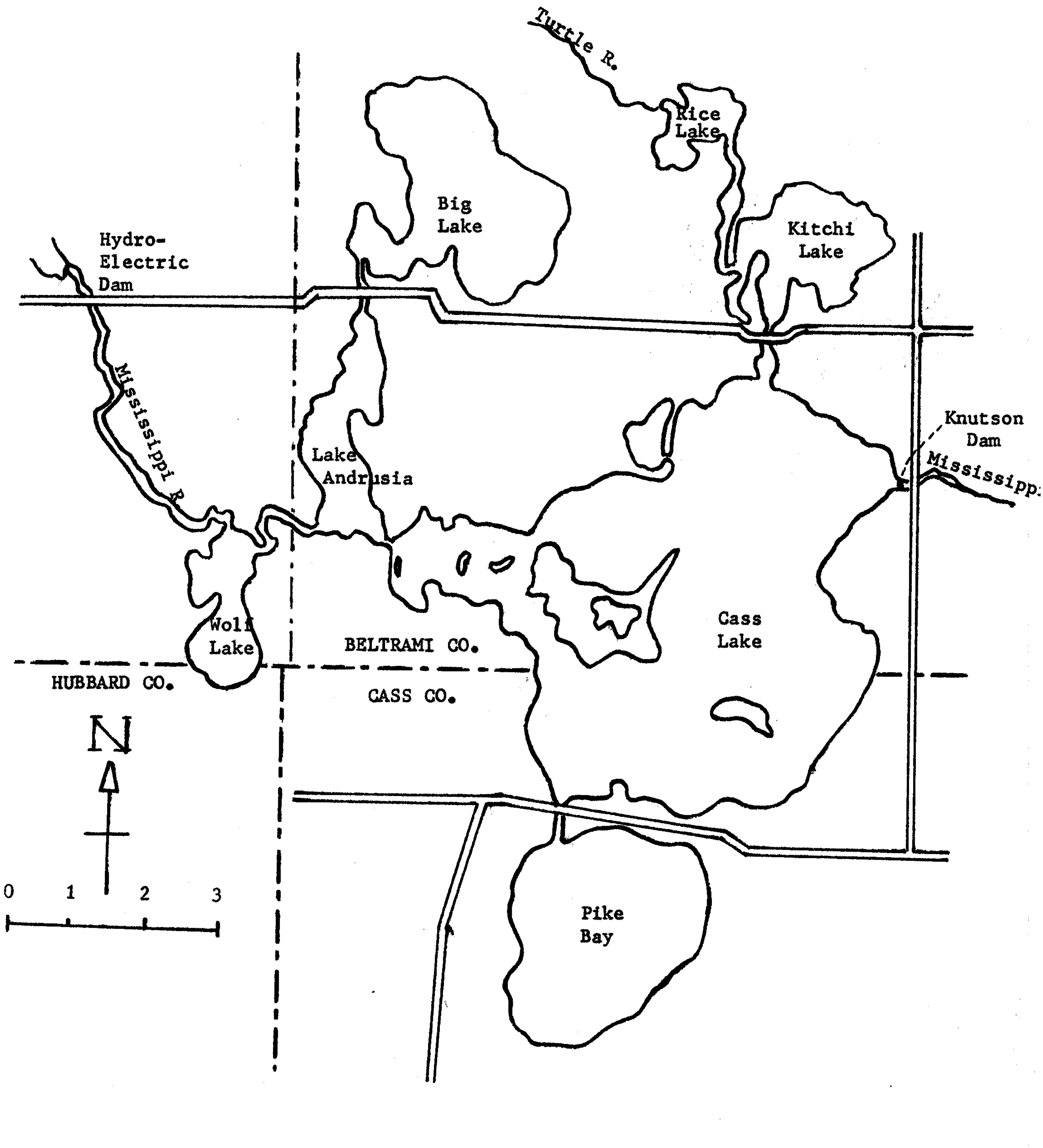

Fig. 1. Upper Mississippi reservoir lakes study area.

There are two river systems associated with the study lakes. The principal system is the Mississippi which flows through all three study lakes. The Mississippi watershed above Knutson Dam (outlet of Cass Lake) drains about 1,088 square miles. The Turtle River watershed drains into Cass Lake and has a drainage area of 270 square miles.

Initially, Pike Bay was included in the study area. Pike Bay is a 4,760 acre body of water situated in northwestern Cass County just to the south of, and connected to, Cass Lake. Because of relatively low fishing pressure, a low walleye population, and an apparently insignificant interchange of fish with the other lakes, it was dropped from the area of study after one year. Estimates of fishing pressure and harvest for the year of investigation are included in an appendix table.

Big Wolf Lake, with 1,051 surface acres, is the smallest of the study lakes and the farthest upstream on the Mississippi River. It has an irregular shoreline and a gently sloping basin with a maximum depth of 58 feet and a mean depth of 28 feet. There are scattered beds of hardstem bulrush (Scirpus acutus).

Submerged aquatic plants are abundant, and the lake is subject to nuisance algal blooms. There are seven resorts on the lake. A hydro-electric dam on the Mississippi River five miles above Big Wolf Lake is a barrier to upstream fish movement.

Andrusia Lake is approximately one mile downstream from Big Wolf and covers 1,510 surface acres. The lake is long and narrow on a north-south axis and has a gently sloping basin with a maximum depth of 60 feet and a mean depth of 26 feet. Scattered stands of hardstem bulrush are present and submerged aquatic plants are abundant.

Cass Lake, the largest of the study lakes, is one-half mile downstream from Andrusia and covers 15,600 surface acres not including four sizeable islands. There are eighteen resorts, four youth camps, and one large marina on the lake.

The village of Cass Lake is located near the southwest corner of the lake. There is considerable undeveloped shoreland under federal ownership which is administered by the Chippewa National Forest. These holdings are primarily along the east shore and on the islands, but include other scattered parcels. The Turtle River empties into Cass Lake from the north and a one mile flowage of this stream separates Cass Lake from Kitchi Lake to the north. A marsh and channel connects Cass Lake with Pike Bay. Water levels are controlled by a dam on the Mississippi River outlet of Cass Lake (Knutson) which is operated by the U.S. Forest Service.

Cass Lake differs from Big Wolf and Andrusia in that a smaller proportion of the lake is littoral. The lake consists of several deep basins separated by bars and extensive shoal areas. The dropoffs, from the bars, are usually quite sharp and maximum depth is 120 feet. The mean depth is 25 feet. The bottom soils are primarily sand and clay. On the main part of the lake, the shoreline is largely sand with patches of gravel and rock. There are scattered stands of bulrush, but submerged vegetation is sparse due to the sand bottom and wave action. In Allen's Bay, near the mouth of Pike Bay, and along the west side of Star Island the shoreline is swampy and submerged vegetation is common.

Previous investigations of Cass Lake have included lake surveys in 1936 and 1948 and a special investigation of bullhead removal in 1943. The U.S. Fish and Wildlife Service prepared a report on fish and wildlife resources in relation to water development plans for Cass Lake in 1950[1/].

Investigations on Andrusia Lake have included test-netting (hoopnets) in 1945 to determine the status of the bullhead population, a lake survey in 1948, and test-netting (gillnet) in 1969 for walleye and northern pike.

1/ A preliminary evaluation report on fish and wildlife resources in relation to the water development plans for Cass Lake, Minnesota, Mississippi headwaters, Upper Mississippi river basin. Fish and Wildlife Service, U.S. Dept. of the Interior.

Big Wolf Lake was also test-netted in 1945 to determine the status of its bullhead population and lake surveys were conducted in 1948 and 1970.

