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A 15-YEAR STUDY OF THE HARVEST, EXPLOITATION, AND MORTALITY OF FISHES IN MURPHY FLOWAGE, WISCONSIN

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ABSTRACT

Complete angling records were obtained through a compulsory, registration-type creel census conducted on 180-acre Murphy Flowage from 1955 to 1970. On the average each year, anglers fished 73.6 hours per acre and harvested fish at the rate of 1.88 per hour. Annually the harvest of panfish averaged 21.7 lb/acre and of game fish, 8.8 lb/acre. Among panfish, bluegills dominated the harvest at all times. The number of game fish harvested were about equally divided between northern pike and largemouth bass, however, northern pike comprised about 70 percent of the pounds of game fish harvested. A remarkable feature of the yield has been the stability in the proportion of species harvested throughout the 15-year study period.

Sixty-three percent of all angler trips were successful. Generally the most successful 10 percent of all anglers harvested 50 percent of the fish. The harvest in winter was more productive than in summer, with anglers taking 4.2 fish/hour compared to 1.6 fish/hour in summer. Based on the regression of harvest on pressure, one could expect an estimated increase in harvest of 8 lb of fish per acre in winter and 3.5 lb of fish per acre in summer for each increase in pressure of 10 hours per acre. Variation in numbers and length of larger fish in the harvest were believed to be more closely related to variations in year-class strength and growth rates than to any other factors.

The annual exploitation rate averaged 9 percent for panfish while bluegills were caught at an average annual rate of 12 percent. Game fish were harvested at an average annual rate of 27 percent with a variation of 14 to 45 percent for largemouth bass and 3 percent to 50 percent for northern pike. The estimated annual natural mortality averaged 46 percent for panfish and 30 percent for game fish while total annual mortality averaged 57 percent for all species combined and also for panfish and game fish when figured separately.

The relationship between natural mortality and harvest rate was found to be significant for bluegill, pumpkinseed, and northern pike. Most of the pike caught were taken from potential natural losses, therefore, the catch by anglers had little effect on total mortality. For bluegills and largemouth bass, about half the catch was taken from potential survivors and half from potential natural losses. The estimated natural mortality (in the absence of fishing) averaged 49 percent for all species combined.

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INTRODUCTION

Approximately one million anglers fished 18½ million times and caught about 110 million fish in Wisconsin during the winter of 1970 and summer of 1971 (Churchill 1971, 1972). Nationally the number of habitual fresh-water anglers increased from about 22 million in 1960 to 29 million in 1970 for an increase of 35 percent during the 10-year period (U. S. Bureau of Sport Fisheries and Wildlife 1972). Fishing is indeed a very popular form of outdoor recreation and its importance is increasing steadily.

There is a constantly increasing fishing pressure on our inland lakes, however, there are relatively few waters where the actual harvest is known. Such information from selected waters is important to the management of warm-water fisheries. This report summarizes harvest information from Murphy Flowage in northwestern Wisconsin where a compulsory creel census and liberalized angling regulations were in effect for 15 years. A previous paper (Churchill and Snow 1964) summarized harvest data at Murphy Flowage over a 5-year period with special emphasis on angling characteristics. This paper is a more comprehensive report on the characteristics of the harvest. Special consideration is given to the quality of fishing as measured by catch rate, percent successful trips, size of fish caught, seasonal and annual trends, and other related factors.

Harvest is an important angling statistic, however, it does not indicate what proportion of the available fish are caught or to what extent it contributes to total annual mortality. Therefore, a basic and important section of this paper deals with total annual mortality and its two components, natural mortality and exploitation rate, and the relationship between these parameters. Hypothetical examples are discussed and the calculated results are presented. In addition, the estimated mortality in the absence of fishing is also presented.

THE STUDY AREA

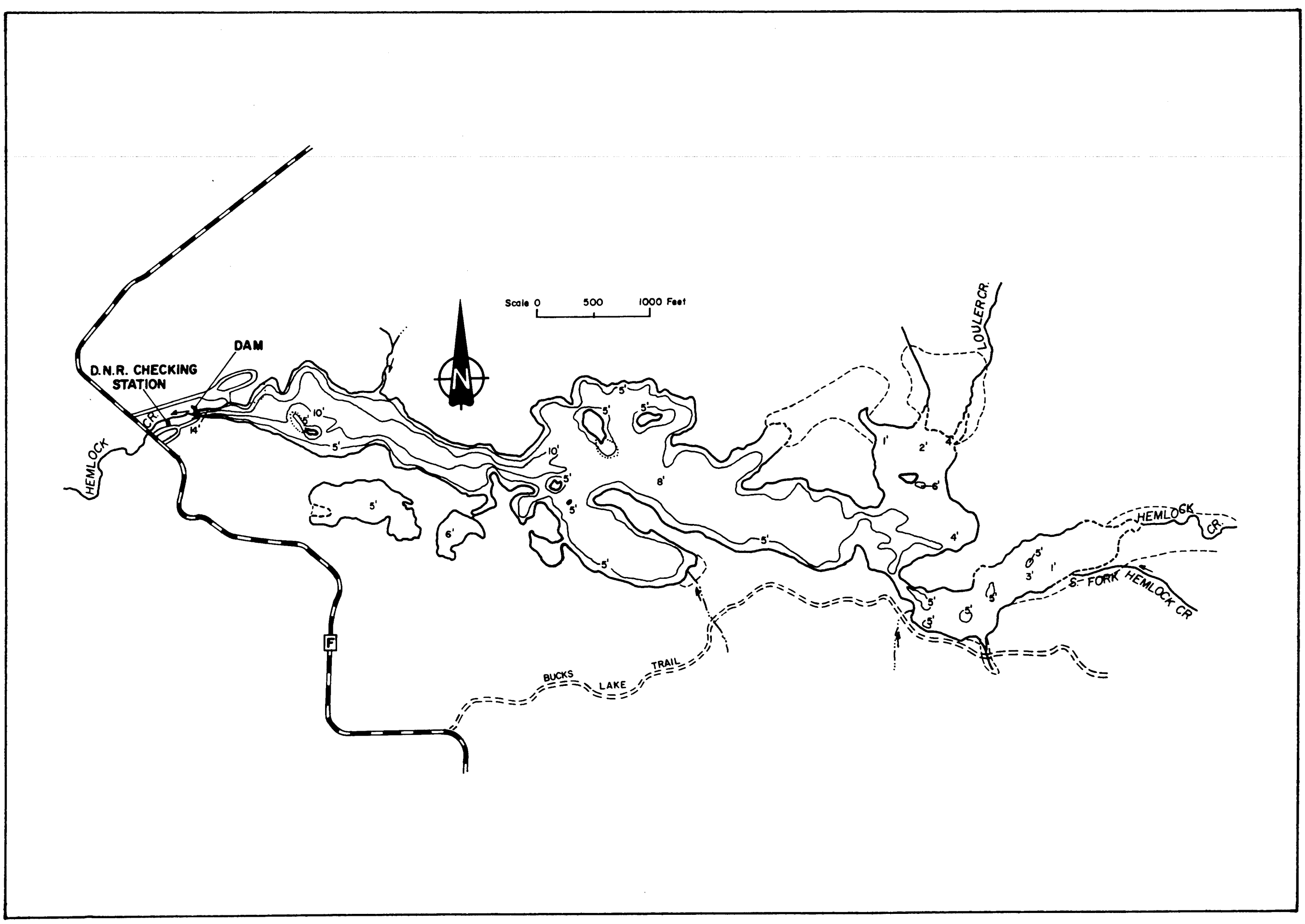
Murphy Flowage was* located in northwestern Wisconsin in the headwaters region of the Red Cedar River, a tributary of the Chippewa and Mississippi Rivers.* The flowage, which was formed in 1937 by impoundment of Hemlock Creek, a trout stream, had an elevation of 1,258 ft and was located within a hilly rocky region known as Barron Hills. Although the maximum depth of Murphy Flowage was 14 ft, over 70 percent was less than 10 ft in depth. The 180-acre flowage had a volume of 874 acre-ft of water and approximately 7 miles of irregular shoreline (Fig. 1). The average annual alkalinity was 37 ppm and the mean annual flow at the outlet was 18 cfs.

