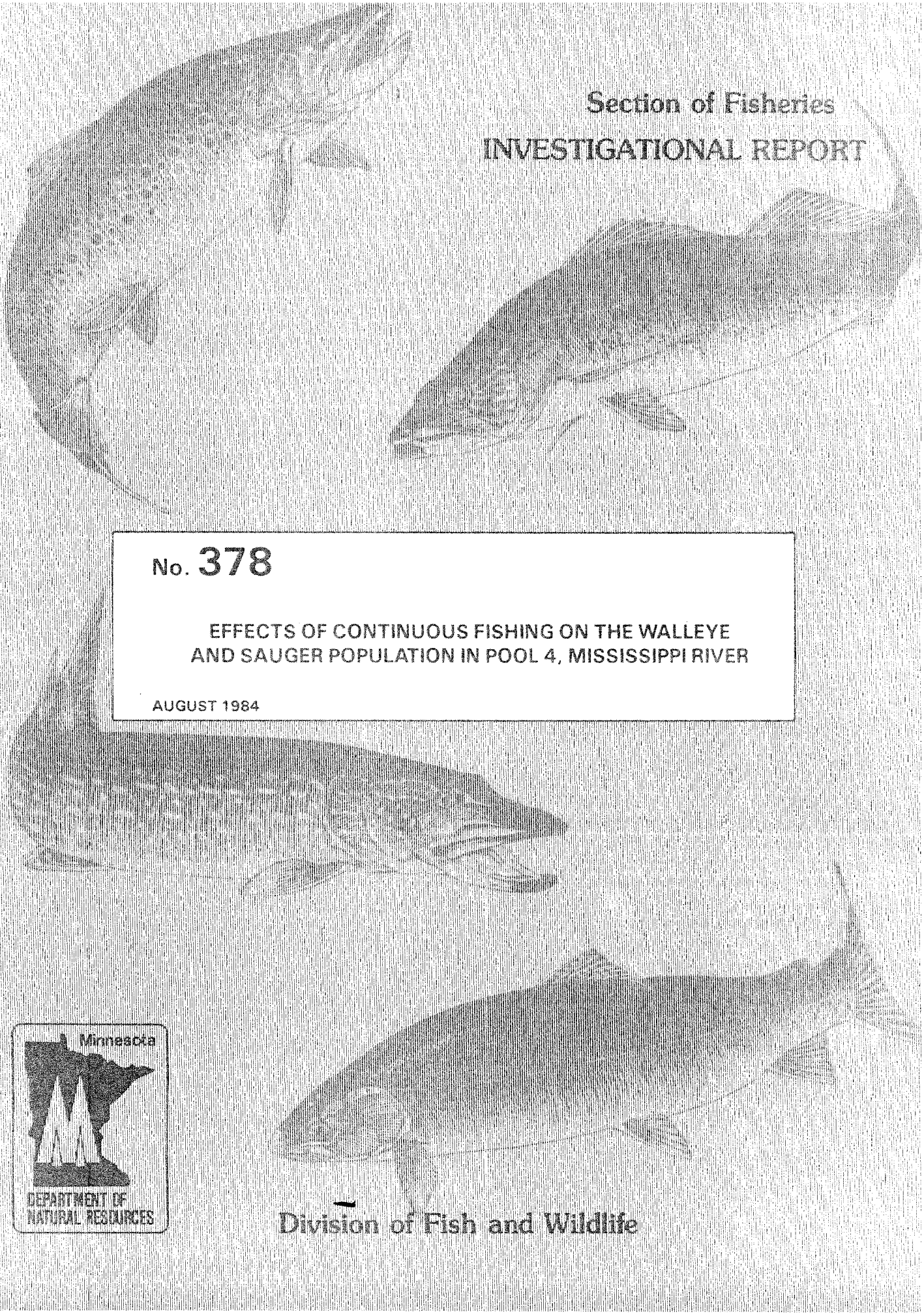

Section of Fisheries

INVESTIGATIONAL REPORT

No. 378

EFFECTS OF CONTINUOUS FISHING ON THE WALLEYE AND SAUGER POPULATION IN POOL 4, MISSISSIPPI RIVER

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DEPARTMENT OF NATURAL RESOURCES

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EFFECTS OF CONTINUOUS FISHING ON THE WALLEYE AND SAUGER POPULATION IN POOL 4, MISSISSIPPI RIVER[1]

by

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ABSTRACT

A 15 year (1967-81) continuous fishing season during 15 years (1967-81) for walleye and sauger in Pool 4 of the Mississippi River had no adverse effects on either population. Although fishing pressure increased as a result of the spring season and during the rest of the year, test netting indicated that the abundance of walleye after 15 years of continuous fishing was similar to the abundance before spring fishing was allowed. The spring fishery accounted for 16.4% of the annual fishing pressure and 17.3% of the annual walleye harvest. The average estimated number of walleye harvested and the catch rate during 1977-81 was 22,457 and 24.0 hr/fish as compared to 1962 at 19,881 and 25.6 hr/fish, respectively. The average weight of walleye harvested in spring was 0.93 kg compared to 0.73 kg for the entire season. The average weight of walleye harvested for the full season since 1967 has varied between 0.65 and 0.80 kg with no trend being evident. The abundance and harvest of sauger has fluctuated widely since 1967 and appears to be unrelated to changes in fishing pressure. Total harvest and fishing success for both walleye and sauger was dependent on year-class strength.

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[1] This project was funded in part by Federal Aid Fish Restoration (Dingell-Johnson) Program. Completion report, Study 116 D-J Project F-26-R Minnesota.

Harvest and catch rates of walleye were correlated with the combined abundance of age II and III fish and for sauger with the combined abundance of age classes I-III. Walleye year-class strength was highly correlated with water levels during the spawning and incubation period in April-May. Growth rates of walleye and sauger in Pool 4 are rapid with high rates of total and natural mortality. Both species reach maturity two to three years earlier than populations in northern Minnesota. The combination of rapid growth, high natural mortality and early maturity allows a fast turnover of the Pool 4 populations and thus they could probably withstand even greater fishing pressure without adverse effects on the population.

INTRODUCTION

A closed fishing season during the pre-spawning and spawning periods for game fish has been a traditional fish management tool. In 1967, Wisconsin initiated a continuous season for game fish on its portion of the Mississippi River where it forms the Minnesota-Wisconsin boundary. Minnesota's season remained closed from mid-February to May 1. Confusion for anglers and enforcement problems prompted Minnesota to allow continuous fishing on the Minnesota-Wisconsin boundary waters of the Mississippi River starting in 1969. This was the only area in Minnesota where continuous fishing for walleye (Stizostedion vitreum vitreum) and sauger (Stizostedion canadense) was allowed. Anglers now fish during winter and spring whenever the river is ice-free.

The spring fishery (March-April) was concentrated in the tailwaters of the navigational dams. After several years, local anglers in both states became concerned about or opposed to continuous fishing. The major reasons were the ethics of fishing before and during spawning and resentment toward non-local anglers. Many of the spring anglers were from the Twin Cities metropolitan area.

The Minnesota Department of Natural Resources (MDNR) initiated a creel census at Locks and Dams (L&D) #3 and 4 during March and April in 1968. Results through 1974 were reported by Sternberg (1974b) who recommended further creel census and fish population assessment and noted that fishing would be prohibited within 300 feet of L&D #3 and 4 during March and April starting in 1975. This restriction was based on a MDNR Commissioner's Order allowing the establishment of fish refuges. Wisconsin concurred with the restriction.

Available data included three annual estimates of total fishing pres-

sure and harvest in Pool 4 and indices of population abundance from gill netting since 1965. Creel surveys were conducted under the auspices of the Upper Mississippi River Conservation Committee (UMRCC) at 5 year intervals beginning in 1962 (Daley and Skrypek 1964; Sternberg 1969, 1974a).

Angler concern and opposition to spring fishing persisted. In response, MDNR initiated this 5 year study of walleye and sauger populations of Pool 4 in the Mississippi River. The objective was to determine if these populations were adversely affected by continuous fishing and if more restrictive regulations would be necessary.

STUDY AREA

Pool 4 of the Mississippi River extends from L&D #3 near Red Wing, Minnesota, downstream to L&D #4 at Alma, Wisconsin (Fig. 1). The pool is 71 km long and covers 15,702 ha. Lake Pepin is located in the middle of the pool and is about 35 km long, 2.8 km wide and covers 10,118 ha. There are about 17.7 river km upstream and downstream from Lake Pepin to the locks and dams.

Although the Mississippi River flows through it, Lake Pepin has many characteristics of an inland lake. It is subject to wave action, has little current and has an average depth of 6.4 m. Mean Secchi disc readings in Lake Pepin in 1978-79 were less than 1.0 m. Transparency in the lower portion of the lake was twice that of the upper portion (1.0 m vs. 0.5 m) (Minnesota Pollution Control Agency, personal communication 1981.)

METHODS

Fish populations in Lake Pepin have been assessed with standard experimental gill nets 76 m long by 1.8 m deep with sections of 38, 51, 64, 76 and 102 mm bar mesh. Twenty netting stations were sampled during September-October since 1965 with the smallest mesh set at the 3.1 m contour and