The creel census method used for the first three years of study (1971-73) was that described by Schupp (1964) for use on large lakes. The lakes were divided into 28 sampling areas of a size that could be covered by one man. Four census clerks sampled four areas each day for two hours on 6 of every 8 days between mid-May and October 1. Clerks were rotated among census areas on a randomized schedule. For purposes of calculation, a census day was considered to be 16 hours long (6 a.m. to 10 p.m.).

The creel census method was changed for 1974 and 1975 to alleviate criticism of "idle" census clerks operating out of resorts. The creel census method used was that described by Daley and Skrypek (1964). Wolf and Andrusia Lakes were each treated as one sampling sector and Cass Lake was divided into five sectors to accommodate instantaneous angler counts. Census clerks, operating by boat, rotated through the sectors and worked each for a two-hour period. Three sectors were sampled each census day and a half hour was allowed for travel to the beginning sector and for travel time between sectors. The change allowed a reduction in manpower from four to two census clerks.

The major differences between the methods were in the method of counting anglers and in a change from contacting completed trips to incompleted trips. Recent studies by Fierstine, et al (1978) and Malvestuto, et al (1978) indicate that angler catch rates calculated from incomplete and complete trips do not differ significantly. The reduction from four to two census clerks was accompanied by a 16% reduction in hours sampled (Table 1). It was estimated that more than 95% of the anglers present in a sampling area were contacted during the hours sampled by either method.

Table 1. Percentage of fishing hours sampled on Upper Mississippi reservoir lakes using different census methods.

	% of hours sampled		
Lake	Summer 1971-73	Summer 1974-75	Winter 1971-72
Cass	4.1	3.3	5.0
Andrusia	4.0	3.1	5.3
Big Wolf	3.4	3.2	6.7
Pike Bay	2.5	-	7.3

Winter census was conducted for only one season (1971-72) on Cass, Andrusia, Big Wolf, and Pike Bay since there was almost no angling for walleye. The creel census method used was a modification of that described by Schupp (1964) for use on large lakes. The lakes were divided into 12 sampling areas. Two census clerks censused two areas each day for 4 hours on 6 of every 8 days between December 1 and mid-February. Weekly fish house counts were made through the season tallying total structures on each lake and also the number of houses in the areas which were being censused. Estimates of pressure and harvest were made for the houses in the areas censused and the data was expanded to total houses on the lake.

River spawning concentrations of walleye were captured by pound net to determine number, sex ratios, size distributions, and temporal sequence of spawning migrations. Walleye captured in the runs were tagged with disc-dangler tags to provide information on the source of the fish comprising the runs. Big Lake Creek was monitored in 1971, the Turtle River in 1972, and the Mississippi River above Big Wolf Lake in 1973.

The quality of spawning habitat and status of walleye reproduction in the Mississippi River above Big Wolf Lake to the hydro-electric dam was evaluated from 1971 to 1973. Egg deposition sites, rate of development and hatching success were examined by systematic egg sampling with scap nets. Fry traps were operated to determine time and duration of fry drift and relative abundance.

Population sampling was conducted for four years (1971-74), using a 25-foot otter trawl, 250-foot multi-mesh gill nets, and a 100-foot by 6-foot quarter-inch mesh seine. The trawl was operated at selected stations during June, July, and early August each year. Walleye over 9.7 inches TL captured in the trawl were tagged to provide data on distribution and movement. Shoreline seining was conducted on a systematic basis in mid-August each year to provide an index of walleye reproductive success and to provide comparative catch data for young-of-year and yearling fishes. Standard Minnesota graduated mesh gill nets were fished each year from late August to late September to provide baseline data on relative abundance of walleye and other species.

FINDINGS

Fish Population Structure

The population structure of the study lakes is typical of walleye waters in north central Minnesota. Walleye and northern pike are the main predators. Yellow perch (*Perca flavescens*) are abundant and are probably the most important prey species.

Gillnetting indicated that walleye and yellow perch catches were above statewide medians and northern pike catches were about average. Catches of walleye and northern pike were highest in Andrusia Lake and lowest in Big Wolf Lake (Table 2). Yellow perch catches were highest in Cass and Big Wolf lakes. No consistent significant differences were evident nor were any temporal trends noted in the gillnet catches.

Yellow perch, walleye, and forage species were most susceptible to capture by trawl. Perch represented from 46 to 68% of the trawl catch by number (exclusive of young-of-year) during four years of sampling. Walleye made up 7 to 32% of the catch and forage species consisting of emerald shiner (*Notropis* *atherinoides*), spottail shiner (*Notropis hudsonius*), bluntnose minnow (*pimephales notatus*), trout perch (*Percopsis omiscomaycus*), log perch (*Percina caprodes*), and other darters 16 to 20%.

Table 2. Mean number per lift of walleye, yellow perch, and northern pike in experimental gillnets from Upper Mississippi reservoir lakes, 1971-74.

	Year	Cass[a]	Andrusia[b]	Big Wolf[c]
Walleye	1971	7.2	12.4	2.7
	1972	5.1	5.2	6.9
	1973	5.7	4.0	3.8
	1974	4.4	6.9	4.3
Yellow Perch	1971	53.6	25.8	24.9
	1972	29.0	22.4	27.2
	1973	40.3	25.9	59.6
	1974	34.9	20.9	33.0
Northern Pike	1971	2.7	2.7	1.3
	1972	2.5	5.0	3.0
	1973	1.8	2.2	1.4
	1974	2.6	2.3	3.0

[a] Based on 21 gillnet lifts annually, 1971-73, and 24 lifts in 1974.

[b] Based on 7 lifts in 1971, 9 lifts in 1972 and 1974, and 10 lifts in 1973.

[c] Based on 10 lifts in 1971 and 1973 and 9 lifts in 1972 and 1974.

Sport Fishery

Cass, Andrusia, and Big Wolf lakes are intensively fished. The three lakes combined supported an average of 250,294 angler hours per year during the period mid-May through September 30. Fishing pressure emanated primarily from resorts and most fishing was done from small boats. There was some fishing from chartered launches on Cass Lake and a small amount of shore fishing.

Year to year variation in fishing pressure on the individual lakes was considerable. Big Wolf Lake received the heaviest fishing pressure (Table 3).

Table 3. Estimated summer sport fishing effort and harvest, Big Wolf Lake, 1971-1975.

	1971		1972		1973		1974		1975		5-Year Average	
	Total	Per Acre	Total	Per Acre	Total	Per Acre	Total	Per Acre	Total	Per Acre	Total	Per Acre
Effort												
Angler trips	12439	11.8	14206	13.5	12494	11.9						
Angler hours	32534	31.0	36761	35.0	32073	30.5	36665	34.9	46370	44.1	36880	35.1
Harvest, numbers												
Walleye	2841	2.7	3043	2.9	3992	3.8	6380	6.1	8624	8.2	4976	4.7
Northern Pike	3374	3.2	2586	2.5	2109	2.0	3190	3.0	2735	2.6	2799	2.7
Yellow Perch	7123	6.8	10911	10.4	6715	6.4	9423	8.0	13864	13.2	9607	9.1
Rock Bass	315	0.3	2278	2.2	502	0.5	440	0.4	602	0.6	827	0.8
Other	890	0.8	469	0.4	121	0.1	293	0.3	139	0.1	382	0.4
Harvest, pounds												
Walleye	3344	3.2	2997	2.9	4492	4.3	5212	5.0	6553	6.2	4520	4.3
Northern pike	5598	5.3	3988	3.8	3317	3.2	5984	5.7	5604	5.3	4898	4.7
Yellow perch	3132	3.0	4473	4.3	2753	2.6	3863	3.7	5684	5.4	3981	3.8
Rock bass	213	0.2	1549	1.5	341	0.3	299	0.3	409	0.4	562	0.5
Other	481	0.5	272	0.3	70	0.1	170	0.2	80	0.1	215	0.2
Total	12768	12.1	13279	12.6	10973	10.4	15528	14.8	18330	17.4	14176	13.5

The range in estimated angler-hours per acre was 30.5 to 44.1, and the five year average was 35.1. The estimates on Andrusia varied from 15.6 to 27.9 hours per acre and the average was 22.9 (Table 4). Pressure at Cass Lake varied from 10.1 to 13.1 anglers hours per acre and averaged 11.5 (Table 5).