Beard (1973) found 24 species of aquatic plants present in Murphy Flowage in 1967. *Potamogeton robbinsii* was the most abundant species and covered an area of approximately 104 acres. Other common species in order of decreasing abundance were *Nuphar* spp., *Myriophyllum* spp., *Ceratophyllum demersum*, and *Potamogeton amplifolius*. A large percentage of the total area was covered by dense aquatic vegetation.

The total annual biomass of fish at Murphy Flowage was estimated to be 325 lb/acre (25 lb of game fish and 300 lb of panfish). The bluegill, *Lepomis macrochirus* Rafinesque, comprised about 80 percent of the total biomass of panfish. The largemouth bass, *Micropterus salmoides* (Lacepede), comprised about 30 percent of the total biomass of game fish and the northern pike, *Esox lucius* Linnaeus, comprised about 60 percent. Other panfish present were black crappie, *Pomoxis nigromaculatus* (Lesueur); pumpkinseed, *Lepomis gibbosus* (Linnaeus); rock bass, *Ambloplites rupestris* (Rafinesque); yellow perch, *Perca flavescens* (Mitchill); and brown bullhead, *Ictalurus nebulosus* (Lesueur). The white sucker, *Catostomus commersoni* (Lacepede); the tadpole madtom, *Noturus gyrinus* (Mitchill); and several species of minnows were present in limited numbers. Muskellunge, *Esox masquinongy* Mitchill, had been stocked but were not numerous.

*The dam impounding Murphy Flowage on Hemlock Creek washed out on 31 May 1970, hence the use of past tense to describe the study area.

FIGURE 1. *Contour map of Murphy Flowage, Wisconsin.*



METHODS

CREEL CENSUS

Complete angling records were collected through a compulsory registration-type creel census operated throughout the entire study from 30 April 1955 through 31 May 1970. Information on the hours fished and number, length, and weight of fish caught were recorded for each angler at the end of the fishing trip. All fish were measured to the nearest 0.1 inch in total length and weighed to the nearest 0.01 lb. An angling trip was considered successful if one or more fish was harvested. Throughout this paper, the terms "catch" and "caught" refer to fish which were harvested. No records were kept of fish caught and released. For further details of the procedures used see Churchill and Snow (1964).

Throughout this report an "angling year" includes the open water season plus the ensuing ice fishing season. All annual figures given therefore include data from two calendar years, on the average from April 15 one year to April 15 of the year following. There was no closed fishing season and neither a bag limit nor size limit was in effect on Murphy Flowage at any time. Angling was permitted form 4:00 a.m. to 10:00 p.m. in the summer and from 8:00 a.m. to 6:00 p.m. in the winter.

Unless otherwise indicated, the terms "summer fishing" and "open water fishing" are used interchangeably. Likewise the terms, "winter fishing" and "ice fishing", are also used interchangeably throughout this paper.

ESTIMATES OF MORTALITY

All estimates of mortality were obtained from marked fish. Early each spring, fish of the following sizes and larger were given a fin-clip for future identification: bluegill, pumpkinseed, and rock bass, 4.0 inches; yellow perch and black crappie, 5.0 inches; brown bullhead and largemouth bass, 8.0 inches; and northern pike, 12.0 inches. Annual survival and mortality rates for all marked fish were determined by making a Petersen estimate of the marked segment of the population surviving from the previous year.

The notations used for mortality are those of Ricker (1975) and the statistics used in this study are: A = expectation of death from all causes, or total mortality; v = expectation of death from natural causes, or natural mortality; and u = expectation of death from angling, or exploitation rate.

MANAGEMENT AND PUBLICITY

The entire 15-year study was divided into 3 five-year periods from a management viewpoint. They are as follows: (1) From 1955 to 1959, intensive publicity was aimed to increase fishing pressure on the Flowage. No attempts were made to manipulate the fish population or the environment. (2) From 1960 to 1964, there was less publicity. Manipulation of the fish population by removal of panfish occurred in 1960 and 1961 and the stocking of northern pike in December 1963. (3) From 1965 to 1969, very little publicity was issued. Manipulation of the environment by winter drawdown (October-March) took place in 1967, 1968, and 1969.

Muskellunge were also stocked, 1,000 3-inch fingerlings in the summer of 1955 and 200 8- to 12-inch fingerlings each fall from 1955 through 1964.

Neither the panfish management nor muskellunge stocking programs are evaluated in this paper, however, they are mentioned here and in various sections of this report where pertinent.

RESULTS AND DISCUSSION

PRESSURE

Angling Trips

The number of angler trips made at Murphy Flowage during the 15-year study period averaged 3,576 annually and varied annually from 2,293 to 5,993 trips. Aside from the first year of study, the annual pattern of angler trips falls into three five-year groups. From 1956 through 1959 there were 4,000 to 6,000 trips; from 1960 through 1964 3,000 to 4,000 trips; and from 1965 through 1969, 2,000 to 3,000 trips (Table 1).