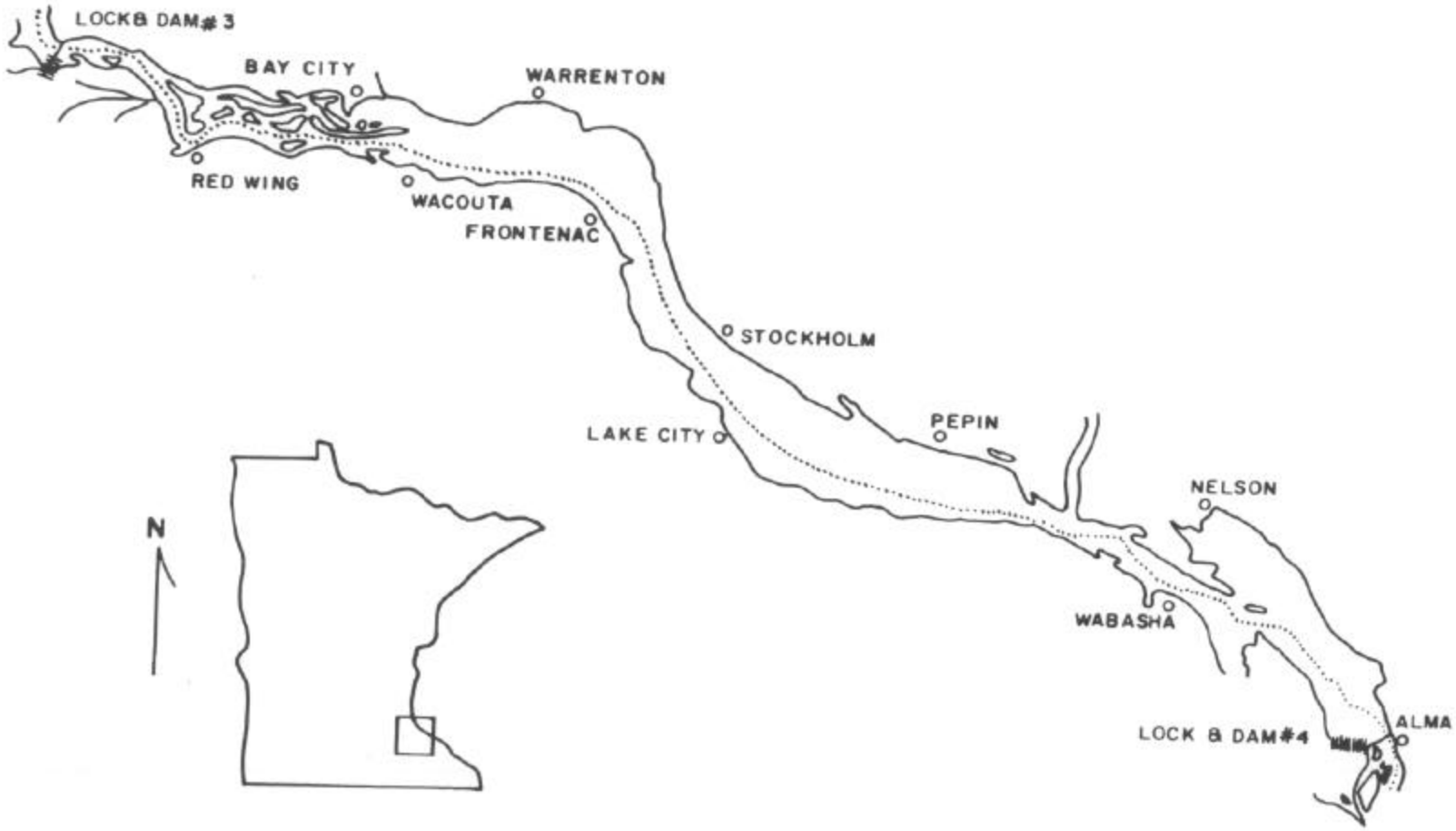

Figure 1. Pool 4, Mississippi River.

larger meshes extending into deeper water. Analysis of the data from 1965-1976 indicated that larger walleye were not being adequately sampled. A 567 m commercial seine with 25 mm bar mesh was used during 1978 and 1979 but also failed to adequately sample larger walleye. Larger walleye were successfully sampled in Lake Pepin by electrofishing during September-October 1979-81 with a boom-type A.C. electrofisher. Gill nets adequately sampled the most abundant sauger age-classes and use of this gear was continued to assess abundance of sauger and young walleye (ages I and II). Data from gill nets were used to develop an index of abundance for walleye and sauger similar to that described by Carlander et al. (1960). Length of all walleye and sauger was measured and a representative sample of weights and scales was taken.

Walleye and sauger were tagged to determine movement and rates of exploitation. During the study, 5,113 walleye and 2,115 sauger were tagged. Minimum tagging size was 356 mm for walleye and 305 mm for sauger. Floy Model FD-67 tags were used in 1976 and FD-68B tags in 1977-80[1]. Fish were to be tagged during April at L&D #3 and September-October in Lake Pepin to determine if Lake Pepin fish were being harvested by spring anglers. Signs were posted at access areas advertising a $50 reward for "lucky tags" as an inducement for voluntary tag returns. Most fish for tagging were captured by electrofishing, however, sauger could not be captured in Lake Pepin by this method. Small numbers of sauger, during the summers of 1978 and 1979, and walleye in 1978 were tagged from seine catches in Lake Pepin.

Angling pressure for walleye and sauger and harvest of walleye and sauger were estimated during 1977-81. A creel survey year began 1 March

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[1] Mention of a specific product does not constitute endorsement of that product.

and ended 28 February. Study years in this report are designated by the year they began. A non-uniform probability creel survey (Fleener 1971) and completed trip interviews were used to estimate angling trips per week. A survey clerk counted all boats and anglers completing fishing trips during two 4 h periods/day and 5 days/week at access sites frequented by walleye and sauger fishermen. The clerk interviewed as many anglers as possible during the 4 h periods. "Months" did not conform to a calendar month but a constant number of weeks per month was maintained during the study. All "months" contained four weeks except May, July, October and January which had five. The weekly trip estimate was multiplied by the number of weeks/month to estimate the number of trips/month. This estimate was then multiplied by the average hours/trip for the month to estimate angling hours for the month. The catch/trip was calculated from completed trip interviews and was used to estimate monthly harvest. Monthly estimates of pressure and harvest were summed to calculate annual totals. Walleye and sauger were measured and weighed when possible and a representative sample of scales was taken each year.

The UMRCC annual surveys estimated pressure and harvest based on stratified, instantaneous angler counts and completed and incompleted trip interviews (Daley and Skrypek 1964). The survey year began 1 April and ended 30 March. Walleye and sauger fishing pressure were not initially estimated and were extrapolated from total trips, the percent of anglers seeking these species and the average trip length. Fish were measured and weighed and scales were taken from a representative number of fish.

The annual spring creel surveys at L&D #3 estimated fishing pressure and harvest for walleye and sauger through instantaneous angler counts and fishermen interviews (Sternberg 1974b). The Prairie Island Nuclear Plant

monitoring group provided similar data and estimates for 1975 and 1976 (S. Gustafson, MN Dept. Nat. Res., personal communication 1977).

Rates of exploitation were calculated from voluntary tag returns within one year of tagging. A tag loss of 15% (T.C. Osborn, MN Dept. Nat. Res., personal comunication 1983) and a nonreporting rate of 50% (T. Bolland, Iowa Cons. Comm., personal communication 1983) were used to adjust rates of exploitation. Survival rates were calculated from catch curves (Ricker 1975). Scales were read by two readers and a nomograph was used for back-calculating growth to the last annulus.

RESULTS

Population Assessment

The walleye population of Pool 4 appears to have been stable since 1965 (Table 1). Catch per unit effort (CPUE) has not changed significantly for the total or age I walleye ($r = -0.314$ and 0.187, respectively, $P > 0.05$). The low CPUE in 1978 was probably due to inadequate sampling of age I fish which appeared to be of near normal abundance at age II.

The sauger population of Pool 4 has fluctuated since 1965 (Table 2). Sauger abundance indicates three periods of relative stability: 1965-68; 1970-74; and 1975-81. Abundance increased markedly in 1968 and 1969 and decreased in 1970 and 1975. The mean 1975-81 CPUE was 34% higher than in years before continuous fishing began (1965-66).

Fishing Pressure

Fishing pressure for walleye and sauger on Pool 4 has increased since 1962. The percentage of fishermen seeking walleye and sauger increased from 36% in 1962-63, to 45% in 1967-68, to 57% in 1972-73 (Daley and Skrypek 1964; Sternberg 1969, 1974a) with the corresponding estimates of walleye-sauger fishing trips being 40,597, 76,212 and 82,261, respectively. Estimated

Table 1. Abundance of walleye in fall gill nets (N = 20), Pool 4, Mississippi River, 1965-1981.

Year	Total	Age o	Age I	Age II	Age II+
1965	53	2	11	16	24
1966	69	3	40	16	10
1967	72	-	17	37	18
1968	66	1	14	36	15
1969	75	1	46	17	51
1970	80	5	28	6	41
1971	71	4	22	26	19
1972	55	1	24	13	17
1973	73	6	40	20	7
1974	54	1	34	13	6
1975	47	7	13	16	11
1975/6	62	4	29	7	22
1977	60	-	18	25	17
1978	31	-	43	13	15
1979	68	4	17	17	30
1980	68	3	39	5	21
1981	61	-	36	16	9
Mean	63	2	23	18	20

Table 2. Abundance of sauger in fall gill nets (N = 20), Pool 4, Mississippi River, 1965-1981.

Year	Total	I	II	III	IV	V	VI	VII+
1965	388	52	169	112	33	20	1	1
1966	368[a]	68	63	141	55	30	9	1
1967	362	119	157	35	29	12	9	1
1968	760	45	346	315	37	11	5	1
1969	1,253	117	184	757	175			20
1970	873	271	86	172	248	86	5	5
1971	952	262	404	83	89	102	10	2
1972	807	170	294	229	28	55	24	7
1973	869	148	341	253	88	20	18	1
1974	1,005	432	243	182	92	28	10	18
1975	580[a]	53	326	118	27	32	4	19
1976	771a	166	162	300	92	23	11	15
1977	649	186	189	53	167	21	22	11
1978	568	35	318	123	40	32	4	16
1979	234	39	29	117	28	13	3	5
1980	598a	184	126	99	130	39	11	5
1981	523	202	145	71	12	73	15	5
Mean	680	150	211	186	81	37	10	8

[a] Includes 1-4 age 0.

walleye-sauger fishing trips during the present study averaged 129,814 (±13,399) and ranged from 97,811 (±13,773) to 189,122 (±28,298) (Table 3).

During the present study, fishing pressure for walleye and sauger decreased after the first year and fluctuated little the final four years. Estimated pressure for the 5 years averaged 32.1 hr/ha and ranged from 25.2 to 47.8 (Table 3). The spring fishery accounted for 16.4% of the annual pressure and 12.1% of the trips.

Spring fishing pressure (Table 4) has increased significantly since 1968 ($r = 0.638$, $P < 0.05$). Pressure increased through 1973 after which it has been relatively stable. This spring pressure is assumed to be entirely for walleye and sauger. Spring pressure and mean water level were not correlated ($r = -0.309$, $P > 0.05$) but fishing pressure in 1969 and 1971 was considerably reduced due to high water.

Annual fishing pressure for walleye and sauger has increased more rapidly than can be accounted for by the spring fishery. By 1972-73, the spring fishery had increased to 15,500 trips, about 20% of the annual total. During the present study, the mean estimate of spring fishing trips was similar (15,642) but had decreased to 12% of the annual estimate. The annual estimate of trips increased 42% between 1967-68 and 1977-71.

Walleye Fishery

Success of the walleye fishery appeared to be related to abundance of walleye. Harvest and catch rates of walleye during 1967-68, 1972-73 and 1977-81 were correlated with abundance of age II and III walleye ($r = 0.899$, $P < 0.01$ and $r = 0.891$, $P < 0.01$, respectively) (Figs. 2 and 3). Age II and III walleye were predominant in the creel during three of four years (Table 5).

Walleye catch rates have fluctuated since 1962-63 and during the

Table 3. Estimated fishing pressure (manhours) for walleye and sauger, Pool 4, Mississippi River, 1977-81.