Collectively, the variation in fishing pressure was not as great as indicated by analysis of individual lakes. Total fishing hours for Cass, Andrusia, and Big Wolf combined, ranged from 221,544 to 271,489. Regression analysis suggests that fishing pressure increased at Andrusia and Big Wolf lakes during the study period but was stable at Cass Lake (Fig. 2). Because of the proximity of the three lakes, anglers may tend to fish where reports indicate walleye fishing is best. The increased pressure on the smaller lakes appeared to be related to higher walleye catch rates (Fig. 2), but the short series of years included and sampling errors inherent in creel census estimates precludes ascribing any statistical significance to the analysis.

Summer sportfishing harvest consisted primarily of four species. Walleye, northern pike, yellow perch, and rock bass (Ambloplites rupestris) contributed over 99% of the catch by number and weight. Yellow perch ranked first in the catch by number in all lakes and in pounds harvested at Cass Lake (Table 5). Walleye and northern pike harvests exceeded those of perch in Big Wolf and Andrusia lakes (Tables 3 and 4). Other species included in the summer sportfishing catch were black crappie, bluegill, pumpkinseed sunfish, black bullhead and brown bullhead. Collectively they made up less than two percent of the harvest from the three lakes. Largemouth bass and muskellunge were also taken in limited numbers. Catch data for the latter two species was not expanded to total harvest estimates because of the small numbers tallied, even though these lakes, especially Cass, are comparatively good muskellunge waters.

Yields of fish varied considerably from year to year for each lake (Tables 3, 4, and 5). Differences in yield between Cass, Andrusia and Big Wolf were

Table 4. Estimated summer sport fishing effort and harvest, Andrusia Lake, 1971-1975.

	1971		1972		1973		1974		1975		5-Year Average	
	Total	Per Acre	Total	Per Acre	Total	Per Acre	Total	Per Acre	Total	Per Acre	Total	Per Acre
Effort												
Angler trips	10562	7.0	8901	5.9	12626	8.4						
Angler hours	32001	21.2	23540	15.6	34497	22.8	42160	27.9	40673	26.9	34574	22.9
Harvest, numbers												
Walleye	3688	2.4	2295	1.5	4296	2.8	6197	4.1	9639	6.4	5223	3.5
Northern pike	2324	1.5	1569	1.0	2632	1.7	1855	1.2	2562	1.7	2188	1.4
Yellow perch	12195	8.0	6186	4.1	8575	5.7	7462	4.9	9395	6.2	8763	5.8
Rock bass	514	0.3	908	0.6	958	0.6	927	0.6	854	0.6	832	0.6
Other	128	0.1	53	0.0	120	0.1	126	0.1	162	0.1	118	0.1
Harvest, pounds												
Walleye	4403	2.9	2474	1.6	4049	2.7	4220	2.8	7091	4.7	4447	2.9
Northern pike	4354	2.9	2872	1.9	5912	3.9	2521	1.7	4437	2.9	4019	2.7
Yellow perch	5364	3.6	2536	1.7	3516	2.3	3059	2.0	3851	2.6	3665	2.4
Rock bass	348	0.2	617	0.4	652	0.4	630	0.4	580	0.4	565	0.4
Other	73	trace	31	trace	69	trace	73	trace	93	0.1	68	trace
Total	14542	9.6	8530	5.6	14198	9.4	10503	7.0	16052	10.6	12765	8.5

Table 5. Estimated summer sport fishing effort and harvest, Cass Lake, 1971-1975.

	1971		1972		1973		1974		1975		5-Year Average	
	Total	Per Acre	Total	Per Acre	Total	Per Acre	Total	Per Acre	Total	Per Acre	Total	Per Acre
Effort												
Angler trips	48358	3.1	59025	3.8	67419	4.3						
Angler hours	157009	10.1	192975	12.4	204919	13.1	163015	10.4	176285	11.3	178840	11.5
Harvest, numbers												
Walleye	23387	1.5	33916	2.1	36725	2.4	27712	1.8	36568	2.3	31661	2.0
Northern pike	5749	0.4	6517	0.4	6976	0.4	4727	0.3	4750	0.3	5744	0.4
Yellow perch	73428	4.7	111019	7.1	112722	7.2	69933	4.5	105910	6.8	94602	6.1
Rock bass	5955	0.4	4410	0.3	9219	0.6	4075	0.3	2613	0.2	5254	0.3
Others	1340	0.1	1081	0.1	560	trace	489	trace	200	trace	734	trace
Harvest, pounds												
Walleye	25449	1.6	31943	2.0	33785	2.2	22585	1.4	29252	1.9	28603	1.8
Northern pike	14025	0.9	13517	0.9	18136	1.2	13897	0.9	12861	0.8	14487	0.9
Yellow perch	32301	2.1	45518	2.9	46216	3.0	28672	1.8	43422	2.8	39226	2.5
Rock bass	4043	0.3	2998	0.2	6269	0.4	2771	0.2	1775	0.1	3571	0.2
Others	631	trace	627	trace	325	trace	284	trace	114	trace	396	trace
Total	76449	4.9	94603	6.1	104731	6.7	68209	4.4	87424	5.6	86283	5.5