Hours Fished

Hours fished average 13,242 annually and varied annually from 7,304 to 23,654. On an area basis, pressure averaged 73.6 hours/acre. The average fishing pressure in Murphy Flowage is within the range of that reported for other north central waters, but is considerably less than the 567 hours/acre reported for 12 intensively managed Alabama lakes (Table 2). Previous studies have shown that the average distance travelled by anglers is inversely related to fishing pressure (Churchill and Snow 1964). Therefore at Murphy Flowage, which is over 100 miles from a major population center, one could not expect exceptionally high fishing pressure. Even in years of excellent fishing and publicity to inten-

TABLE 1. *Annual fishing pressure, harvest, and fishing quality for Murphy Flowage, 1955-69.*

	Fishing Pressure			Harvest				Fishing Quality			
Year	Number Trips	Total Hours	Hours/ Acre	Total Fish	Total Pounds	Fish/ Acre	Pounds/ Acre	% Successful Trips	Fish/ Hour	Pounds/ Hour	Fish/ Trip
1955	2,718	11,292	62.7	14,067	3,986	78.1	22.1	55	1.25	0.35	5.2
1956	4,156	18,805	104.5	31,595	8,191	175.5	45.5	68	1.68	0.44	7.6
1957	4,802	19,005	105.6	36,005	8,434	200.0	46.8	69	1.89	0.43	7.5
1958	5,993	23,654	131.4	43,519	10,043	241.8	55.8	68	1.84	0.42	7.3
1959	5,305	20,622	114.6	44,837	9,036	249.1	50.2	67	2.17	0.44	8.5
1960	3,719	13,190	73.3	43,288	7,826	240.5	43.5	71	3.28	0.59	11.7
1961	3,554	11,976	66.5	23,508	5,301	130.6	29.6	60	1.96	0.44	6.6
1962	3,987	13,480	74.9	23,134	5,288	128.6	29.4	60	1.72	0.39	5.8
1963	3,779	13,345	74.1	27,228	5,682	151.3	31.6	59	2.04	0.43	7.2
1964	3,112	10,827	60.2	17,944	3,951	99.7	22.0	59	1.65	0.36	5.8
1965	2,574	8,560	47.6	12,651	2,671	70.0	14.8	55	1.47	0.31	4.9
1966	2,293	7,304	40.6	11,907	2,552	66.1	14.2	57	1.63	0.35	5.2
1967	2,382	8,169	45.4	15,313	3,373	85.1	18.7	55	1.87	0.41	5.2
1968	2,304	8,275	46.0	11,211	2,607	62.4	14.5	56	1.35	0.32	4.9
1969	2,959	10,121	56.2	17,310	3,428	96.2	19.0	61	1.71	0.34	5.8
TOTAL	53,637	198,625		373,520	82,376						
AVG.	3,576	13,242	73.6	24,901	5,491	138.3	30.5	63	1.88	0.41	7.0

TABLE 2. *Fishing pressure, yield, and success rate on selected waters.*

Lake and State	Size of Lake (Acres)	Fishing Pressure (Hour/ Acre)	Yield (Lb / Acre)	Catch Rate (Fish/ Hour)	Years of Study	Source
Murphy Flowage, Wis.	180	73.6	30.5	1.88	15	Present study
Escanaba Lake, Wis.	293	65	20	0.84	24	Kempinger et al. (1975)
Ridge Lake, Ill.	18	219	42	0.75	21	Bennett et al. (1969)
14 Lakes, Minn.	220-1,783	38	15	0.79	1	Johnson & Kuehn (1956)
12 Lakes, Mich.	117-675	119	-	1.22	5	Christensen (1953)
8 Lakes, Mich.	1-130	21	4.4	0.81	12	Patriarche (1960)
12 Lakes, Ala.	32-250	567	174	1.04	2-8	Byrd (1959)

tionally increase angler use, pressure did not exceed 131.5 hours/acre. Conversely during periods of no intentional publicity and poorer fishing, pressure reached a low of 40.6 hours/acre. If the research study had not been in progress, fishing pressure in Murphy Flowage would have been considerably less. Based on these comparisons pressure at Murphy Flowage could be considered about average as compared to other north central waters but above average when compared to waters in sparsely populated areas.

Angler hours/acre increased steadily the first four years of study then decreased most of the remaining years (Fig. 2). The 15-year pattern of pressure follows the same trend as the number of trips and averaged 104, 70, and 47 hours/acre during each successive 5-year interval of study.

Seasonally, 88 percent of all fishing occurred during the open water season and 12 percent in the ice fishing season. Three-fourths of all fishing was concentrated in the 3½-month period from 16 May through 31 August.

During 10 of the 15 years of study, maximum pressure in semimonthly intervals occurred during the first half of July when 14 percent of all fishing took place (Fig. 3). Maximum pressure during the ice fishing season occurred between 16 and 31 December. Pressure was at a minimum during the intervals between open water and ice fishing seasons, 1-15 April and 16 October through 15 November.

The number of hours fished/trip averaged 3.7 and declined during the year from a high of 3.8 during open water fishing before 1 July to a low of 3.5 during the ice fishing season.

HARVEST

All Species

In 15 years, 373,520 fish weighing 82,376 lb were taken from Murphy Flowage (Table 1). The annual harvest averaged 24,901 fish weighing 5,491 pounds or 138.3 fish and 30.5 lb/acre. The average annual harvest of 30.5 lb/acre was higher than most other north central waters (Table 2) and therefore the harvest could be considered above average especially for sparsely populated areas for the same reason as described for fishing pressure.

Annually, the catch in lb/acre varied considerably. During the first four years of study there was a steady increase in the yield to a high of 55.8 lb/acre in 1958. Thereafter the yield decreased in most years and reached a low of 14.2 lb/acre in 1966 (Fig. 4). The annual catch in numbers of fish followed the same general trend as yield except that the maximum in numbers occurred in 1959, at 249.1 fish/acre and the minimum in 1968 at 62.4 fish/acre (Table 1). Lack of exact annual sychronous variation between yield and number can be attributed to variations in the proportion of the different species in the catch.

Seasonally, 76 percent of all fish by number and weight were caught during the open water season, of which 65 percent were caught in the 3½-month period from 16 May through 31 August. Maximum harvest occurred the first half of June when 13 percent of the total poundage was caught (Fig. 5). Peak harvest in the ice fishing season occurred between 16 and 31 December when 6 percent of the total annual poundage was caught. The time of capture was quite consistent during the 15 years of study in that during 9 years in the open water seasons and 8 years in the ice seasons, the maximum harvest occurred during the 1-15 June and 16-31 December periods, respectively. Minimum harvest occurred during the periods of spring and fall breakup when less than 1 percent of the total harvest was caught.