Year	Trips	Standard error	Manhours (mh)	Manhours/ha
1977	189,122	14,438	751,004	47.8
1978	124,704	7,874	522,641	33.3
1979	108,421	6,102	432,212	27.5
1980	97,811	7,027	396,020	25.2
1981	129,012	6,836	479,738	30.6
Mean	129,814	6,836	503,820	32.1

Table 4. Estimated fishing pressure (mh) for walleye and sauger, mean water level (ft msl), harvest, mean weight (kg) and catch rate (hrs/fish), spring creel census near Lock and Dam #3, Mississippi River, 1968-81.

Year	Manhours	Water level	Walleye			Sauger		
			Number	Mean weight(kg)	Hours/ fish	Number	Mean weight(kg)	Hours/ fish
1968	22,350	668.5	4,389	0.99	5.4	6,955	0.40	3.2
1969	3,540	675.1	297	0.83	12.0	1,323	0.35	2.7
1970	41,067	669.9	5,874	0.95	6.4	13,332	0.41	3.3
1971	17,455	673.6	1,835	0.89	9.7	6,629	0.58	3.0
1972	43,766	673.4	3,048	0.91	11.2	21,103	0.54	2.3
1973	75,051	673.9	4,115	0.68	18.2	35,755	0.47	2.3
1974	100,935	671.6	6,049	0.74	16.7	36,514	0.59	3.0
1975	63,737	670.5	3,190	0.92	19.6	15,040	0.62	4.2
1976	73,556	672.4	2,260	0.96	33.3	33,156	0.67	2.2
1977	118,019	668.6	5,969	1.16	19.6	30,658	0.58	3.8
1978	102,832	672.1	6,895	1.31	10.9	13,507	0.57	7.6
1979	68,270	673.7	2,844	0.75	23.8	8,411	0.42	8.1
1980	45,199	670.9	1,037	1.11	43.5	6,750	0.47	6.7
1981	78,029	669.4	2,694	0.82	28.6	9,316	0.49	8.4
MEAN	60,986	--	3,607	0.93	18.5	17,034	0.51	3.5

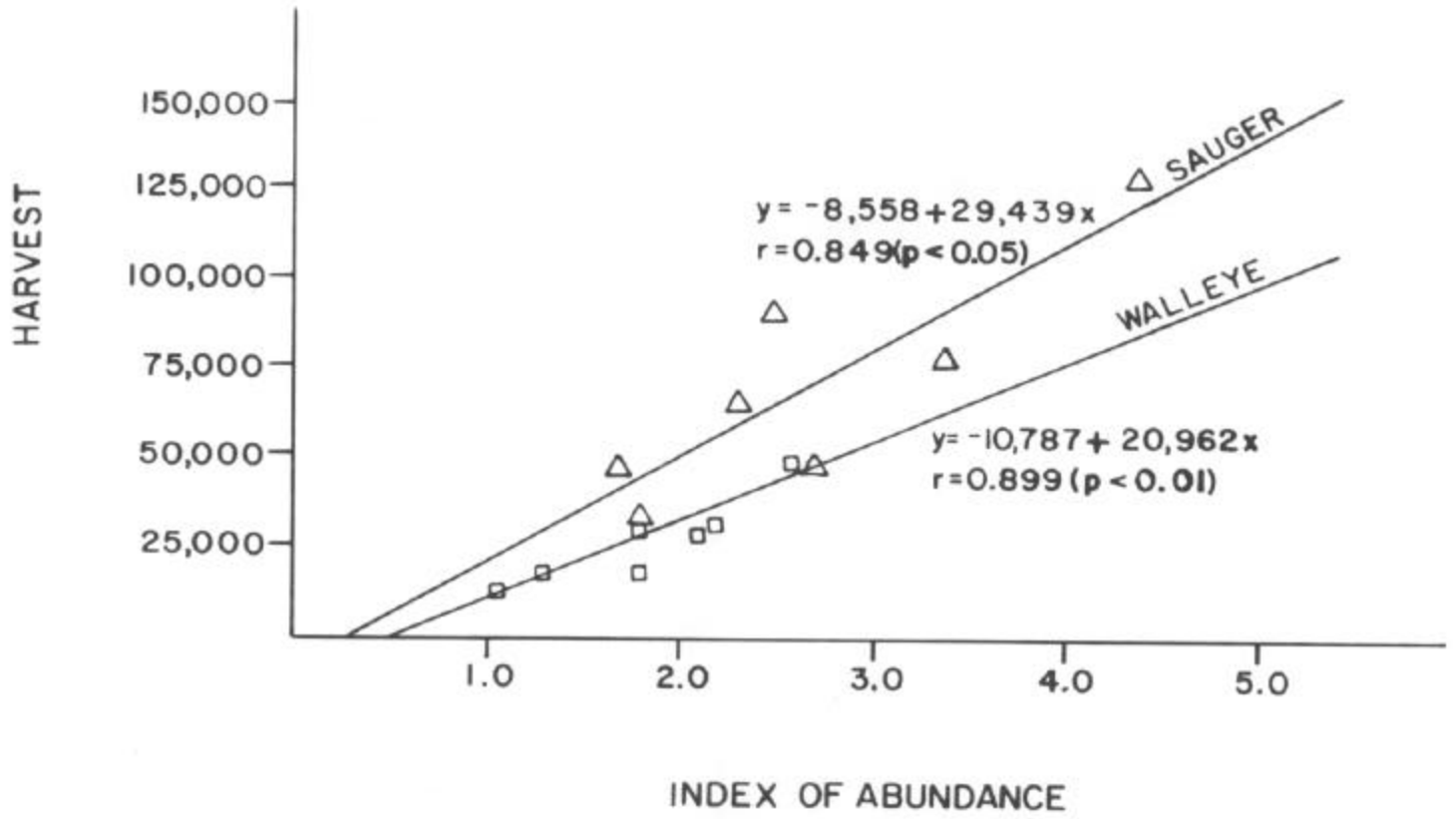

Figure 2. Linear regression of harvest of walleye and sauger on abundance of walleye (ages II and III) and sauger (ages I-III); Pool 4, Mississippi River; 1967, 1972, 1977-81.

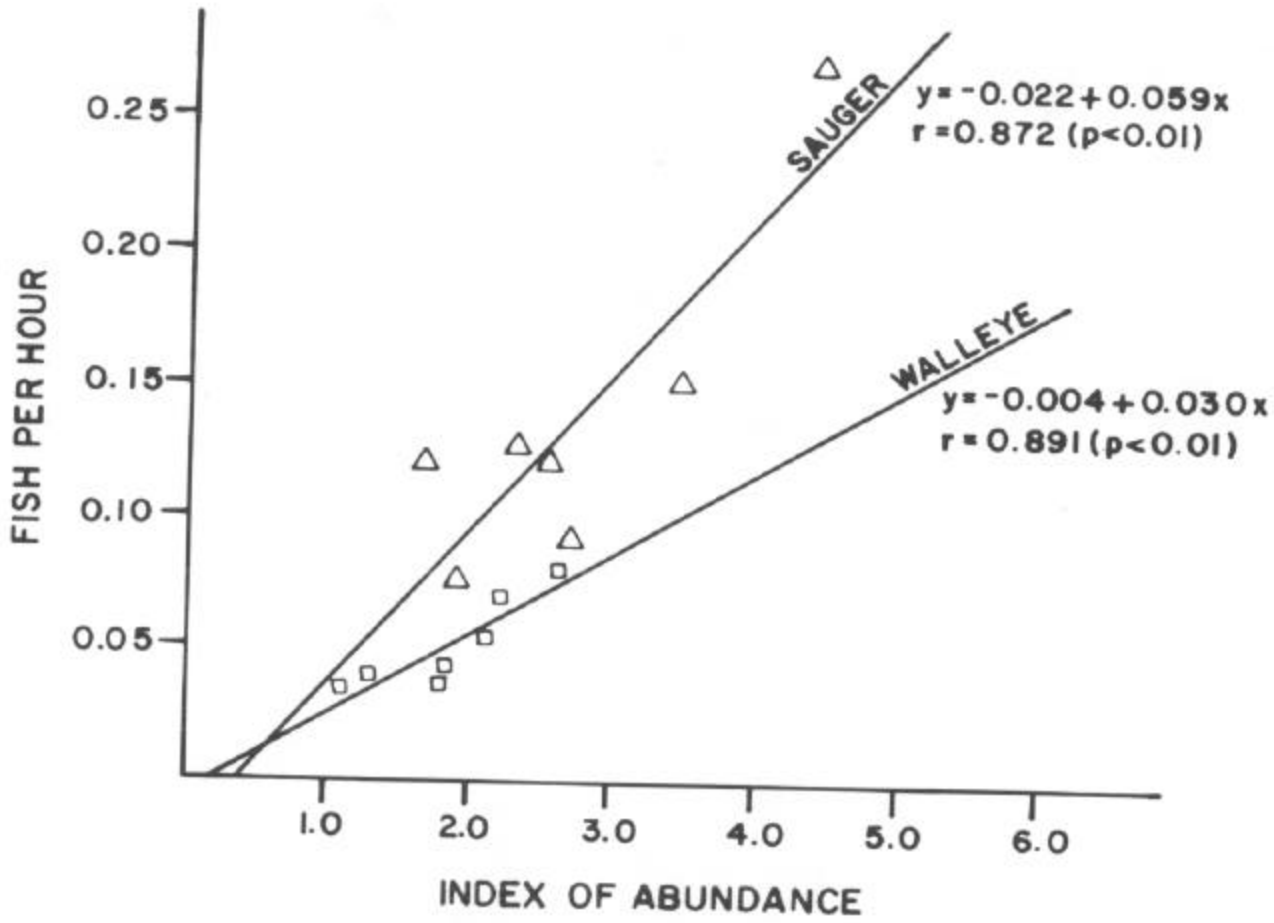

Figure 3. Linear regression of catch rate (fish/hr) on abundance of walleye (ages II and III) and sauger (ages I-III); Pool 4, Mississippi River; 1967, 1972, 1977-81.

Table 5. Catch rate (hrs/fish), estimated harvest (standard error), yield (kg/ha) and mean weight (kg) for walleye and sauger, annual creel censuses, Pool 4, Mississippi River.

Year	Hours/Fish		Harvest		Yield(kg/ha)		Mean weight(kg)	
	Walleye	Sauger	Walleye	Sauger	Walleye	Sauger	Walleye	Sauger
1962-63	25.6	12.3	19,881	39,624	[a]	1.2	[a]	0.47
1967-68	12.2	6.5	49,553	79,083	2.5	2.3	0.80	0.46
1972-73	14.3	3.7	33,362	129,529	1.6	3.2	0.72	0.39
1977	22.6	8.3	33,276(3,465)	90,893(8,071)	1.7	3.0	0.80	0.51
1978	17.9	7.9	29,166(3,594)	66,539(4,905)	1.4	1.7	0.75	0.40
1979	25.5	13.4	16,979(1,431)	32,446(2,262)	0.7	0.8	0.65	0.39
1980	28.2	8.5	14,455(1,689)	48,640(3,933)	0.7	1.4	0.80	0.44
1981	25.6	10.9	18,405(1,290)	47,173(3,037)	0.8	1.3	0.66	0.42
1977-81								
Mean	24.0	9.8	22,457(1,791)	57,138(5,134)	1.1	1.6	0.73	0.43

[a] Mean weight not available.

present study were similar to those of 1962-63 (Table 5). Catch rates increased from 25.6 hrs/walleye in 1962, to 12.2 in 1967-68, to 14.3 in 1972-73 and decreased to a 5 year mean of 24.0 hrs/walleye in 1977-81. Monthly catch rates during 1977-81 varied with the best success in May and June (Table 6). These months accounted for 43.3% of the annual harvest compared to 17.3% during the spring fishery.