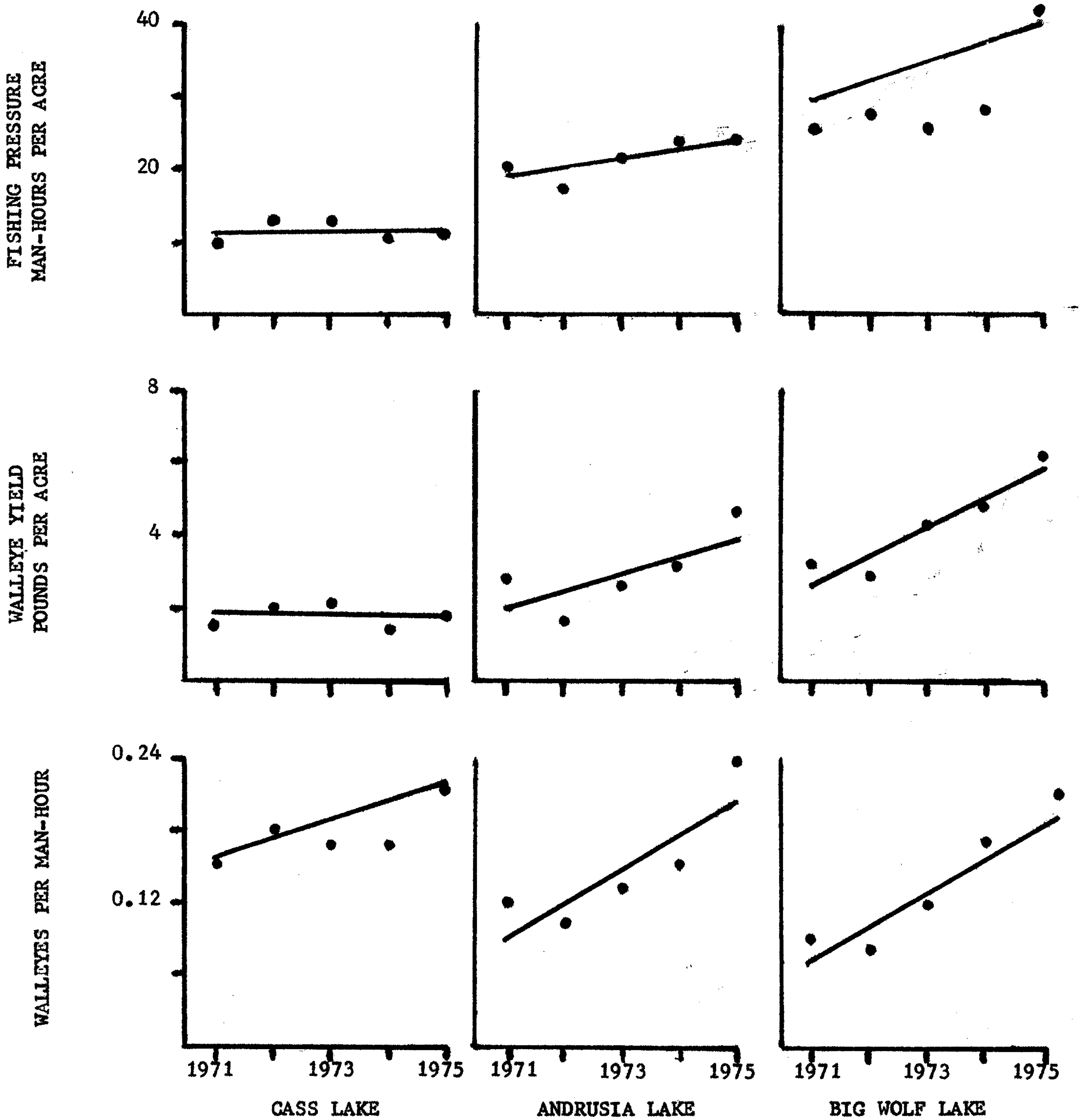

Fig. 2. Trends in sport fishing pressure, walleye yield, and walleye angling success (catch per man-hour), Upper Mississippi reservoir lakes, 1971-75.

sizeable. Total yield at Cass Lake averaged 5.5 pounds/acre ranging from 4.4 to 6.7. The yield from Andrusia averaged 8.5 pounds/acre and ranged from 5.6 to 10.6. At Big Wolf, yields averaged 13.5 pounds/acre and ranged from 10.4 to 17.4.

The variations in yield among the lakes is partly a function of lake size and productivity but also reflects fluctuations in fishing pressure that appeared to be related to variations in fishing success.

The ratio of walleye yield to total yield was similar in the three lakes. Walleye made up 33% of the yield from Cass Lake, 35% from Andrusia, and 32% from Big Wolf. Walleye yield from Cass Lake ranged from 1.4 to 2.0 pounds/acre and averaged 1.8. The range for Andrusia was 1.6 to 4.7 pounds/acre and averaged 2.9. Big Wolf produced an average of 4.3 pounds/acre and ranged from 2.9 to 6.2. Northern pike made up 16.8, 31.5, and 34.6% of the yield from Cass, Andrusia, and Big Wolf respectively.

There was a distinct seasonal pattern to walleye angling success (catch/man-hour) in all years on the three lakes. Catch rates were highest in late May and early June and lowest in July and early August. Fishing improved in late August and September, and September catch rates approached those of late May and early June. A similar pattern has been observed on most other walleye lakes in Minnesota. Catch rates at Cass Lake were higher, and more stable throughout the study than those at Andrusia and Big Wolf. Annual catch rates at Cass Lake ranged from 0.15 to 0.21 fish per hour and averaged 0.18. Catch rates were lowest on Big Wolf, ranging from 0.08 to 0.19 and averaged 0.13 fish per hour. Catch rates at Andrusia were similar to Big Wolf, ranging from 0.10 to 0.24 fish per hour and averaged 0.14. Catch rates at Andrusia and Big Wolf lakes increased steadily from 1972 through 1975 (Fig. 2).

The winter fishery for the one season censused was mainly darkhouse spearing. Only eight of 341 fishermen contacted (2.3%) were angling, so estimates from these data were not made.

Winter fishing pressure on the study lakes was relatively low compared to summer angling. Winter fishing pressure was 6.4, 10.3, and 11.5% of the mean annual summer fishing pressure on Cass, Andrusia, and Big Wolf lakes respectively. At Mille Lacs Lake, winter fishing pressure often exceeds that in summer (Maloney, 1978), but at Leech Lake and Lake of the Woods, winter fishing makes up only about one percent of the season's effort (Schupp, 1972; 1974). The heaviest pressure (4.0 man-hours per acre) was on Big Wolf Lake though 44.6% of all winter trips were on Cass Lake (Table 6).

Table 6. Estimated winter darkhouse spearing effort and harvest, Upper Mississippi reservoir lakes.

	Cass		Andrusia		Big Wolf		Pike Bay	
	Total	Per Acre	Total	Per Acre	Total	Per Acre	Total	Per Acre
Effort								
Angler trips	2564	0.2	740	0.5	893	0.8	1549	0.3
Angler hours	11441	0.7	3579	2.4	4241	4.0	6431	1.3
Catch, numbers								
Northern pike	912	0.1	747	0.5	448	0.4	498	0.1
Whitefish	1774	0.1	458	0.3	100	0.1	234	trace
Common sucker	116	trace	151	0.1	120	0.1	40	trace
Tullibee	254	trace	445	0.3	48	trace	13	trace
Yellow perch	208	trace	-	-	827	0.8	736	0.1
Catch, pounds								
Northern pike	3492	0.2	1565	1.0	966	0.9	2758	0.6
Whitefish	4111	0.3	1105	0.7	190	0.2	521	0.1
Common sucker	354	trace	402	0.3	342	0.3	77	trace
Tullibee	270	trace	437	0.3	40	trace	19	trace
Yellow perch	134	trace	-	-	286	0.3	525	0.1
Total	8361	0.5	3509	2.3	1824	1.7	3900	0.8

Winter yield of all species varied considerably among the four lakes censused. The highest yield (2.3 lbs./acre) was from Andrusia Lake which was 27.1% of the average annual summer yield. Yields from Cass and Big Wolf lakes were 0.5 and 1.7 pounds per acre respectively (9.1 and 12.6% of the average summer yields).

The predominance of darkhouse spearing was reflected in the species composition of the catch. Northern pike made up 49.9% of the total yield and the other species harvested (lake whitefish, *Coregonus clupeaformis*; cisco, *C. artedi*; white sucker, *Catostomus commersoni*; and yellow perch) are among those that can be legally speared. Spearing of walleye is illegal and none were tallied in the catch of the anglers contacted.

The proportion of northern pike taken by spearing at Cass, Andrusia, and Big Wolf lakes in relation to total annual yield of the species was similar to that observed on other Minnesota lakes. The winter yield of northern pike was 20.5% of the year's total, similar to the 18.4% reported by Johnson, et al (1957) for a series of 32 Minnesota lakes. Northern pike taken by spearing averaged 0.7 lbs. heavier than those caught by summer anglers.

STATUS OF WALLEYE POPULATIONS

River Spawning Runs

The Mississippi and Turtle River runs were trapped frequently as a source of walleye spawn from the late 1920's through the early 1940's. Big Lake Creek was evaluated as a potential source during the same period.[2/] These records provide historical data on the two runs which were utilized, and an estimate of the magnitude of the run in Big Lake Creek.

2/ Personal communication H.O. Swenson, Chief of Fisheries, MN D.N.R.(retired).