During the 15 years of study, the number of panfish harvested was 25 times the number of game fish caught and 2½ times the poundage of game fish caught. Annually, the catch of panfish averaged 132.8 fish weighing 21.7 lb/acre and of game fish, 5.5 fish weighing 8.8 lb/acre.

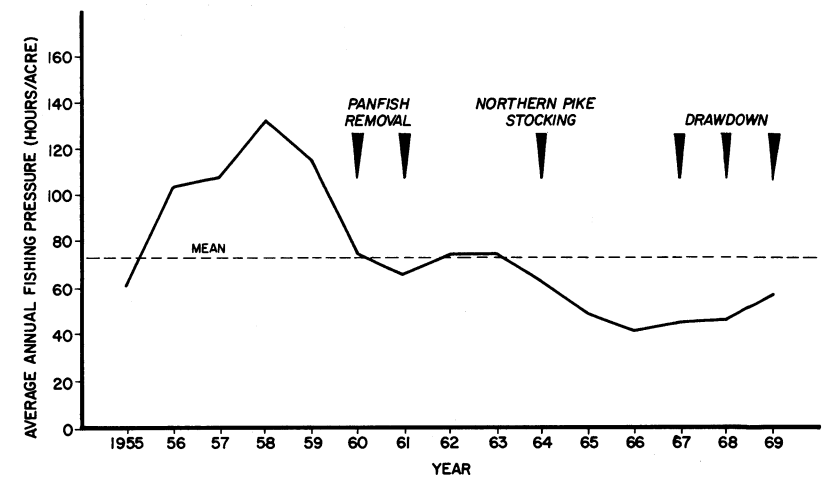


FIGURE 2. *Average annual fishing pressure at Murphy Flowage, 1955-69.*

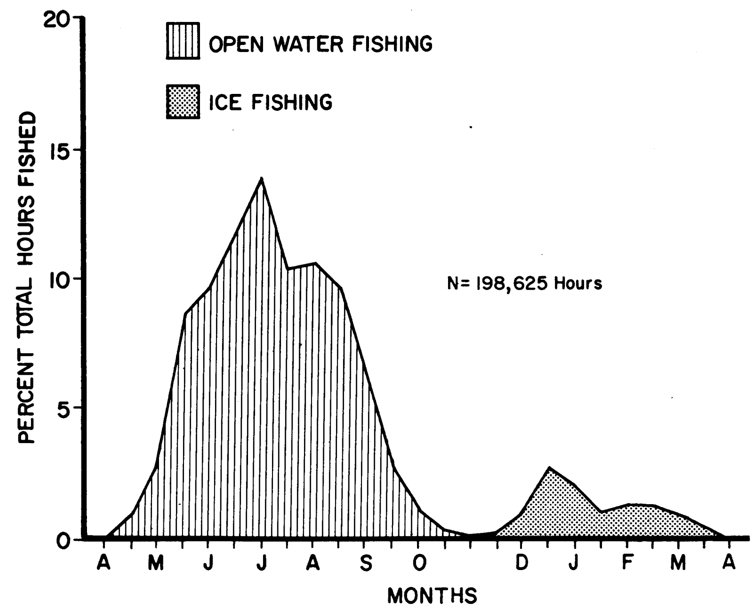


FIGURE 3. *Semimonthly distribution of hours fished at Murphy Flowage, 1955-69.*

Panfish

Bluegills dominated the catch at all times in both numbers and poundage caught. Annually the catch in numbers of bluegills averaged 20,823 and ranged from 9,007 to 38,510 fish while the catch in poundage of bluegills averaged 3,237 and ranged from 1,209 to 6,256 lb. The annual catch of bluegills/acre averaged 115.7 fish weighing 18.0 lb (Table 3).

The next most important panfish species in the catch were the black crappie which annually averaged 1,099 fish weighing 318 lb or 6.1 fish weighing 1.8 lb/acre, and the yellow perch which averaged 5.4 fish/acre.

The other species of panfish in order of decreasing numbers caught were rock bass, pumpkinseed, and brown bullhead. The catch of these species each comprised less than 4 fish and 1.0 lb/acre.

Game Fish

The catch of largemouth bass totaled 7,176 fish compared to 7,528 northern pike. In contrast to the almost equal catch in numbers, the catch