The spring catch rate during 1968-81 averaged 18.5 hrs/walleye (Table 4) but a significant decrease has occurred ($r = 0.764$, $P < 0.01$). Spring catch rates were not correlated with fishing pressure ($r = 0.272$, $P > 0.05$).

Angler harvest of walleye varied with the largest harvest recorded in 1967-68 (Table 5). The 1979-81 harvests were similar to that of 1962-63. Average harvest and yield for 1977-81 was 22,457 ($\pm$3510) walleye and 1.1 kg/ha. Annual harvest was correlated with pressure during 1977-81 ($r = 0.901$, $P < 0.05$).

The spring walleye harvest during 1968-81 has fluctuated and was dependent on fishing pressure. The average spring harvest was 3,607 walleye (Table 4) and has not changed significantly ($r = 0.002$, $P > 0.05$). Spring harvest was correlated with pressure ($r = 0.653$, $P < 0.05$) but not with mean spring water level ($r = 0.454$, $P > 0.05$) or population abundance as indicated by gill net catches of the previous fall ($r = 0.113$, $P > 0.05$). Spring harvest was correlated with annual harvest during 1977-81 ($r = 0.940$, $P < 0.05$).

The mean weight of walleye creeled has varied little since 1967 (Table 5). The mean weight of the full season for 1977-81 was 0.73 kg and did not change significantly ($r = -0.496$, $P > 0.05$). The mean weight of walleye in the spring creel was 0.93 kg and has not changed significantly ($r = 0.227$, $P > 0.05$) from early creel surveys (Table 4). Mean weight of creeled walleye

Table 6. Seasonal catch rates (hours/fish), harvest (% of annual) and mean weight (kg) of walleye and sauger, Pool 4, Mississippi River, 1977-81.

Month	Hours/Fish		Harvest (%)		Mean weight (kg)	
	Walleye	Sauger	Walleye	Sauger	Walleye	Sauger
March	21.3	7.4	9.5	9.9	1.06	0.53
April	34.9	8.0	7.8	14.1	0.94	0.50
May	16.1	10.9	21.8	14.3	0.67	0.39
June	14.6	9.5	21.5	12.5	0.60	0.34
July	31.1	17.1	9.7	6.4	0.60	0.30
August	72.2	26.4	9.6	8.6	0.67	0.31
September	51.7	17.3	8.3	11.1	0.51	0.34
October	23.4	5.2	9.5	13.7	0.58	0.45
November	22.3	5.7	1.4	2.1	0.54	0.47
December	26.6	13.5	0.4	1.3	—	0.26
January	132.0	9.7	0.6	3.1	0.48	0.31
February	28.4	7.3	1.9	2.9	0.98	0.46

varied by month but generally was greatest during spring (including February when the river was ice-free) (Table 6).

The lower mean weights of walleye between individual years during spring fishing was the result of age I+ fish (immature) entering the creel. The percentage of age I walleye harvested in the spring was positively correlated with year-class strength (percent of age I walleye in previous fall gill nets) (Fig. 4) and mean weight in the spring creel was negatively correlated with the harvest of age I walleye (Fig. 5).

Young walleye were predominant in the anglers' catch. Age-classes I-III were most common in the annual creel (Table 7) and few walleye older than age V were observed. Walleye older than age V were also relatively uncommon in the spring creel of which 26.6% were age I+. The mean percentage of "large" ($\geq$610 mm) walleye in the spring creel (1968-74, 1977-81) was 3.7% compared to 3.0% in the annual creel (1977-81). There was a strong correlation between percentage of "large" walleye observed in the two creels during 1977-81 ($r = 0.962$, $P < 0.01$).

Sauger Fishery

Success of the sauger fishery was also related to sauger abundance. Harvest and catch rates of sauger during 1967-68, 1972-73 and 1977-81 were correlated with abundance of age I, II and III sauger ($r = 0.849$, $P < 0.05$ and $r = 0.872$, $P < 0.01$; respectively) (Figs. 2 and 3).

Sauger catch rates have fluctuated with the best catch rates recorded in 1967-68 and 1972-73 (Table 5). The 1977-81 mean was higher than recorded in 1962-63. The highest catch rates were noted in October-November (Table 6).

Sauger catch rates in spring were relatively stable during 1968-76, then decreased and stabilized during 1977-81 (Table 4). Spring catch rates

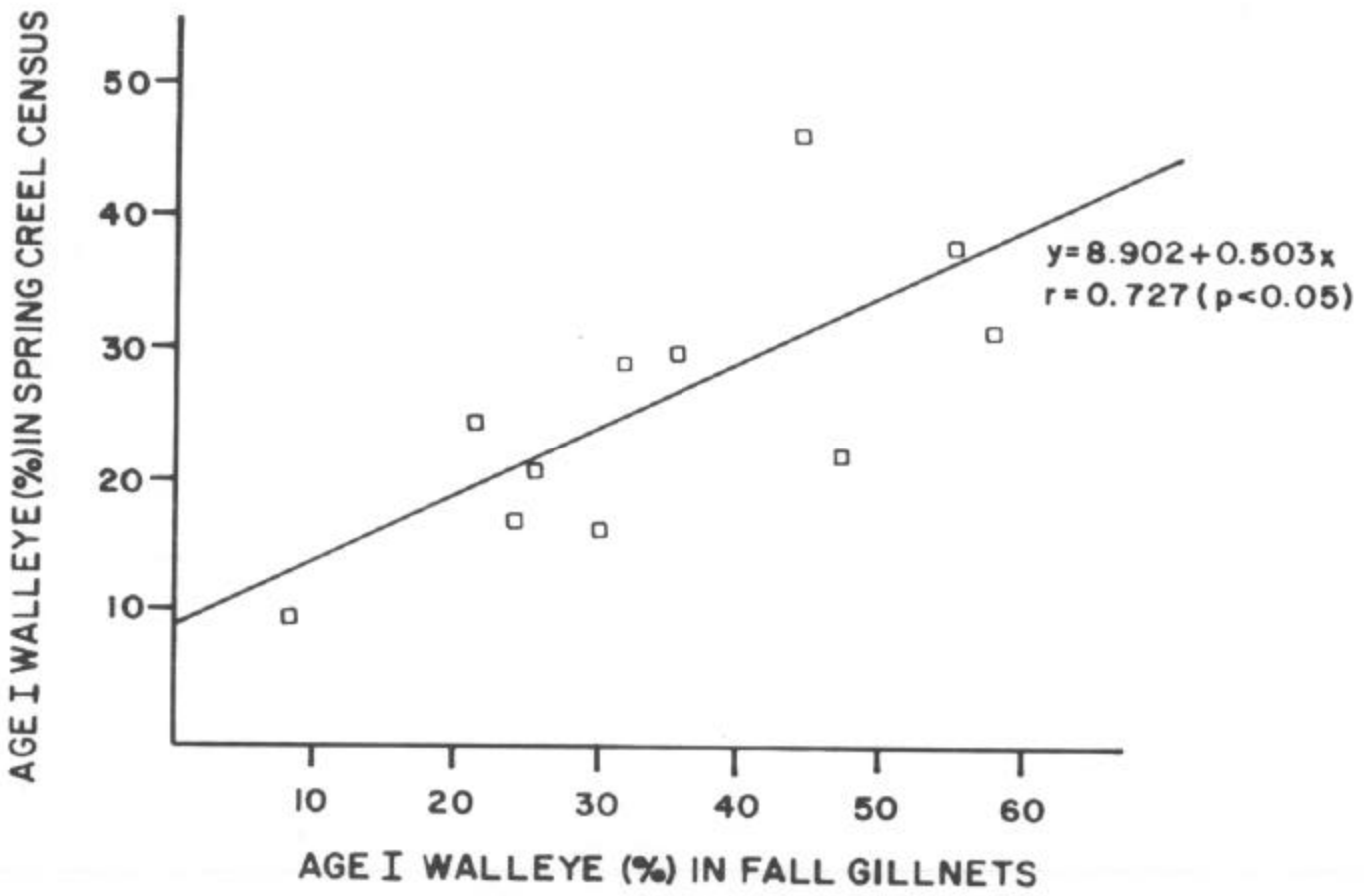

Figure 4. Linear regression of percent age I walleye spring creel on percent age I walleye in fall gillnets, 1968-81; Pool 4, Mississippi River (1978 data excluded, no spring creel data available for 1975-76).