The 1971 walleye spawning run in Big Lake Creek first appeared on April 17 when the 24-hour low water temperature reached 39°F., and continued until May 5 when walleye left the stream. Peak migration occurred at 45° - 47°F. Total number of walleye present in the spawning run numbered 2,016 of which 1,566 were males and 450 females. The sex ratio was 3.48 males per female. The size of the 1971 run compared favorably with an estimate of 2,000 fish made in the early 1930's.

The number of marked fish returning to Big Lake Creek was monitored for four years. The lowest number of tagged fish (16) was noted in 1975, and the highest (143) in 1973.

The percentage return of surviving fish was estimated each year from 1972 through 1975 and appeared to vary with weather and stream flow conditions. Assuming an annual mortality of 0.55 (data to be presented later) an estimated 15.5 to 49.3% of surviving tagged fish returned to the same stream. The two years of lowest return, 1972 (15.5%) and 1975 (27.1%), were also the years of smallest spawning runs. Stream flows were low in 1972 following a mild winter and early spring. In 1975, a late spring, there was a reversal of stream flow during the spawning season which probably influenced the run.

The Turtle River spawning run was trapped in 1972. The spawning migration began when stream temperature reached 38°F on April 18 and continued until May 4. The peak of the run occurred when the temperature was 45°F. A total of 2,223 walleye (1,427 males and 796 females) were caught.

The size of the 1972 run was within the range of those observed from 1937 through 1942 (Table 7). Excluding the exceptionally large run of 1939, the 1972 run was comparable to the average of 2,408 fish in the earlier years. The sex ratio in 1972 was lower than the 5-year average (3.00:1) but similar to that in 1942.

Table 7. Number of walleyes caught and sex ratio in the Turtle River spawning run, 1972.

Year	Period of Run	Males	Females	Total	Sex Ratio ♂ : ♀
1937	4-28 to 5-5	2110	573	2683	3.68:1
1938	4-12 to 4-29	1955	578	2533	3.38:1
1939	4-22 to 4-30	5096	1446	6542	3.52:1
1940	4-23 to 5-5	1550	620	2170	2.50:1
1942	4-15 to 4-23	1485	762	2247	1.94:1
1972	4-18 to 5-4	1427	796	2223	1.79:1

A complete evaluation of the Mississippi River spawning run above Big Wolf Lake was not accomplished. An early thaw in 1973 resulted in a high stream flow with excessive debris that interfered with trapping operations and prevented enumeration of the run. Walleye appeared in the river on April 13 when water temperature reached 39°F, and remained through April 27. Because of a series of intermittent cold periods, no apparent peak was reached. Catches at the trapping site were supplemented by seining below the upstream dam to provide fish for tagging. A total of 661 walleye were caught, and the sex ratio was 4.29:1 (536 male and 125 female). Historically, this portion of the river has had a significant walleye spawning run. This run was trapped for 16 of 19 years from 1928 to 1946 for spawn taking purposes. In those years, the number of walleye taken ranged from 3,117 to 13,806 and averaged 7,078 per year. Whether the current run was of this magnitude was not determined.

Egg sampling on spawning areas and catches of drifting fry indicated that the contribution to the walleye population from natural reproduction in this portion of the Mississippi River was insignificant. Seven riffle areas which appeared to be good walleye spawning habitat were sampled. All were characterized by a coarse gravel and rubble substrate with water depth at six to twenty inches. They appeared to be ideal for egg deposition in early spring, being free of detritus and periphyton growth on the rock substrate.

In each of the three years of investigation, a marked change in river substrate condition was noted during the period of egg incubation. There was a continuous increase of periphyton and filamentous algae attached to the substrate, particularly in the riffle areas where egg deposition was heaviest. By the time walleye egg incubation should have been completed, almost all the riffle areas were covered by these growths.

Too few walleye eggs were sampled in 1971 to determine rate of development and hatching success, partly because of a late start on sampling. However, white sucker spawning activity was at its peak. A high degree of egg drift during sucker spawning was noted. The egg drift was associated with swift current and led to the deposition of many eggs on substrates unsuitable for incubation. This drift probably also influenced walleye egg deposition since the spawning behavior of walleye and suckers is similar. Sucker eggs were readily sampled and a high mortality was apparent. A large percentage of the eggs were dead or had fungus infections within 48 to 72 hours after deposition.

Night observations were made in 1972 to determine which areas were being used by spawning walleye. Peak activity occurred on the nights of April 28 and 29, and continued until May 4. Egg sampling was begun on April 30 and continued through May 10. On April 30, walleye eggs were sampled in limited numbers on riffle areas where spawning activity was greatest. This also suggests that the rate of egg drift associated with spawning was high. A continual decrease in egg numbers was observed and after eleven days of incubation so few were present that they could not be effectively sampled. An eleven-day period would place the eggs approximately halfway through incubation under the temperature regime encountered and suggests a high mortality of eggs not lost through drift.

Fry collecting nets were operated for five-day periods in 1971 and 1972. The dates selected were based on time of peak spawning activity in the river and on the development of walleye eggs in a fish hatchery immediately upstream which used the river for its water supply. Walleye fry were collected both years. In each year, the catch rate coincided with the rate of walleye hatching in the hatchery. Investigation of the hatchery discharge pipe in 1971 confirmed that walleye fry were escaping into the river at a significant rate.

Large numbers of fry were released at one time in 1971 and 1972 when the hatchery was flushed and then shut down. The nets were operated through the time necessary for the fry to pass downstream and numerous fry were collected. In both years the nets were operated following hatchery shutdown when no fry were being discharged. Based on spawning dates and water temperatures, a natural hatch should still have been taking place. No walleye fry were taken in the period after hatchery shutdown.

Of the physical factors affecting spawning success, turbidity and temperature were the least significant. The river bottom below the hydro-electric dam is stable, at least through that portion where the spawning riffles are located and the water was clear. The most important limiting factor appeared to be current speed. A high rate of egg drift was associated with spawning and a very small percentage of eggs were actually deposited on suitable substrate. It was apparent that temperature was not a limiting factor since walleye eggs were successfully incubated in the hatchery upstream in each of the three years considered.

A high mortality of eggs not lost through drift was noted. The heavy growth of periphyton which developed on the riffle areas during incubation probably impaired egg metabolism. The river has received the effluent discharge from the City of Bemidji sewage treatment plant upstream since 1956 and the increased nutrient load has almost certainly contributed to algal and periphyton growth.

Distribution and Movement

Walleye from Cass Lake contributed to all three river spawning migrations marked, and the source of fish comprising the runs included two or more lakes in all cases. Returns of walleye tagged at Big Lake Creek in 1971 indicated that fish from Andrusia and Cass lakes made up most of the run (Table 8). This was supported by recaptures of fish tagged from summer trawl catches in the Big Lake Creek spawning run in subsequent years. Of 17 summer-tagged walleye, 13 (76%) were from Andrusia Lake and 3 (18%) were from Cass Lake. These values are similar to the proportion of spawning fish recaptured in the respective lakes (64 and 21%).

Table 8. Location of walleyes caught by angling that were tagged in stream spawning runs, expressed as a percentage of recaptures by sex, Upper Mississippi reservoir lakes, 1971-75.