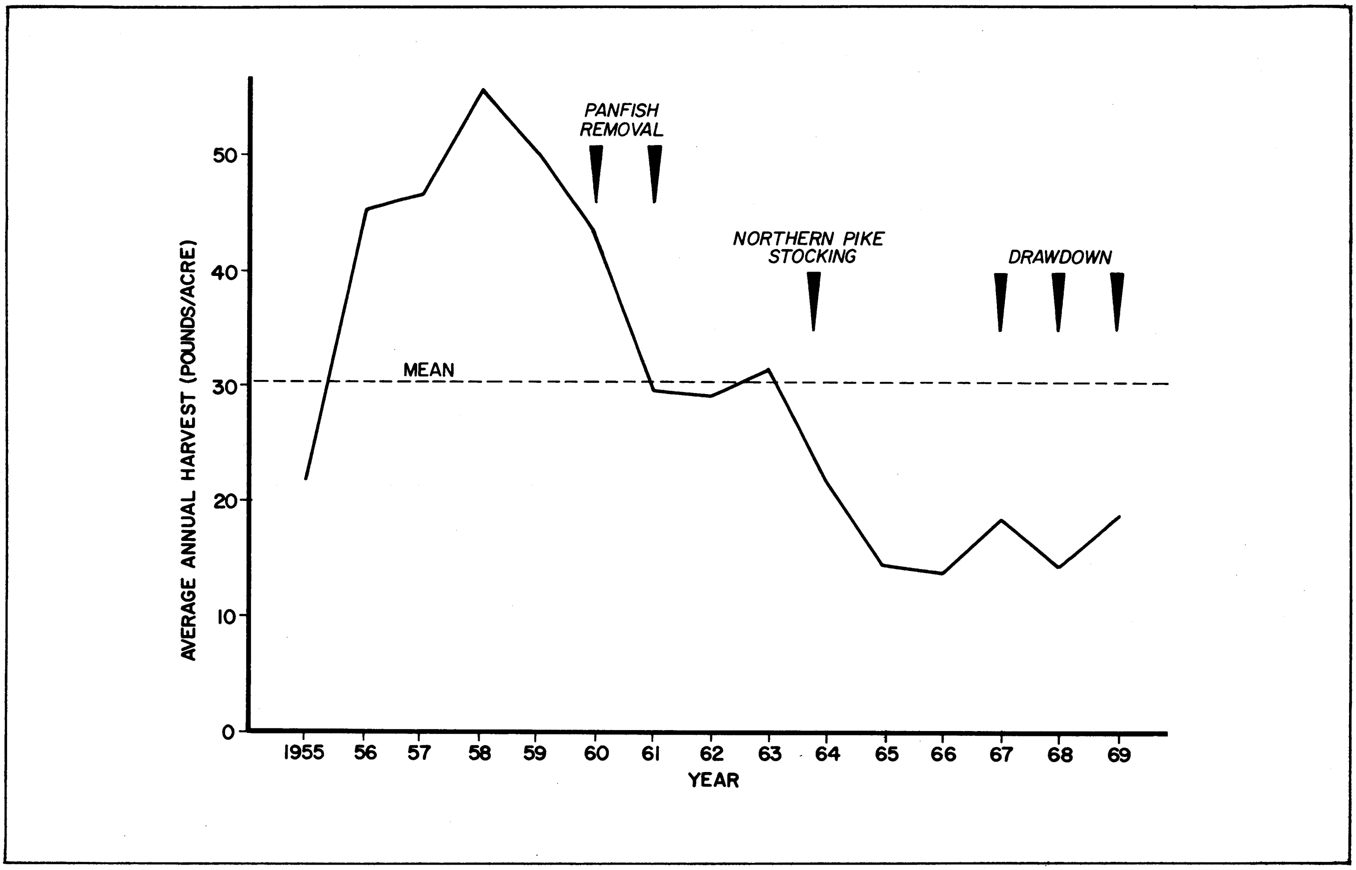


FIGURE 4. *Average annual harvest of fish from Murphy Flowage, 1955-69.*

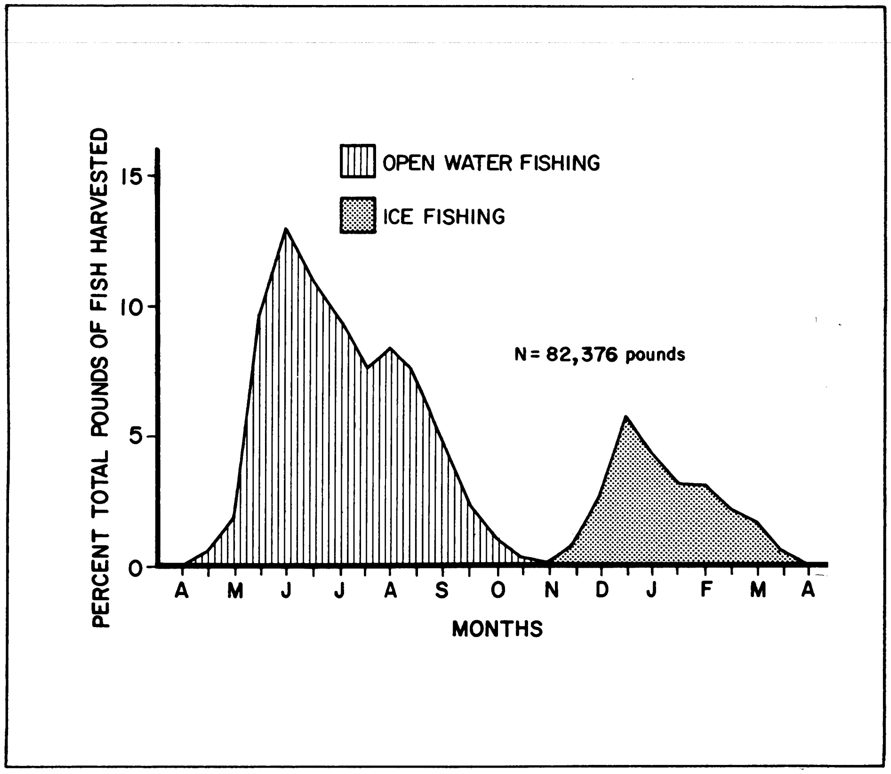


FIGURE 5. *Semimonthly distribution of fish harvested from Murphy Flowage, 1955-69.*

in poundage was drastically different — 7,431 lb of largemouth bass compared to 16,113 lb of northern pike. Annually the catch of largemouth bass varied from 302 to 808 fish and averaged 478, while the catch of pike ranged from 163 to 808 and averaged 502. On an acreage basis, the catch of largemouth bass averaged 2.7 fish weighing 2.8 lb while the catch of northern pike averaged 2.8 fish weighing 6.0 lb (Table 3).

The catch of northern pike after 1963 was influenced by the stocking of 47 pike/acre weighing 40 lb/acre. Stocked pike comprised a major part of the pike harvest only in 1964 when 61 percent of the number and 49 percent of the poundage of pike caught had been stocked. Further details on the effects of stocking pike are covered in a separate publication (Snow 1974).

The catch of muskellunge totaled 42 fish weighing 241 lb and varied annually from 0 to 6 fish and 0 to 35 lb. Although muskellunge contribute little to the total fishery, they are important in that they represent returns of stocked fish.

Stability of Species Composition

By Rank. A remarkable feature of the harvest has been the relative stability in the proportion of species harvested. When the yield is ranked by pounds caught annually in decreasing values, five of the seven major species caught received the same ranking 80 to 100 percent of the time. Bluegill ranked first during 15 years, northern pike second, 13 years; largemouth bass third, 12 years; black crappie fourth, 14 years; and rock bass fifth, 12 years. Yellow perch and pumpkinseed were approximately equally divided between the sixth and seventh rank. Ranking by numbers caught annually varied more than by poundage; however, bluegill ranked first at all times and black crappie second during 10 of the 15 years of study. Most other species varied in rank from third to seventh during various years of study.

By Percentage. The stability of the species composition is also demonstrated by a comparison of the percentage of the annual catch for each species; however, these comparisons express greater stability among numbers than pounds caught.

Panfish as a group comprised 96 percent of the total 15-year harvest by numbers and 71 percent by weight. Annually, panfish ranged by number from 93 to 98 percent and by poundage from 61 to 81 percent of the total catch. Based on the total 15-year harvest, bluegills comprised 84 percent of the total number and 59 percent of the total poundage caught (Table 4). The black crappie comprised 4 percent of the total number and 6 percent of the total pounds caught. All other species of panfish individually comprised less than 4 percent of the total number and less than 3 percent of the total weight caught each year.