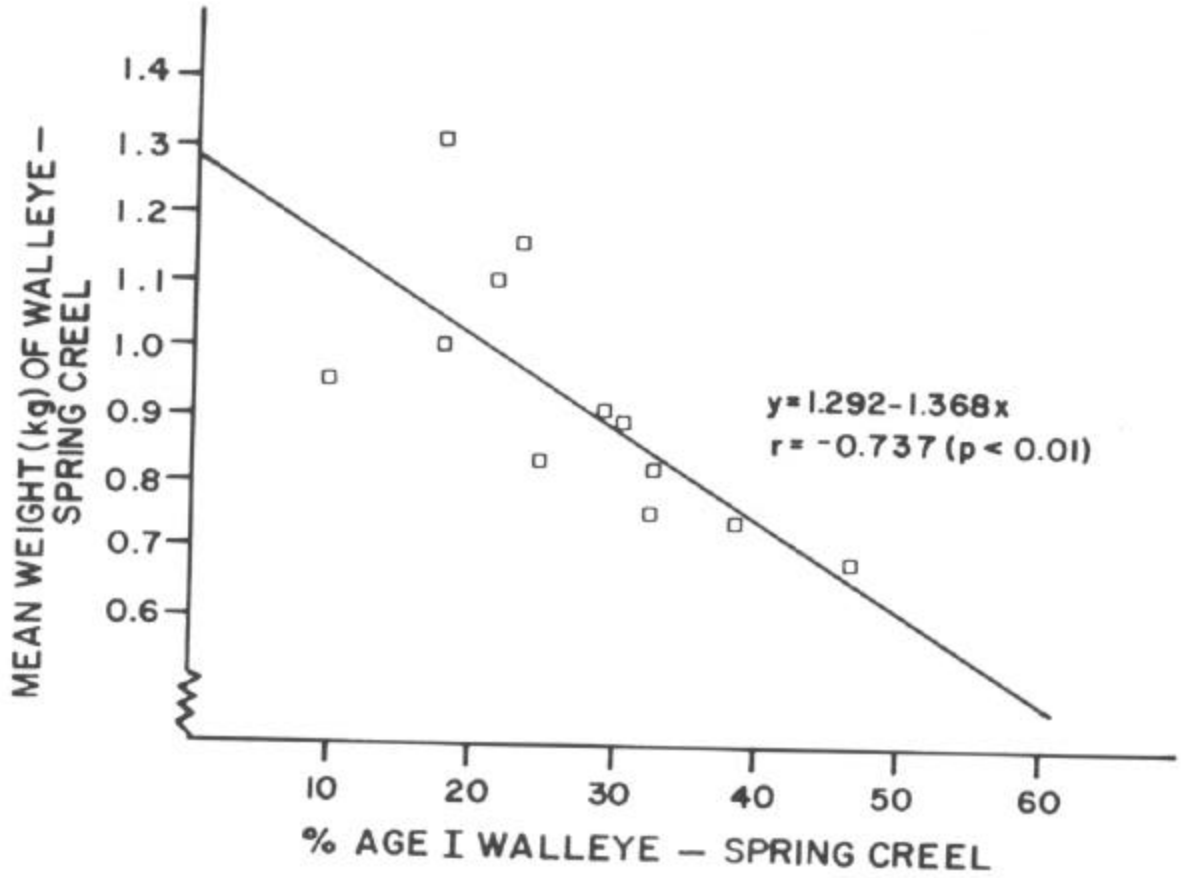

Figure 5. Linear regression of mean weight (kg) of walleye on percentage of age I walleye in the spring creel; Pool 4, Mississippi River; 1968-81 (no data 1975-76).

Table 7. Age distribution of walleye and sauger in the angler's creel, Pool 4, Mississippi River, 1978-81. Percent in parentheses.

Year	Sample Size	Age I	II	III	IV	V	VI	VII	VIII	IX
Walleye										
1978	746	23(3.1)	508(68.1)	91(12.2)	90(12.1)	18(2.4)	3(0.4)	6(0.8)	3(0.4)	4(0.5)
1979	1,029	81(7.9)	668(64.9)	148(14.4)	58(5.6)	34(3.3)	13(1.3)	16(1.5)	9(0.9)	2(0.2)
1980	620	111(17.9)	184(29.6)	236(38.0)	36(5.8)	37(6.0)	7(1.1)	6(1.0)	3(0.5)	
1981	1,321	687(52.0)	250(18.9)	204(15.4)	130(9.8)	20(1.5)	23(1.7)	4(0.3)	2(0.2)	1(TR.)
Sauger										
1978	2,001	101(5.0)	1,123(56.1)	444(22.2)	211(10.5)	69(3.5)	28(1.4)	22(1.1)	3(0.2)	
1979	2,168	93(4.3)	1,004(46.3)	820(37.8)	129(6.0)	98(4.5)	13(0.6)	9(0.4)	2(0.1)	
1980	2,722	192(7.1)	750(27.6)	1,383(50.8)	262(9.6)	86(3.2)	35(1.3)	13(0.4)		1(TR)
1981	3,592	730(20.3)	1,418(39.5)	696(19.4)	541(15.1)	130(3.6)	48(1.3)	24(0.7)	5(0.1)	

were not strongly correlated with increased fishing pressure ($r = 0.304$, $P > 0.05$). The decrease in catch rate between the periods 1968-76 and 1977-81 appears to be the result of increasing pressure and decreasing abundance.

Sauger harvest varied with and was related to fishing pressure. The largest harvest was recorded in 1972-73 and the smallest in 1962-63 (Table 5). Average harvest and yield during 1977-81 were 57,138 fish and 1.6 kg/ha. During 1977-81, harvest was correlated with pressure ($r = 0.924$, $P < 0.05$). Similar harvests were recorded for the months of March-June and September-October (Table 6).

Sauger harvests during the spring were greatest during 1972-78 (Table 4). The spring sauger harvest was also correlated with fishing pressure ($r = 0.670$, $P < 0.01$) but not with mean spring water level ($r = 0.028$, $P > 0.05$). The best harvest years (1972-78) appear to coincide with high abundance but spring sauger harvest was not correlated with the gill net CPUE of the previous year ($r = 0.247$, $P > 0.05$) (Table 2).

The mean weight of sauger caught has varied little since 1962-63 with the average during 1977-81 being 0.43 kg (Table 5). Mean weight of sauger in the spring creel was 0.51 kg and has not changed significantly during the years 1968-81 ($r = 0.323$, $P > 0.05$). Highest mean weights were recorded during 1971-78.

Ages II and III sauger were predominant in the annual creel during 1978-81 but age I were numerous in 1981 as a result of a strong 1980 year class (Table 7).

Walleye and Sauger Movements

Tag returns indicated that walleye from Lake Pepin migrated upstream prior to spawning and moved back downstream immediately after spawning.

During the spring tailwater fishing season in 1977, anglers returned tags from 36 walleye tagged the previous September-October in Lake Pepin. Electrofishing in the same vicinity in spring 1977, 1978 and 1980 captured 12, 19 and 9 walleye, respectively which were tagged the previous September-October in Lake Pepin. The post-spawning fishery in 1978 (May-June in Lake Pepin) accounted for 63% of the first year tag returns of walleye tagged prior to spawning.

Walleye did not move extensively within Pool 4. Average distance moved by walleye tagged in Lake Pepin during 1976 and 1977 and caught by anglers in Lake Pepin was 8.0 and 6.4 km, respectively. Recaptures of tagged walleye by electrofishing in Lake Pepin indicated an average movement of 3.2 km. Few recaptures were reported from upstream or downstream of Pool 4 (Table 8).

Walleye movement upstream out of Pool 4 increased with elevated water levels in spring. The largest percentage of walleye tag returns reported upstream of L&D #3 was spring 1978 during the highest level water recorded during this study (Tables 4 and 8). A weak correlation was found between the percentage of walleye tags returned from upstream of Pool 4 and the mean April water level during the spring of tagging or the spring immediately after tagging ($r = 0.799$, $P < 0.10$).

Movement patterns of sauger appeared to be similar to those of walleye. Most sauger tagged at L&D #3 were taken downstream in Lake Pepin during May-June and few sauger were recaptured other than in Pool 4 (Table 8). Upstream movement prior to spawning was indicated from spring angling near L&D #3 in 1979 and 1980 when 2 tagged sauger were recaptured from the small numbers that were tagged the previous summer in Lake Pepin. Also during spring electrofishing near L&D #3 in 1980, 3 sauger were recaptured that had

Table 8. Location of tag returns from walleye and sauger tagged in Pool 4, expressed as a percentage of the total, Mississippi River, 1976-80.

Location of Tag Return	Season Tagged						
	Fall 1976	Spring 1977	Fall 1977	Spring 1978	Summer 1978	Fall 1979	Fall 1980
Walleye (N=708)							
Pool 3 and St. Croix R.	3	5	8	11	3	8	1
Pool 4	95	90	91	84	94	84	96
Pool 5 and Chippewa R.	2	5	1	3	3	8	1

	Spring 1978	Summer 1978	Spring 1979	Summer 1979	Spring 1980
Sauger (N=522)					
Pool 3 and St. Croix R.	7	0	13	0	2
Pool 4	92	100	86	100	97
Pool 5 and Chippewa R.	1	0		0	1

been tagged the previous summer in Lake Pepin.

Sauger also appeared to exhibit more upstream movement in years of higher water levels. Sauger were not tagged in a sufficient number of years to allow statistical analysis, however, the percentage of sauger tags returned from upstream of Pool 4 was considerably greater for fish tagged in spring of 1978 and 1979 than in 1980 (7% and 13% vs. 2%). Mean April-May water levels in 1978 and 1979 were the highest recorded during 1977-81.

Vital Statistics

Annual mortality of walleye and sauger was calculated to be greater than 50%. Annual mortality of walleye estimated from a catch curve based on creeled fish from 1978-81 (ages II-IX) was 55% (Table 7). Annual mortality of sauger based on gill net catches (ages III-VI) was estimated to be 63% for the 1962-75 year classes (from Table 2) and 59% for age classes II-VII based on creeled fish for the years 1978-81 (Table 7).

Adjusted rates of exploitation were greater for sauger than for walleye. Rates of exploitation for walleye from 1976 through 1980 were 25.2%, 26.8%, 33.6%, 29.5% and 33.0% with an average of 29.6%. Rates of exploitation for sauger tagged during the springs of 1978-80 and summers of 1978-79 were 32.6%, 33.8%, 58.0%, 27.6% and 37.2% with an average of 37.8%.

The annual expectation of death from natural causes was similar for the two species with natural mortality for walleye estimated to be 25% and for sauger 23%. Natural mortality for walleye was in the higher portion of the range reported by Ney (1978) for exploited populations. Conditional natural mortality rates (Ricker 1975) were 36 and 37% for walleye and sauger, respectively.

Walleye grew faster than sauger in Pool 4, both species grew faster than the Minnesota average and females of both species grew faster than

males and lived longer (Table 9). The Brody growth coefficients (K) (Ricker 1975) for walleye in Lake Pepin were at least twice that of Lake of the Woods on the Canadian border:

	Male	Female
Lake Pepin	0.329	0.310
Lake of the Woods	0.177	0.107

Growth increments of walleye and sauger have not changed significantly since 1957 (Tables 10 and 11).

Year-class strength of walleye but not sauger was related to water level during spawning and incubation. The number of age I walleye in gill nets for the 1964-80 year-classes was correlated with mean water levels during 20 April-10 May ($Y = 2.007X - 1330.935$, $r = 0.628$, $P < 0.01$). A similar correlation did not exist for age I sauger (1964-80 year-classes) or age III sauger (1962-78 year-classes) (age at which fully recruited to gill net) in the gill net and water level during April 27-May 17 ($r = 0.131$ and 0.266, respectively, $P > 0.05$).

DISCUSSION

During 15 years of continuous fishing (1967-1981) for walleye and sauger on Pool 4 of the Mississipi River (Lake Pepin) fishing pressure has increased but neither species has been adversely affected. The walleye population has remained stable while the sauger population has widely fluctuated.

The spring fishing season has added fishing pressure but pressure during the rest of the year has also increased. The estimated fishing pressure for walleye and sauger on Pool 4 of 32.1 hr/ha was similar to or greater than pressure on major Minnesota walleye lakes. Osborn (in press) and Maloney (1978) both estimated about 32 hr/ha for Lakes Winnibigoshish

Table 9. Growth of walleye and sauger (mm) sampled during creel census, 1979-81, (sex undetermined) and during spring electrofishing (sexes separate), 1979-80 in Pool 4, Mississippi River. Growth back-calculated to last annulus only.