	Tagging Locations					
	Big Lake Creek		Turtle River		Mississippi River	
	Male	Female	Male	Female	Male	Female
Total tagged	1112	321	1125	450	536	125
Number recaptured	465	80	433	82	226	53
Location recaptured						
Cass Lake	19.4	28.8	51.0	68.3	14.6	22.6
Andrusia Lake	66.0	52.5	1.2	2.4	16.8	9.4
Big Wolf Lake	3.9	6.2	0.5	0.1	57.1	50.9
Pike Bay	0	1.2	0.7	3.7	1.3	7.5
Kitchi Lake	0.4	1.2	22.6	8.5	0	0
Mississippi River	4.5	0.5	0.2	0.0	9.3	9.4
Turtle River	0.9	0	17.1	9.8	0	0
Other	4.9	9.6	6.7	7.2	0.9	0.2

Returns of tagged fish indicated that the main source of the Turtle River run was Cass Lake. During the 1972 angling season, 158 of 287 tag returns (55.0%) were reported from there and 57 (19.9%) from the lower portion of the Turtle River just above Cass Lake. Nearly all of the marked fish caught in the river were taken early in the season and had already migrated downstream through two lakes, so it can probably be assumed that these were also Cass Lake fish. Most of the remaining tagged fish (54) were reported from Kitchi Lake, the second lake downstream from the tagging site.

Tag returns from walleye tagged in the Mississippi River two to five miles upstream from Wolf Lake indicated that Wolf Lake was the primary source of fish for the run. Of 279 tag returns, 55.9% were from Wolf Lake, 15.4% from Andrusia Lake, and 16.1% from Cass Lake. Observations during the 1930's support these data.[2/] Walleye trapped in spawning runs between Cass and Andrusia lakes were frequently too "green" for stripping, while those above Big Wolf Lake were "ripe". Walleye were caught above Big Wolf Lake that showed "crib wear", probably from being trapped previously and held between Andrusia and Cass lakes before being released as too "green".

A small proportion of the tagged fish, as indicated by angler tag returns, from Big Lake Creek and Turtle River continued upstream after release. Nineteen of 545 tag returns (3.5%) were from fish caught in Big Lake, which is upstream from the Big Lake Creek tagging site. Seventeen of 515 (3.3%) tagged fish reported were taken upstream from the Turtle River tagging site at Big Rice, Pimush, and Turtle River lakes. Male fish made up 84% of the upstream migrants in Big Lake Creek and 88% in the Turtle River. The percentage of males tagged in the respective runs was 78 and 71%. This suggests a slightly greater tendency for continued upstream movement by males, but numbers of upstream migrants were too small to detect statistically significant differences. Ten marked males from the Turtle River spawning run were caught in Winnibigoshish Lake, which is downstream from Cass Lake via the Mississippi River.

A higher percentage of females than males tagged in the three spawning runs were caught in Cass Lake (Table 8) while the percentage of males was consistently higher than females in the first lake downstream from each run. This is probably the result of the greater vulnerability of males to angling immediately after spawning.

Tag returns from trawl-captured walleye tended to support data from the spawning runs. There was some interchange of fish between lakes but most were recaptured in the same lake where they were tagged (Table 9). No specific pattern of movement was evident for fish that were caught in other lakes. More than 70% of tagged fish caught were reported from the lake in which they were tagged. The lowest incidence of movement was noted for fish tagged in Big Wolf Lake and differed significantly from fish tagged in Cass and Andrusia lakes (X^2, $P < 0.005$). The difference between Cass and Andrusia was not significant (X^2, $P > 0.10$).

Table 9. Angling recaptures of walleye captured by trawl that were tagged and caught in the same lake, Upper Mississippi reservoir lakes, 1971-75.

Lake	Number Tagged	Number Caught	% caught in same lake and 95% C.L.
Cass	1936	303	75.9 ± 4.8
Andrusia	689	125	70.4 ± 8.0
Big Wolf	540	163	87.7 ± 5.2

Cass Lake was the only lake large enough to warrant an analysis of movement within the lake. For all years combined the total number of tagged fish caught in Cass Lake with known capture location was 236 fish. Of these, only 52 (22%) were caught in the same area where tagged while 184 (78%) were caught in an area other than where tagged. This is in contrast to the observations reported from Leech Lake (Schupp, 1972) where most recaptures (> 60%) were taken from the area where they were originally tagged.

Trawl-tagged walleye were mainly immature, but the catch did include mature age-classes. No difference in movement between immature and mature fish could be detected outside of the spawning season.

Annual Mortality

Estimates of annual mortality calculated from independent sources of data were in good agreement (Table 10) and were similar for all ages older than young-of-the-year. The mean of these estimates (0.59) is higher than observed in other Minnesota sport fisheries, but is similar to estimates for walleye populations exploited by combined sport and commercial fisheries (Heyerdahl and Smith, 1971; Smith and Pycha, 1962). Estimates of total mortality for mature fish tagged in spawning runs suggested that males survive at a lower rate than females. The annual mortality estimates for males was higher than that of females in two of the three spawning runs trapped.

Rate of Exploitation

The exploitation rates presented in Table 10 are minimum rates based on voluntary tag returns. Attempts to estimate the true percentage of tagged fish caught through tallied fish in the creel census and by the method of Youngs (1963) gave unreasonable results. Estimates of recaptures based on Youngs' method resulted in estimates of exploitation that exceeded total mortality. Too few tagged fish were observed during the creel census to provide reliable data and resulted in an estimated tag return of more than 100%.

Table 10. Annual mortality and minimum rates of exploitation for walleye in Upper Mississippi reservoir lakes, 1971-75.

Type of estimate	Sex	Age classes	Annual mortality	Minimum rate of exploitation
Catch curve				
Angling		IV-VI	0.632	-
Gillnet		III-V	0.553	-
Trawl		I-IV	0.597	-
Voluntary tag returns				
1971 trawl		II-IV	0.556	0.268
1972 trawl		II-IV	0.686	0.270
1973 trawl		II-IV	0.515	0.199
Big Lake Creek	Male	V+	0.573	0.238
(spawning run)	Female	VI+	0.465	0.114
Turtle River	Male	V+	0.627	0.238
(spawning run)	Female	VI+	0.645	0.114
Mississippi River	Male	V+	0.708	0.303
(spawning run)	Female	VI+	0.541	0.245
Unweighted average			0.591	

The rate of exploitation was higher for mature males than for females from the spawning runs tagged. The rates estimated for fish tagged in Big Lake Creek and Turtle River were identical and males were harvested at more than twice the rate of females. Chi-square was used to compare observed ratios of tag returns annually for each sex to the ratio tagged. The values for Big Lake Creek ($X^2$4df = 27.11) and the Turtle River ($X^2$3df = 44.12) were significant ($P<0.01$). Tagged females from both runs were reported at less than the expected ratio.

The rates of exploitation for fish tagged in the Mississippi River were higher for both sexes than for the other runs. Big Wolf Lake is the most heavily fished lake in the system and more than 80% of the walleye tagged in the

Mississippi River were caught in Wolf Lake. The higher rate of exploitation for females was associated with a smaller average size of females in the spawning run (Fig. 3). The size frequency distribution of females among the three runs differed significantly (X^2, $P<.01$).

The difference between exploitation rates for males and females was not as great for Mississippi River fish as for the other runs. The difference in the expected ratio of returns was significant ($X^2_{2df} = 6.97$, $P<0.05$), but this is attributed to sampling variation within years since the observed and expected ratios for three years combined were nearly identical.

The rate of exploitation for juvenile fish (Ages II-IV) tagged from trawl catches was nearly the same as that for mature males and for females from the Mississippi River run. Thus it appears that walleye in the system are subjected to a high rate of exploitation beginning in their third year.

Age Structure

The age structure of the walleye harvest changed during the study years. The age structure from the three lakes was similar, so data were combined for analysis (Table 11). In 1971, the walleye harvest was dependent mostly on three age classes. Ages 3 through 5 contributed 78% of the total catch in numbers. In 1972, these age classes made up 75% of the total.