Game fish comprised 4 percent of the total harvest by number and 29 percent by weight. Most important among game fish was the northern pike which averaged 2 percent by number and 20 percent by weight. Largemouth bass also averaged about 2 percent by number but only 9 percent by weight (Table 4).

The harvest of muskellunge was less than 0.05 percent of the total catch by number and weight. Annually the catch by number was also below 0.05 percent, however, by weight, the percent of muskellunge ranged as high as 1.4 percent.

In contrast to the stability in species composition of the harvest in Murphy Flowage, the harvest in Escanaba Lake, Wisconsin fluctuated constantly (Kempinger et al. 1975). While bluegills dominated the catch in Murphy

TABLE 3. *The yield from Murphy Flowage by species, 1955-69.*

Species	Unit	Total	Annual Average	Annual Range	Annual Avg./Acre
Bluegill	Number	312,342	20,823	9,007 - 38,510	115.7
	Pounds	48,564	3,237	1,209 - 6,256	18.0
Pumpkinseed	Number	6,880	459	187 - 1,080	2.5
	Pounds	1,163	78	33 - 172	0.4
Black crappie	Number	16,489	1,099	721 - 2,029	6.1
	Pounds	4,767	318	181 - 631	1.8
Rock bass	Number	8,084	539	278 - 1,499	3.0
	Pounds	2,335	156	82 - 412	0.9
Yellow perch	Number	14,652	977	179 - 3,403	5.4
	Pounds	1,490	99	30 - 240	0.5
Brown bullhead	Number	319	21	1 - 65	0.1
	Pounds	264	18	1 - 54	0.1
Largemouth bass	Number	7,176	478	302 - 808	2.7
	Pounds	7,431	495	265 - 831	2.8
Northern pike	Number	7,528*	502	163 - 808	2.8
	Pounds	16,113*	1,074	321 - 2,060	6.0
Muskellunge	Number	42	3	0 - 6	Tr
	Pounds	241	16	0 - 35	0.1
Miscellaneous**	Number	8	< 1	0 - 3	Tr
	Pounds	8	< 1	0 - 3	Tr
Total	Number	373,520	24,901	11,211 - 44,837	138.3
	Pounds	82,376	5,491	2,551 - 10,044	30.5

*Includes 561 northern pike weighing 657 lb which were returns from a single stocking made in December 1963 of 8,534 pike weighing 7,253 lb .

**Includes 4 brook trout, 3 white suckers, and 1 creek chub.

Tr = less than .05.

TABLE 4. *Species composition of the harvest as a percentage of the total catch in Murphy Flowage, 1955-70.*

Species	Unit	15-year Total	Annual Range
Bluegill	Number	83.5	77.8 - 86.0
	Pounds	59.0	46.4 - 71.2
Pumpkinseed	Number	1.9	1.1 - 3.1
	Pounds	1.4	0.9 - 2.1
Black crappie	Number	4.4	2.6 - 8.9
	Pounds	5.8	3.6 - 11.0
Rock bass	Number	2.2	1.0 - 4.8
	Pounds	2.8	1.7 - 5.0
Yellow perch	Number	3.9	1.2 - 7.9
	Pounds	1.8	0.9 - 3.1
Brown bullhead	Number	0.1	Tr - 0.3
	Pounds	0.3	Tr - 1.0
Largemouth bass	Number	1.9	0.9 - 4.8
	Pounds	9.0	5.6 - 22.5
Northern Pike	Number	2.1	1.0 - 4.3
	Pounds	19.6	10.7 - 28.2

Tr = Less than 0.05.