Year	I	II	III	IV	V	VI	VII	VIII	IX
Walleye									
1979-81 average	168	290	396	485	533	592	650	688	683
Minnesota average b	130	229	312	384	439	488	531	561	594
Male 1979-80		295	386	457	511	533	561		
Female 1979-80		330	437	511	589	620	660	661	699
Sauger									
1979-81 average	142	257	330	394	442	481	505	489	
Minnesota average b	109	201	264	300	330	361	363		
Male 1979-80		259	330	386	409	455			
Female 1979-80		262	438	411	465	478	511	559	

b From Scidmore (1970).

Table 10. Growth increments (mm) of walleye and sauger collected by creel census (1957, 1967-68, 1979-81), gill nets (1965-68, 1978-81) and spring electrofishing (male and female; 1968, 1979-80), Pool 4, Mississippi River.

Year	Gear	Year of Growth 1	2	3	4	5	6	7
WALLEYE								
1957	Creel census	150	129	107	69	41	53	25
1967-68	Creel census	165	119	122	66	36	61	46
1979-81	Creel census	168	122	106	89	48	59	58
1965-68	Gill net	163	137	111	72			
1978-81	Gill net	160	132	89	79			
1968 Male	Electrofishing			97	71	25	43	25
1979-80 Male	Electrofishing			91	71	54	22	28
1968 Female	Electrofishing			84	76	53	20	122
1979-80 Female	Electrofishing			97	84	78	31	40
SAUGER								
1957	Creel census	135	94	78	51			
1967-68	Creel census	145	106	79	54	73	13	
1979-81	Creel census	142	115	73	64	59	47	
1965-68	Gill net	127	119	92	63	49	28	
1978-81	Gill net	137	125	73	54	56	22	
1968 Male	Electrofishing			79	58	25	13	
1979-80 Male	Electrofishing			74	53	23	46	
1968 Female	Electrofishing			91	59	43	23	
1979-80 Female	Electrofishing			86	63	54	13	

Table 11. Calculated and tabular values of t (t and t_{05}) of differences in growth increments of walleye and sauger, 1957-81, Pool 4, Mississippi River.

	1967-68 Creel Census		1979-81 Creel Census		1978-81 Gill Net		1979-80 Male Electrofishing		1979-80 Female Electrofishing	
	t	t_{05}	t	t_{05}	t	t_{05}	t	t_{05}	t	t_{05}
Walleye										
1957 Creel Census	-0.224	2.179	-0.450	2.179						
1967-68 Creel Census			-0.206	2.179						
1965-68 Gill net					0.212	2.447				
1968 Male Electrofishing							-0.052	2.306		
1968 Female Electrofishing									0.235	2.306
Sauger										
1957 Creel census	-0.248	2.447	-0.355	2.447						
1967-68 Creel census			-0.167	2.228						
1965-68 Gill net					0.075	2.228				
1968 Male Electrofishing							-0.285	2.728		
1968 Female Electrofishing									0.000	2.228

and Mille Lacs, respectively, while Schupp (1972) reported a 3 year range of 17.4-19.1 hr/ha for Leech Lake.

Walleye fisheries in northern Minnesota lakes subjected to increasing fishing pressure have produced higher yields, a reduced average size and a decline in catch rate (Johnson and Johnson 1971; Maloney 1978; Osborn, in press). Percid populations may exhibit several responses to overexploitation: increased variability of recruitment, increased growth rates and reduced age at maturity (Spangler et al. 1977). None of these responses were evident in Pool 4. Harvest and catch rates were dependent on abundance of walleye and sauger. Average weight in the creel and growth rates of both species have not changed and overexploitation was not indicated.

Annual rates of mortality and exploitation for walleye and sauger were comparable to those of other exploited populations and do not appear excessive. Ney (1978) stated that annual mortality of exploited walleye populations may range up to 57% and that natural mortality may range from 5-30%. This study estimated rates of annual mortality, natural mortality and exploitation as 55%, 25% and 30%, respectively. Recent estimates of walleye annual mortality in Minnesota range from 37% at Leech Lake (Schupp 1972) to 59% for three upper Mississippi River reservoir lakes (Strand 1980). Minimum (unadjusted) rates of exploitation as high as 35% have been reported for walleye in Minnesota lakes (Strand 1980; Osborn, in press). Annual rates of mortality and exploitation for exploited sauger populations of 45% and 10.4-33%, and 87.7% and 22.1% for Missouri River and Tennessee River impoundments, respectively, have been reported (Nelson 1969; Nelson and Walburg 1977; Fitz and Holbrook 1978; Hackney and Holbrook 1978). Rates of annual mortality and exploitation for sauger in this study were 59-63% and 38%.

Angling success for both walleye and sauger was greatly influenced by year-class strength. Strong year-classes of walleye have been shown to dominate the angler's catch in other Minnesota waters (Schupp 1974; Osborn, in press). Serns and Kempinger (1981) found an inverse relationship between exploitation rate and the mean length and age of walleye in Escanaba Lake, Wisconsin.

The most important physical factors affecting walleye reproductive success are water temperature, wind and water level or flow rates (Koonce et al. 1977). Spangler et al. (1977) showed a positive relationship between flow rate and year-class strength for river spawning walleye populations. A positive association between walleye year-class strength and water level at spawning time has been reported for Missouri River reservoirs (Nelson and Walburg 1977) and for lakes with marshes used for spawning (Priegel 1970). It is possible that spring water levels on the Mississippi River may make available both river and marsh spawning habitat and provide sufficient flow rates for adequate reproduction.

Movement of some Lake Pepin walleye upstream to spawning areas and back to Lake Pepin summer feeding grounds appears to be characteristic of many walleye populations (Colby et al. 1979). Movement within the lake was minimal. Schupp (1972) found that walleye tagged in Leech Lake and caught during the summer were generally taken less than 6.7 km from the place of capture.

The fluctuation of the sauger population in Pool 4 was probably due to abiotic factors. The largest increase in sauger abundance coincided with the initiation of continuous fishing. Schupp and Macins (1977) reported that the sauger population in Lake of the Woods fluctuated widely and independently of commercial fishing. Abundance of sauger in Tennessee River

reservoirs fluctuated and year-class strength was attributed to abiotic effects (Hackney and Holbrook 1978).

An examination of biological and physical charactertistics indicate that Lake Pepin is a more favorable environment for sauger than for walleye. Sauger have been predominant in both the gill nets and the anglers' catch. Clady (1978) theorized that the presence of sauger usually indicated a reduced walleye population and that the fish community is more diverse in lakes with a well established sauger population than in a lake where the walleye is the predominant percid. At least 85 species of fish have been reported in Pool 4 (Rasmusson 1979). Colby et al. (1979) stated than an inverse relationship exists between walleye vulnerability to angling and abundance of forage fish and, therefore, low catch rates for walleye in the Mississippi River would be expected. Physiology of the percid eye favors sauger over walleye in turbid water (Ali and Anctil 1977). Schlick (1978) concluded that waters with Secchi disc transparencies less than 0.9 m are best suited for sauger.

Anglers opposed to spring fishing assume that all Lake Pepin walleye and sauger spawn in the tailwaters of Lock and Dam 3. This is probably not a valid assumption. Holzer and VonRuden (1982) described off-channel spawning habitat for walleye in Pool 8 as reed canary grass located in flooded timber. Skrypek (1962) netted Lake Pepin during the spawning season and found "green", "ripe" and "spent" females of both species. He concluded that an abundance of excellent walleye spawning grounds existed and that spawning appeared to be scattered throughout the lake. Priegel (1970) found that not all walleye in Lake Winnebago moved upstream into the Wolf and Fox Rivers to spawn but a substantial number spawned successfully over a large length of shoreline in the lake.

Several walleye populations in Wisconsin have been subjected to continuous fishing for some years. Liberalized regulations have been in effect on Escanaba Lake since 1946 and no detrimental effects upon the fish populations have been noted (Kempinger and Carline 1977). The walleye population of Lake Winnebago has been fished during a spawning migration into the Fox and Wolf Rivers for many years, where Priegel (1970) conducted a three-year tagging study and concluded that high fishing pressure prior to the spawning season had little impact on reproductive success in the Wolf River or the population. Holzer and VonRuden (1981) concluded that exploitation of walleye on the Mississippi River did not indicate overfishing and that the continuous season should be continued.

A closed season for walleye prior to and during spawning in inland Minnesota waters has long been in force. Walleye populations in northern Minnesota lakes are charactertized by slow growth, late maturity (V-VII) and low natural mortality (5-10%). A closed season may benefit populations with these characteristics. However, Mississippi River walleye in the Minnesota-Wisconsin boundary waters grow rapidly, mature earlier (III-IV) and have a high natural mortality rate. In a population with these parameters, more fishing pressure apparently will not have an adverse effect on the population because of high natural mortality rates. Because of this, it appears that a continuous season would have no adverse effect on the walleye population.

Fish that grow fast and approach their ultimate length quickly are likely to have a high natural mortality rate and fish that grow slowly are likely to have a low natural mortality rate (Gulland 1973). Maturity of walleye is determined by length not age (Ney 1978). Walleye in Lake Pepin are about 100 mm longer than in northern Minnesota lakes by age IV and

mature at ages III-IV. Rates of exploitation in Lake Pepin and many northern Minnesota lakes do not differ greatly (30-35%) but natural mortality rates in Lake Pepin (25%) may be several times greater than in northern lakes. The rapid growth rates combined with a high rate of natural mortality assures a high turnover rate for the population. Under these circumstances, it is unlikely that a reduced season length would "save" walleye in sufficient numbers that could be detected by anglers.

The walleye and sauger populations appear capable of sustaining the harvest and yield recorded in this study and the biological characteristics of these species indicate that a continuous walleye-sauger fishing season can be continued on the Mississippi River without adversely affecting either population.

MANAGEMENT IMPLICATIONS

1. Biological parameters of the walleye population including rapid population turnover because of fast growth, early maturity and relatively high rates of natural mortality differ from those of Minnesota inland walleye lakes and are the basis for the difference in management.
2. Angling success for walleye and sauger is dependent upon abundance which appears to be dependent upon environmental or abiotic factors and neither show any symptoms of overexploitation.
3. Lake Pepin (66% of the Pool 4 area) is a more favorable habitat for sauger than for walleye. This is reflected in both populations and fishery where the sauger are predominant and the walleye tends to be part of an incidental fishery.

4. The walleye and sauger populations of Pool 4 of the Mississippi River have not been adversely affected by 15 years of continuous fishing and more restrictive regulations are not necessary.

5. Annually monitor Lake Pepin walleye and sauger populations.

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Table A1. Estimated fishing trips and standard error (upper) and manhours (lower), Pool 4, Mississippi River, 1977-81.