During the remaining years, 1973-75, the sport fishery was primarily dependent on two age classes. In those years walleye age 3 and 4 contributed 67, 80, and 78% respectively of the total catch in numbers. The relative contribution of age 5 walleye was 30.5% in 1971 but averaged only 8.3% for the years 1973-75. The relative contribution of walleye age 6 and older declined steadily from 19.6% in 1971 to 4.3% in 1975.

The marked shift to younger fish in the angler harvest apparently resulted from a combination of factors. Two strong year-classes (1970 and 1971) were

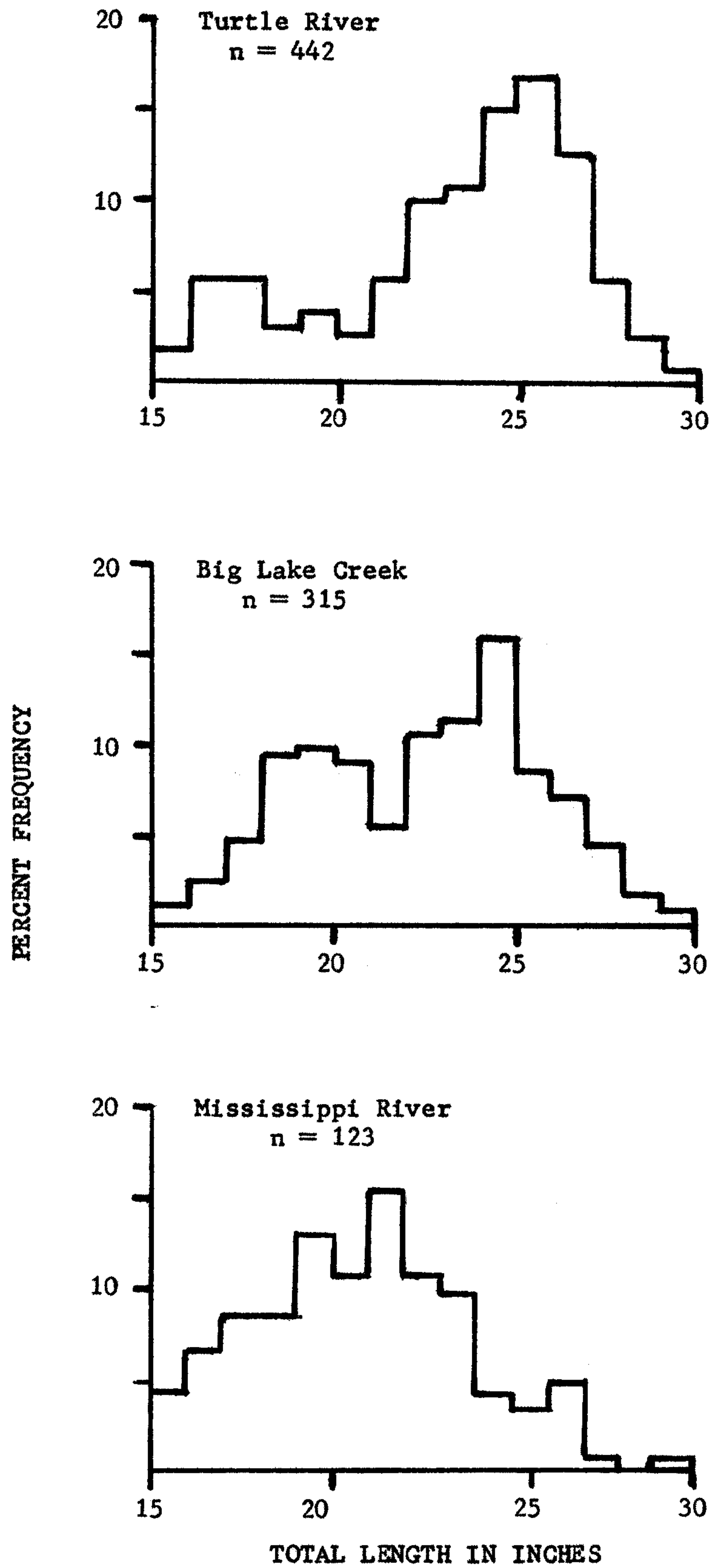

Fig. 3. Length frequency distributions of female walleyes in Turtle River (1972), Big Lake Creek (1971), and Mississippi River (1973) spawning runs.

Table 11. Age-class distribution of walleye in the angler's catch expressed as a percentage of the total harvest from Cass, Andrusia, and Big Wolf lakes combined, 1971-1975.

Year	Estimated total catch	AGE CLASS 1	2	3	4	5	6	7	8	9	10+
1971	30,281	0.2	2.4	11.9	35.3	30.5	5.1	4.8	2.2	2.5	5.1
1972	39,386	0.2	9.8	23.7	32.3	18.7	4.5	4.3	1.5	1.6	3.4
1973	45,166	0.3	8.4	39.4	27.3	8.6	6.9	3.2	1.8	2.5	1.6
1974	40,289	0.1	8.9	54.8	25.1	5.4	2.0	1.5	0.9	0.6	0.7
1975	54,831	0.1	7.1	27.8	50.6	10.0	1.7	1.1	0.6	0.7	0.2

preceded by two relatively weak year-classes (1968 and 1969). Recruitment to the sport fishery occurred mainly at ages III and IV and these four year-classes were fully recruited while the study was in progress.

The effect on the sport fishery of recruitment of these year-classes of varying strength was estimated using Allen's method (Ricker, 1975). This analysis indicated that 7.7% of the walleye in the system were fully recruited to the catch by age II, 32.6% by age III, and 88.7% by age IV.

Table 12. Effects of recruitment on the sport-fishing harvest of walleye and on fishing success, Upper Mississippi reservoir lakes, 1971-75.

	Year 1971	1972	1973	1974	1975
Estimated walleye harvest	30,281	39,386	45,166	40,289	54,831
Recruits	4,368	11,370	17,025	19,373	17,057
Fully recruited	25,913	28,016	28,141	20,916	37,774
% recruits	14.4	28.9	37.7	48.1	31.1
Catch per man-hour					
Recruits	.020	.045	.063	.080	.065
Fully recruited	.117	.111	.104	.086	.143

The relative contribution of recruits rose steadily from 1971 through 1974 and nearly half the walleye catch consisted of newly recruited fish in the latter year (Table 12). The estimated number of recruits harvested increased 4.4 times during this period. Numbers of fully-recruited walleye harvested annually were less variable but were lowest in 1974 and highest in 1975 when the strong 1970 and 1971 year-classes were fully recruited. An estimated 81% of the increased harvests observed from 1972 to 1975 consisted of fish recruited within the season. The catch per man-hour of new recruits and fully recruited fish was inversely related.

There were also indications that an increase in the rate of exploitation of fully-recruited fish occurred during the study period. Catch curves derived from the angler catch and from experimental gillnets had concave right limbs (Fig. 4). Ricker (1975) pointed out that concave right limbs can result either from an increase in rate of fishing or a decrease in natural mortality among older age groups. The former seems the more plausible explanation for the changes observed. The inflexion points on the catch curves suggest that the rate of exploitation increased in the early 1970's.

The decline in contribution of walleye age VI and older also contributed to the shift toward younger fish in the harvest. The absolute number of fish age VI and older was reduced by 63% from the first year of study to the last. The greatest change occurred between 1973 and 1974. The decline was probably partly caused by the weak 1968 and 1969 year-classes but was also evident among stronger year-classes hatched before that. The combined effect of the above factors resulted in a decline in average weight of walleye harvested from 1.1 to 0.8 pounds.