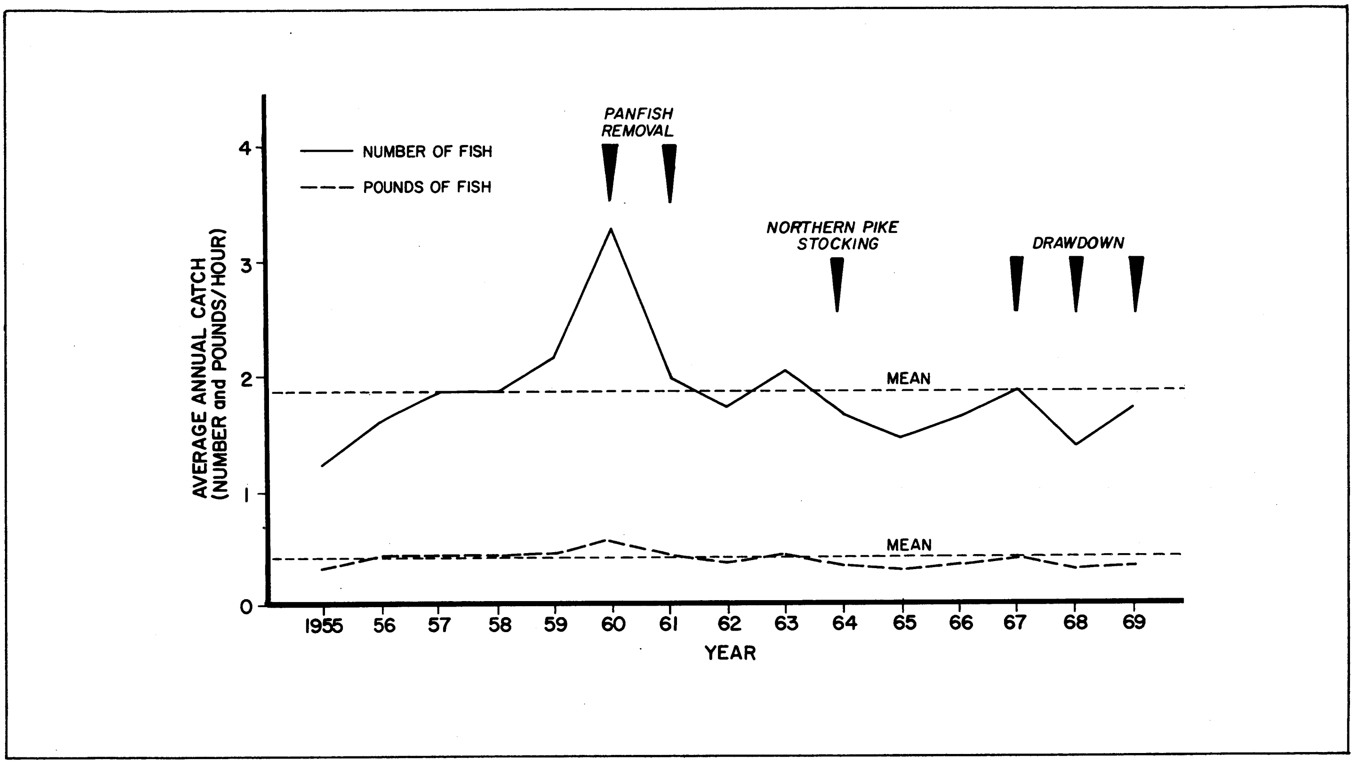


FIGURE 6. *Average annual catch rate at Murphy Flowage, 1955-69.*

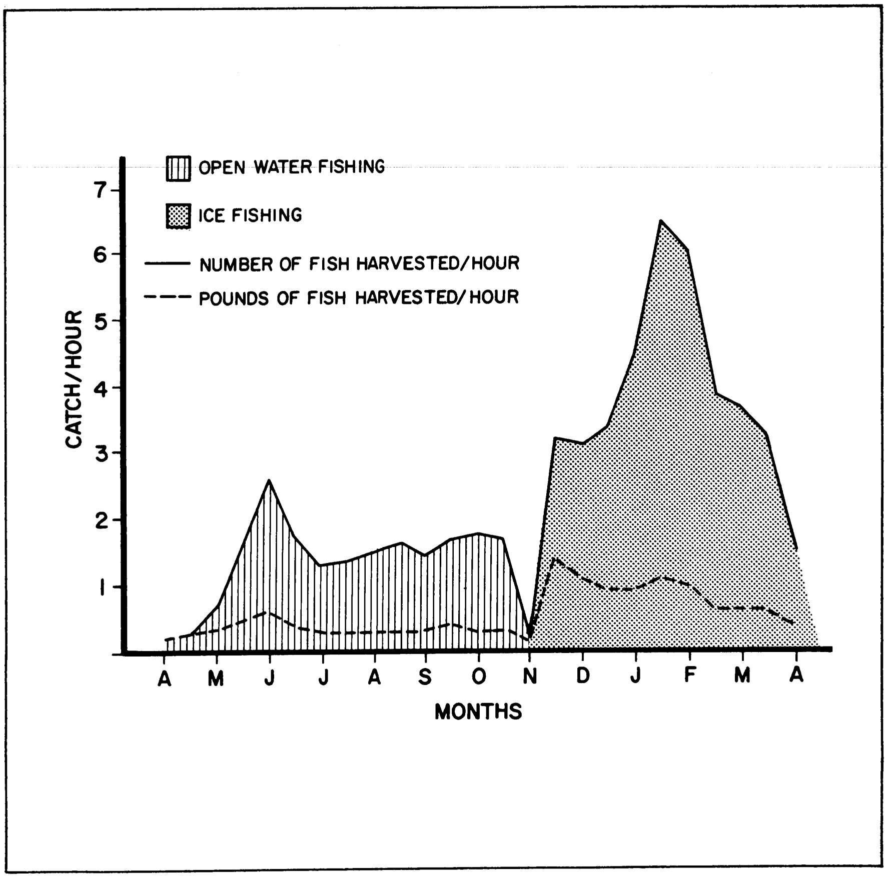


FIGURE 7. *Semimonthly distribution of the catch rate for all species of fish at Murphy Flowage, 1955-69.*

Flowage for 15 years, the catch in Escanaba Lake was in turn dominated by four different species at various times during a 24-year period of compulsory creel census.

QUALITY OF FISHING

Catch Rate

All Species. The catch rate for the 15-year study period averaged 1.88 fish/hour and varied annually from 1.25 to 3.28. The catch rate in lb/hour averaged 0.41 and varied from 0.31 to 0.59. The catch rate as measured in lb/hour therefore exhibited greater stability throughout the study than the catch as measured in fish/hour (Fig. 6). During the early years of study (1955-60), there was a steady increase in catch rate. From 1960 to 1962, the catch rate declined and for the remainder of the study, varied around the mean but was usually below it.

In addition to the peak in catch rate in 1960 there were also minor peaks in 1963 and 1967. A large portion of the annual variation in catch rate can be attributed to seasonal variations in the catch. In those years when a high proportion of the annual catch was taken in spring or winter, the annual catch