	1977 Mar 77-Feb 78	1978 Mar 78-Feb 79	1979 Mar 79-Feb 80	1980 Mar 80-Feb 81	1981 Mar 81-Feb 82	MEAN	MEAN %
March	6,412 (2,157) (35,266)	12,387 (2,021) (64,412)	6,148 (1,013) (29,510)	2,962 (567) (12,734)	6,795 (1,044) (39,411)	6,941 (1,363) (36,267)	5.4 (7.2)
April	15,046 (3,467) (82,753)	7,248 (1,460) (38,414)	8,426 (1,514) (38,760)	6,012 (762) (32,465)	6,775 (878) (38,618)	8,701 (1,461) (46,202)	6.7 (9.2)
May	27,821 (4,583) (116,848	18,267 (2,498) (76,721)	15,289 (3,061) (44,338)	19,864 (4,478) (75,483)	17,140 (2,784) (61,704)	19,676 (1,939) (62,516)	15.2 (12.4)
June	19,688 (5,360) (84,658)	16,783 (2,792) (65,453)	15,564 (2,335) (59,143)	13,671 (2,382) (56,051)	16,292 (2,204) (58,651)	16,400 (874) (64,791)	12.7 (12.9)
July	17,623 (3,685) (68,730)	12,720 (2,504) (52,152)	18,049 (2,284) (75,806)	9,660 (1,899) (39,606)	14,560 (1,724) (50,960)	14,522 (1,399) (57,451)	11.2 (11.4)
August	40,566 (8,569) (121,698)	19,965 (4,026) (71,874)	17,896 (2,384) (83,322)	16,043 (2,181) (62,568)	29,128 (3,590) (110,686)	24,720 (4,074) (90,030)	19.1 (17.9)
September	32,639 (6,894) (130,556)	22,780 (3,995) (95,676)	13,969 (2,314) (53,082)	7,721 (1,124) (33,972)	18,480 (3,532) (57,876)	19,118 (3,758) (74,232)	14.8 (14.7)

October	12,864	6,905	7,529	11,522	10,300	9,824	7.6
	(2,431)	(1,413)	(1,337)	(2,132)	(1,447)	(1,023)	
	(52,742)	(27,620)	(27,104)	(42,631)	(36,050)	(37,229)	(7.4)
November	1,967	2,332	1,480	a1,764	1,278	1,764	1.3
	(621)	(901)	(468)	(1,242)	(354)	(1,242)	
	(8,261)	(9,095)	(4,884)	(6,742)	(4,729)	(6,742)	(1.3)
December	7,503	1,460	359	a2,369	154	2,369	1.8
	(2,455)	(352)	(189)	(2,489)	(90)	(2,489)	
	(21,759)	(4,818)	(682)	(6,834)	(77)	(6,834)	(1.3)
January	4,694	2,164	2,708	3,431	3,859	3,371	2.6
	(1,015)	(486)	(850)	(606)	(1,180)	(394)	
	(18,307)	(6,925)	(10,561)	(12,695)	(11,963)	(12,090)	(2.4)
February	2,299	1,693	1,004	2,792	2,311	2,020	1.6
	(444)	(372)	(268)	(608)	(556)	(276)	
	(9,426)	(9,481)	(5,020)	(14,239)	(9,013)	(9,436)	(1.9)
TOTAL	189,122	124,704	108,421	97,811	127,012	129,426	
	(14,438)	(7,874)	(6,102)	(7,027)	(6,836)	(7,086)	
	(751,004)	(522,641)	(432,212)	(396,020)	(479,738)	(503,820)	

a No census; mean of other four years used.

Table A2. Estimated walleye harvest, (standard error in parentheses), Pool 4, Mississippi River, 1977-81.

	1977	1978	1979	1980	1981	MEAN
March	1,461 (506)	5,693 (2,761)	1,696 (306)	503 (107)	1,380 (238)	2,147 (813)
April	4,508 (1,105)	1,202 (286)	1,148 (244)	534 (84)	1,314 (280)	1,741 (630)
May	6,734 (1,403)	6,686 (1,124)	2,245 (615)	5,335 (1,421)	3,462 (742)	4,892 (796)
June	6,838 (2,238)	5,269 (1,578)	5,963 (1,025)	2,634 (614)	3,494 (676)	4,840 (696)
July	1,535 (507)	3,356 (795)	2,983 (534)	854 (267)	2,155 (408)	2,177 (410)
August	2,997 (1,087)	2,418 (657)	776 (225)	518 (155)	1,777 (256)	1,697 (422)
September	4,324 (1,130)	2,100 (502)	1,051 (273)	367 (135)	1,478 (371)	1,864 (605)
October	4,072 (893)	1,027 (277)	598 (182)	2,453 (552)	2,472 (345)	2,124 (550)
November	420 (170)	229 (114)	284 (129)	320[a] (36)	345 (121)	320 (28)
December	47 (47)	341 (120)	0 (0)	100[a] (70)	10 (10)	100 (56)
January	49 (26)	133 (80)	143 (74)	156 (56)	151 (75)	126 (18)
February	291 (92)	712 (173)	92 (35)	681 (99)	367 (112)	429 (106)
Total	33,276 (3,465)	29,166 (3,594)	16,979 (1,431)	14,455 (1,689)	18,405 (1,290)	22,457 (1,791)

[a] No census; mean of other four years used.

Table A3. Estimated catch per trip of walleye (standard error in parentheses), Pool 4, Mississippi River, 1977-81.

	1977	1978	1979	1980	1981	Mean
March	0.23 (0.02)	0.46 (0.21)	0.28 (0.02)	0.17 (0.02)	0.20 (0.02)	0.27 (0.05)
April	0.30 (0.03)	0.16 (0.02)	0.14 (0.02)	0.09 (0.01)	0.19 (0.03)	0.18 (0.03)
May	0.24 (0.03)	0.37 (0.04)	0.15 (0.02)	0.27 (0.04)	0.20 (0.03)	0.24 (0.03)
June	0.35 (0.07)	0.31 (0.03)	0.38 (0.03)	0.19 (0.03)	0.21 (0.03)	0.29 (0.03)
July	0.09 (0.02)	0.26 (0.04)	0.16 (0.02)	0.09 (0.02)	0.15 (0.02)	0.15 (0.03)
August	0.07 (0.02)	0.12 (0.02)	0.04 (0.01)	0.03 (0.01)	0.06 (0.00)	0.07 (0.01)
September	0.13 (0.02)	0.09 (0.02)	0.08 (0.02)	0.05 (0.02)	0.08 (0.01)	0.09 (0.01)
October	0.32 (0.04)	0.14 (0.03)	0.08 (0.02)	0.21 (0.03)	0.24 (0.03)	0.20 (0.04)
November	0.21 (0.06)	0.10 (0.03)	0.19 (0.06)	a a	0.27 (0.06)	0.19 (0.03)
December	0.01 (0.01)	0.23 (0.06)	0.00 (0.00)	a a	0.07 (0.06)	0.08 (0.04)
January	0.01 (0.01)	0.06 (0.04)	0.05 (0.02)	0.04 (0.01)	0.04 (0.02)	0.04 (0.01)
February	0.13 (0.03)	0.42 (0.04)	0.09 (0.03)	0.24 (0.03)	0.16 (0.03)	0.21 (0.05)
ANNUAL	0.17 (0.01)	0.23 (0.06)	0.14 (0.01)	0.14 (0.01)	0.16 (0.01)	0.17 (0.02)

a No census.

Table A4. Average size (kg) of walleye (standard error in parentheses) in angler's creel, Pool 4, Mississippi River, 1977-81.

	1977	1978	1979	1980	1981	Mean
March	1.1 (0.10)	1.5 (0.13)	0.8 (0.05)	1.1 (0.09)	0.8 (0.04)	1.1 (0.12)
April	1.3 (0.18)	0.8 (0.11)	0.7 (0.06)	1.2 (0.10)	0.8 (0.06)	0.9 (0.10)
May	0.6 (0.07)	0.8 (0.05)	0.7 (0.05)	0.6 (0.04)	0.6 (0.04)	0.7 (0.04)
June	0.8 (0.09)	0.4 (0.03)	0.5 (0.02)	0.7 (0.08)	0.5 (0.03)	0.6 (0.07)
July	— —	0.6 (0.06)	0.6 (0.04)	0.7 (0.08)	0.5 (0.03)	0.6 (0.04)
August	0.8 (0.12))	0.6 (0.09)	1.1 (0.23)	0.2 (0.04)	0.6 (0.06)	0.7 (0.12)
September	0.5 (0.12)	0.4 (0.06)	0.6 (0.10	0.5 (0.09)	0.5 (0.07)	0.5 (0.03)
October	0.6 (0.07)	0.4 (0.06)	0.6 (0.07)	0.6 (0.04)	0.7 (0.06)	0.6 (0.05)
November	0.5 (0.15)	0.3 (0.04)	0.7 (0.18)	— —	0.6 (0.07)	0.5 (0.09)
December	— —	0.3 (0.06)	— —	— —	0.2 (0.00)	0.3 (0.03)
January	— —	0.4 (0.05)	0.6 (0.06)	0.4 (0.04)	0.3 (0.07)	0.5 (0.04)
February	1.3 (0.19)	1.1 (0.07)	1.1 (0.23)	0.7 (0.06)	0.7 (0.08)	1.0 (0.10)
Mean	0.8 (0.04)	0.8 (0.05)	0.7 (0.04)	0.8 (0.06)	0.7 (0.04)	0.7 (0.03)

Table A5. Estimated sauger harvest (standard error in parentheses), Pool 4, Mississippi River, 1977-81.

	1977	1978	1979	1980	1981	Mean
March	8,622 (2,923)	8,392 (1,420)	3,171 (566)	1,280 (267)	6,796 (1,082)	5,652 (1,310)
April	22,036 (5,155)	5,115 (1,102)	5,240 (1,057)	5,470 (735)	2,520 (380)	8,076 (3,158)
May	16,417 (3,089)	7,102 (1,225)	3,062 (474)	10,096 (2,467)	4,285 (887)	8,192 (2,136)
June	5,486 (1,755)	8,327 (1,578)	7,400 (1,266)	8,137 (1,704)	6,338 (1,103)	7,138 (484)
July	6,018 (1,660)	3,317 (824)	2,528 (487)	3,042 (787)	3,334 (565)	3,648 (546)
August	3,797 (1,250)	11,810 (2,760)	2,276 (474)	1,798 (401)	4,923 (1,133)	4,921 (1,618)
September	9,860 (2,388)	13,437 (2,636)	2,406 (554)	1,053 (256)	4,990 (1,044)	6,349 (2,079)
October	12,282 (2,527)	4,357 (982)	4,054 (866)	10,556 (2,131)	7,931 (1,302)	7,836 (1,464)
November	1,338 (447)	1,249 (543)	1,216 (483)	1,184a (76)	933 (286)	1,184 (61)
December	1,852 (686)	832 (251)	17 (19)	722a (360)	185 (130)	722 (288)
January	1,958 (489)	430 (147)	731 (293)	2,320 (523)	3,477 (1,122)	1,783 (495)
February	1,227 (279)	2,171 (500)	345 (117)	2,982 (269)	1,461 (396)	1,637 (398)
TOTAL	90,893 (8,071)	66,539 (4,905)	32,446 (2,262)	48,640 (3,933)	47,173 (3,037)	57,138 (5,134)

a No census; mean of four other years used.