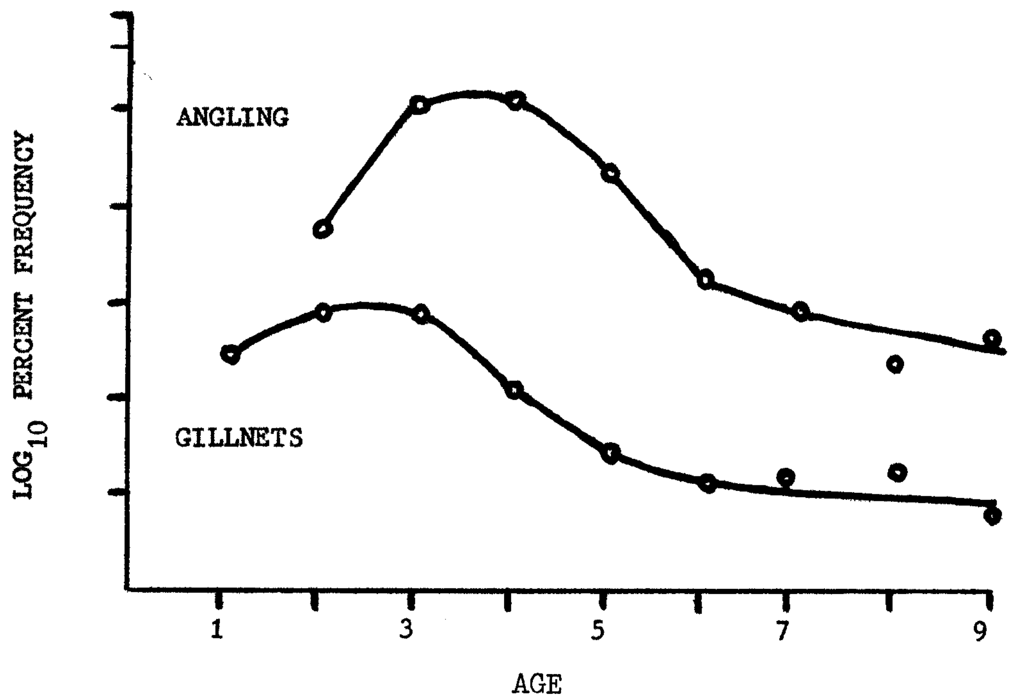

Fig. 4. Catch curves for walleye caught by angling and by gillnets, Upper Mississippi reservoir lakes, 1971-75. Curves are plotted as logarithms of percent frequency and are spaced one log-unit apart.

RELATIVE CONTRIBUTION OF RIVER SPAWNING RUNS

Assessment of the contribution of the major river spawning runs to walleye reproduction in the system was hampered by the inability to estimate the true rate of exploitation and to sample the Mississippi River run completely. Lacking these data, estimates of the importance of the runs is speculative and depends on some assumptions that are, at best, only weakly supported by this study. Nevertheless, the runs appear to be important to the system and warrant the following analysis despite its speculative nature.

Most females do not mature before age VI in northern Minnesota. Females made up 44% of age VI and older fish in the river spawning runs. Assuming the proportion of females in the harvest of age VI and older fish was the same, the average annual harvest of mature females was 2,101. Natural mortality in exploited walleye populations is on the order of 5-30% (Ney, 1978); but, natural mortalities observed in Minnesota waters have ranged from 5-22% (Olson, 1957; Smith, 1977).

The unweighted average total mortality for females in the spawning runs was 0.550. Adjusting this for natural mortality of 5-22% and a 3% loss through emigration suggests that the rate of exploitation for mature females was on the order of 30-47%. The estimated average population of mature females would then be in the range of 4,470 to 7,003. The number of females enumerated in the three runs was 1,371 or 19.6 to 30.7% of the estimated average population.

Numbers in the Turtle River run were similar to those in four of five years from 1937 through 1942 and the 1971 run in Big Lake Creek was similar to that estimated in the 1930's. If numbers of fish and sex ratios in the Mississippi River run have not changed appreciably since the 1928-46 period, an average run of females would number 1,336 and the total number in the three runs would be 2,582. This would represent 36.9 to 57.8% of the estimated average population.

The average of the high and low values for these runs divided by the mid-point of the range in estimated population may be a reasonable estimate of the importance of these runs to the system. This suggests that about one-third of all spawning females are in these runs, but may be as low as 19.6% or as high as 57.8%.

DISCUSSION

The Upper Mississippi River reservoir lakes impounded by the Knutson Dam are one of the larger groups of walleye lakes on a major river system within Minnesota where fish movement is unimpeded by dams. Within this system, there are 10 lakes larger than 600 acres and more than 30 miles of free-flowing rivers. Walleye tagged in the study lakes and in spawning runs from these lakes were caught throughout the system.

Intermingling of walleye tagged at various locations was common, but most tagged fish appeared to be members of relatively discrete populations within the study lakes. Adult walleye from stream spawning runs were strongly associated with one lake and there was little straying of tagged adults between spawning runs in subsequent years. Immature walleye tagged in summer were most often caught from the lake where they had been tagged.

A significant portion of the adult population apparently spawns in streams, but the contribution of stream spawners to annual recruitment is unknown. The presence of strong walleye year-classes from 1970 and 1971 indicates that there is no lack of recruitment. Numbers of walleye in the Big Lake Creek and Turtle River spawning runs have apparently changed little in 40 years and these streams are still assumed to be good spawning areas. Spawning adults still run in the Mississippi River despite the apparent lack of reproductive success. Although egg drift appeared to be the major cause of egg mortality in the Mississippi River, a reduction in the nutrient load entering the river might lead to a significant increase in survival of eggs that do settle on suitable substrates. The presence of spawners in the Mississippi, despite poor spawning success, may be evidence to support the hypothesis of Olson, et al (1978) that homing behavior of spawning walleyes is a learned response.

Walleye yields were within the range usually observed from Minnesota lakes (Carlander, 1977). Annual yields from Cass Lake appeared to vary mainly with fishing pressure. Yields from Andrusia and Big Wolf lakes appeared to be more closely related to fishing success and thus may be more sensitive to variations in recruitment.

Annual mortality rates for walleye were among the highest observed in Minnesota. Voluntary tag returns suggest that a high rate of exploitation by angling was the main component of this mortality. The true rate of exploitation would be high even if natural mortality was in the upper ranges documented in Minnesota. In addition, a gillnet fishery by the Leech Lake Band of Chippewa Indians was legally established during the course of this study. The size of the gillnet harvest is unknown, but it is likely that it consists of a larger proportion of mature fish.

The intensive harvest was probably the main cause of the small size of walleye caught. Declines in average size and age of harvest with increased fishing pressure have been observed at Lake Winnibigoshish (Johnson and Johnson, 1971) and Mille Lacs Lake (Maloney, 1978). At Wilson Lake, the harvest of walleye less than 12 inches TL increased eight-fold with a doubling of fishing pressure (Johnson, 1976). The fisheries examined in this study were heavily dependent on newly recruited year-classes and this will likely continue as long as fishing pressure remains high.

The inverse relationships between catch per man-hour for new recruits and fully recruited walleye suggests that recruitment of strong year-classes to a sport fishery may be a buffer for harvest of older fish. Strong year-classes may thus serve as a compensatory mechanism for maintaining a stable sport fishery where exploitation is high.

Fisheries management in a lake-river complex, such as this, is complicated by the opportunity for free interchange of fish. Walleye from Cass Lake contributed substantially to all stream spawning runs and passed through the smaller lakes during spawning migrations. Cass Lake fish were available to the early season sport fishery in the upstream lakes and mature females would be most vulnerable to a gillnet fishery during spawning runs. The effects of fisheries management at Cass Lake would likely have a measurable influence on the smaller lakes, though the reverse would probably not be true.

The study lakes can probably continue to produce the walleye yields observed in this study so long as good spawning habitat is maintained and brood fish are not impeded during spawning migrations.

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