Table A6. Estimated catch per trip of sauger (standard error in parentheses), Pool 4, Mississippi River, 1977-81.

	1977	1978	1979	1980	1981	Mean
March	1.34 (0.06)	0.68 (0.03)	0.52 (0.04)	0.43 (0.04)	1.00 (0.04)	0.79 (0.15)
April	1.46 (0.06)	0.71 (0.06)	0.62 (0.06)	0.91 (0.04)	0.37 (0.03)	0.82 (0.16)
May	0.59 (0.05)	0.39 (0.04)	0.20 (0.03)	0.51 (0.05)	0.25 (0.03)	0.39 (0.02)
June	0.28 (0.05)	0.50 (0.05)	0.48 (0.04)	0.60 (0.07)	0.39 (0.04)	0.45 (0.05)
July	0.34 (0.06)	0.26 (0.04)	0.14 (0.02)	0.32 (0.05)	0.23 (0.03)	0.26 (0.03)
August	0.09 (0.02)	0.59 (0.07)	0.13 (0.02)	0.11 (0.02)	0.17 (0.01)	0.22 (0.08)
September	0.30 (0.04)	0.59 (0.05)	0.17 (0.03)	0.14 (0.03)	0.27 (0.03)	0.29 (0.07)
October	0.96 (0.08)	0.60 (0.07)	0.54 (0.06)	0.92 (0.08)	0.77 (0.07)	0.76 (0.07)
November	0.68 (0.14)	0.54 (0.12)	0.82 (0.19)	—a —a	0.73 (0.10)	0.69 (0.05)
December	0.25 (0.04)	0.57 (0.11)	0.06 (0.05)	—a —a	1.20 (0.58)	0.52 (0.22)
January	0.42 (0.05)	0.20 (0.05)	0.27 (0.07)	0.68 (0.07)	0.90 (0.10)	0.49 (0.12)
February	0.53 (0.06)	1.28 (0.09)	0.34 (0.08)	1.07 (0.08)	0.63 (0.08)	0.77 (0.16)
ANNUAL	0.60 (0.02)	0.58 (0.02)	0.36 (0.01)	0.57 (0.02)	0.58 (0.01)	0.54 (0.04)

a No census; mean of other four years used.

Table A7. Average size (kg) of sauger (standard error in parentheses) in angler's creel, Pool 4, Mississippi River, 1977-81.

	1977	1978	1979	1980	1981	Mean
March	0.6 (0.03)	0.6 (0.06)	0.6 (0.02)	0.5 (0.02)	0.5 (0.02)	0.5 (0.02)
April	0.6 (0.18)	0.6 (0.03)	0.4 (0.01)	0.5 (0.01)	0.6 (0.01)	0.5 (0.03)
May	0.4 (0.03)	0.4 (0.02)	0.3 (0.01)	0.4 (0.02)	0.4 (0.02)	0.4 (0.02)
June	0.4 (0.07)	0.3 (0.01)	0.3 (0.01)	0.3 (0.02)	0.3 (0.01)	0.3 (0.02)
July	— —	0.2 (0.02)	0.3 (0.02)	0.3 (0.01)	0.3 (0.01)	0.3 (0.02)
August	0.3 (0.08)	0.3 (0.01)	0.4 (0.02)	0.3 (0.02)	0.3 (0.01)	0.3 (0.02)
September	0.4 (0.04)	0.3 (0.01)	0.3 (0.01)	0.3 (0.02)	0.4 (0.01)	0.3 (0.02)
October	0.5 (0.02)	0.3 (0.02)	0.4 (0.02)	0.6 (0.01)	0.4 (0.01)	0.4 (0.04)
November	0.4 (0.06)	0.4 (0.06)	0.5 (0.03)	— —	0.5 (0.03)	0.5 (0.03)
December	0.3 (0.04)	0.2 (0.02)	0.3 (0.00)	— —	0.2 (0.02)	0.3 (0.02)
January	0.2 (0.03)	0.2 (0.02)	0.5 (0.09)	0.3 (0.02)	0.3 (0.01)	0.3 (0.05)
February	0.6 (0.03)	0.6 (0.01)	0.4 (0.03)	0.4 (0.01)	0.4 (0.02)	0.5 (0.05)
MEAN	0.5 (0.01)	0.4 (0.01)	0.4 (0.01)	0.4 (0.01)	0.4 (0.01)	0.4 (0.02)

Table A8. Length-frequency distribution of walleye in the creel, Pool 4, Mississippi River, 1977-1981.

Size group	1977	1978	1979	1980	1981
175-200				2	
201-225				2	1
226-250	24	16	1	3	9
251-275	25	38	13	2	24
276-300	28	61	48	17	58
301-325	25	107	83	49	150
326-350	49	86	150	92	212
351-375	29	66	198	93	208
376-400	16	60	158	73	99
401-425	35	55	100	89	104
426-450	23	63	64	55	90
451-475	31	37	49	42	77
476-500	19	34	27	24	52
501-525	23	27	31	25	30
526-550	16	29	31	11	20
551-575	5	28	25	6	23
576-600	8	18	23	6	5
601-625	5	9	10	8	8
626-650	1	1	8	9	3
651-675	3	6	4	7	7
676-700	1	3	1	1	4
701-725	2	2	2	2	1
726-750	1	1	2	1	
TOTAL	369	747	1,027	618	1,185

Table A9. Length-frequency distribution of sauger in creel, Pool 4, Mississippi River, 1977-1981.

Size group	1977	1978	1979	1980	1981
175-200				1	
201-225	8	5		1	12
226-250	52	87	18	18	115
251-275	74	187	102	129	316
276-300	94	283	340	267	526
301-325	98	411	559	414	485
326-350	155	285	406	583	436
351-375	178	209	271	554	524
376-400	182	174	165	367	524
401-425	124	150	131	209	321
426-450	78	107	89	137	186
451-475	40	51	48	52	88
476-500	19	37	26	29	41
501-525	4	10	11	11	14
526-550	4	5	2	4	3
551-575	2	1	1	1	1
576-600		1			
601-625		1			
TOTAL	1,112	2,004	2,169	2 777	3,592

Table A10. The number of walleye and sauger tagged in Pool 4, Mississippi River, 1976-80, the number and percent returned and percent first year returns.

Year tagged	Number tagged	Number returned	Percent returned	Number first year returns	Percent first year returns
Walleye					
Spring, 1976	302	37	12.3		
Fall, 1976	1,186	163	13.7	127	77.9
Spring, 1977	213	20	9.4		
Fall, 1977	1,231	203	16.5	147	72.4
Spring, 19781	168	214	18.3	167	78.0
Summer, 1978	135	37	27.4		
Fall, 1979	343	51	14.9	43	84.3
Fall, 1980	535	75	14.0	75	100.0
TOTAL	5,113	800	15.6		
Sauger					
Spring, 1978	426	81	19.0	59	72.3
Summer, 1978	171	38	22.2	20	52.6
Spring, 1979	251	64	25.5	36	57.1
Summer, 1979	83	31	16.9	29	93.5
Spring, 1980	1,084	308	28.4	267	87.0
TOTAL	2,115	522	24.7		

Table A11. Return of walleye tagged in Pool 4, Mississippi River, 1976-81.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	TOTAL
A - 1976										13	2	3	18
1977	2	8	12	24	29	25	6	1	2	2	0	0	111
1978	0	1	1	0	5	5	4	2	0	1	4	0	23
1979	0	1	1	1	1	2	1	0	0	1	0	0	8
1980	0	0	1	0	1	1	0	0	0	0	0	0	3
B - 1977									1	8	4	0	13
1978	0	4	2	9	48	33	24	9	6	2	1	2	140
1979	0	3	2	5	5	11	7	2	1	1	0	0	37
1980	0	1	0	2	1	0	1	1	0	0	3	0	9
1981	0	0	0	0	0	1	0	0	0	0	0	0	1
C - 1978				4	65	39	24	12	7	3	1	0	155
1979	1	3	2	6	9	9	6	3	1	4	0	1	45
1980	0	0	3	2	3	1	2	0	0	1	0	0	12
1981	0	0	0	0	0	0	1	1	0	0	0	0	2
G - 1979										1	0	0	1
1980	2	0	0	1	16	12	11	0	0	1	0	0	43
1981	0	0	2	0	1	1	1	1	1	0	0	0	7
H - 1980										5	1	2	8
1981	2	3	1	2	10	9	20	9	11	0	0	0	67
1982	0	0	1	2	2								5
Total No.	7	24	28	58	196	150	108	40	30	43	16	8	708
Total %	1.0	3.4	3.9	8.2	27.7	21.2	15.3	5.6	4.2	6.1	2.3	1.1	

A - Tagged in Lake Pepin fall 1976.
B - Tagged in Lake Pepin fall 1977.
C - Tagged at L&D 3, spring 1978.
G - Tagged in Lake Pepin, fall 1979.
H - Tagged in Lake Pepin, fall 1980.

Table A12. Return of sauger tagged in Pool 4, Mississippi River, 1978-81.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	TOTAL
A - 1978				1	22	13	5	7	5	2	1	0	56
1979	0	2	1	0	0	6	2	5	0	0	0	0	16
1980	0	0	0	0	6	0	1	0	0	0	0	0	7
1981	1	2	2	0	1								6
B - 1978						1	0	5	4	1	0	0	11
1979	1	0	0	2	1	3	0	2	1	0	0	0	10
1980	0	0	0	0	7	1	4	0	0	0	0	0	12
1981	0	0	0	0	1	0	0	0	1				2
C - 1979				2	13	9	2	4	2	1	2	0	34
1980	1	2	2	0	1	1	2	0	0	1	1	0	17
1981	1	2	2	0	1	1	2	0	0	1	1	0	11
1982	1	0	0	0									1
D - 1979						1	0	1	1	0	0	0	3
1980	0	0	0	2	9	7	4	4	1	1	0	0	28
E - 1980				12	128	48	39	4	7	14	6	1	250
1981	1	5	7	4	16	13	4	2	4	1	0	0	57
1982	0	0	1										1
Total No.	5	11	13	25	212	105	54	36	27	23	10	1	522
Total %	1.0	2.1	2.5	4.8	40.6	20.1	10.3	6.9	5.2	4.4	1.9	0.2	

A - Tagged at L&D 3, spring 1978.
B - Tagged in Lake Pepin, summer 1978.
C - Tagged at L&D 3, spring 1979.
D - Tagged in Lake Pepin, summer 1979.
E - Tagged at L&D 3, spring 1980.