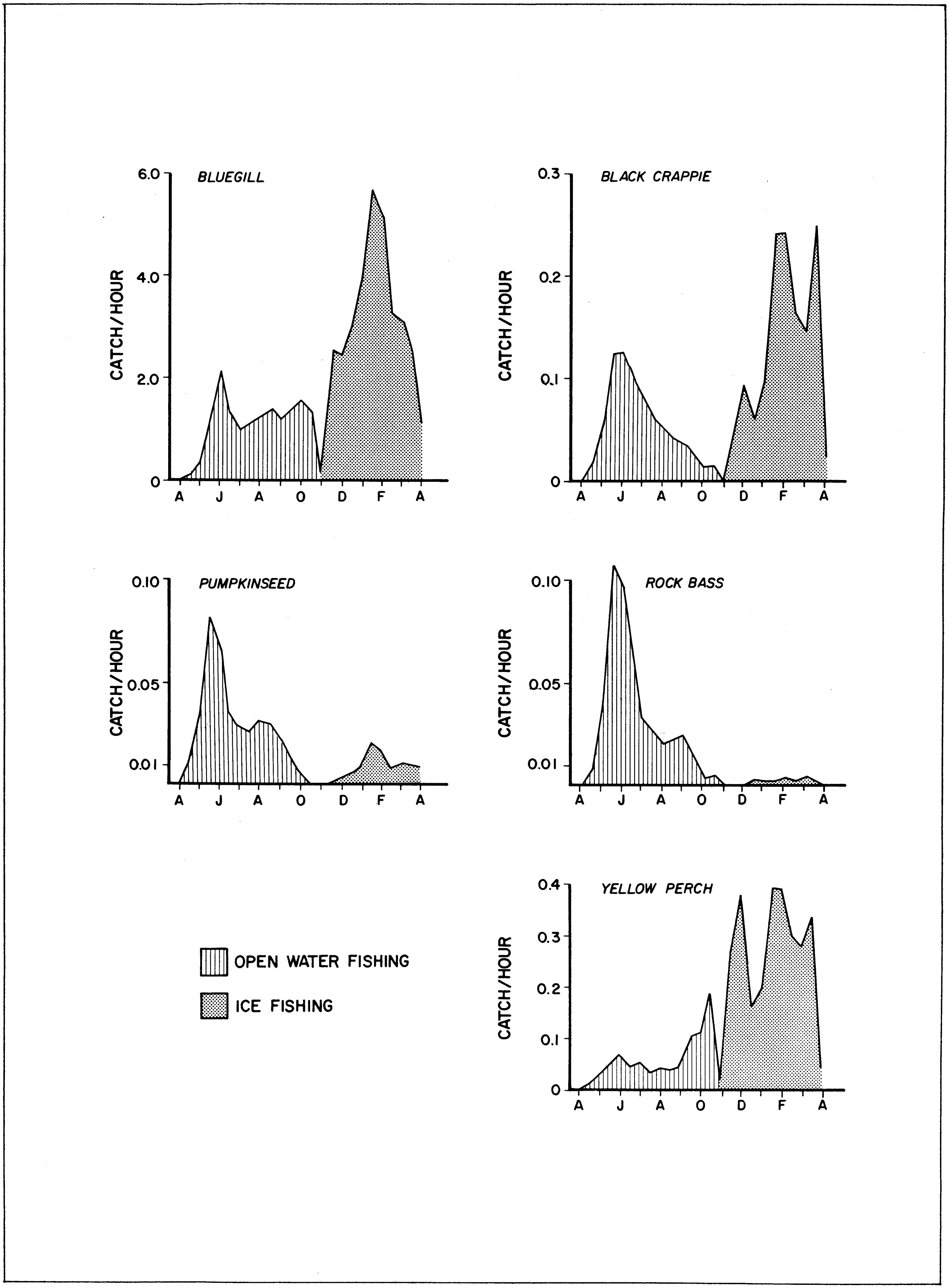


FIGURE 8. *Semimonthly distribution of the catch rate of panfish by species at Murphy Flowage, 1955-69.*

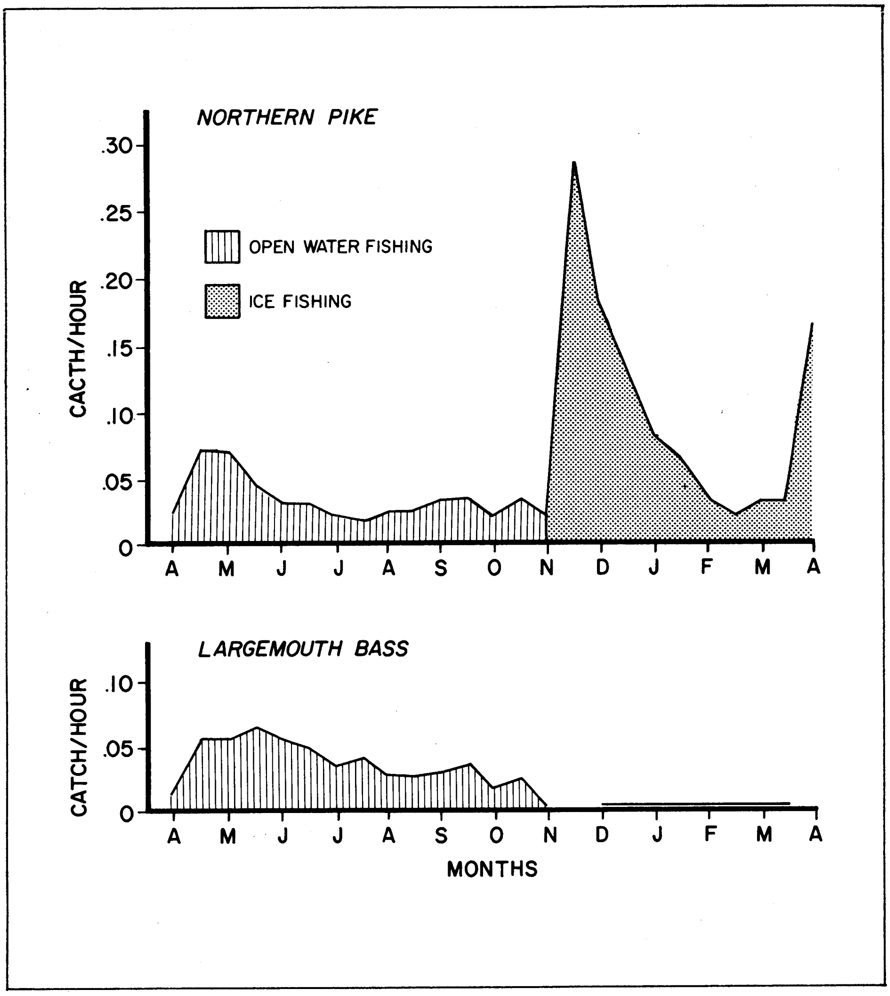


FIGURE 9. *Semimonthly distribution of the catch rate of game fish by species at Murphy Flowage, 1955-69.*

rate was higher than during other years. Although there was considerable variation in the catch rate, the average and the minimum annual catch rates were higher than the catch rates reported for other waters (Table 2).

The catch rate throughout the year, as measured in semimonthly intervals, was considerably more variable than the annual catch rate. The catch in fish and lb/hour during open water fishing reached maximum values of 2.59 fish and 0.55 lb/hour, respectively, during 1-15 June. During winter, the catch rate in fish/hour reached a maximum figure of 6.45 during 16-31 January, while the catch rate in lb/hour was at a maximum value of 1.37 during 16-30 November. A higher proportion of northern pike caught in 16-30 November than in 16-31 January accounts for the higher catch rate in poundage (Fig. 7).

Fishing success from the beginning of the open water season increased steadily until 1-15 June then declined until 1-15 July. During the remainder of open water fishing, there were slight increases in catch rate until 1-31 October during which time catch rate declined. Catch rate in winter started at a level of 3.20 fish/hour then increased to the maximum of 6.45 in 16-31 January, after which there was a steady decline to a season low of 1.44 in 1-15 April (Fig. 7).

Panfish. In addition to considerable variation in total catch rate annually and seasonally, individual species varied seasonally in the harvest. Because bluegills comprised 84 percent of the total fish harvested, the total catch data largely reflect this species as is illustrated by the close synchrony of the bluegill catch rate (Fig. 8) and the catch rate for all species (Fig. 7). While the catch rates for bluegills peaked in January, catch rates for other centrarchids (pumpkinseed, rock bass and black crappie) peaked in May-June, declining thereafter (Fig. 8), but black crappie recovered markedly in winter. Yellow perch catch rates were highest in winter but different from that for other panfish in that the highest summer catch rate occurred from mid-September through mid-October.

Game Fish. During open water, catch rates for northern pike and largemouth bass were generally similar, with the catch rate for largemouth bass being slightly higher than that for northern pike during the periods of heaviest fishing pressure, 15 May through 31 August. During winter, however, catch rates for these two species differed greatly. During the ice fishing season, the catch rate for largemouth bass was almost zero, while the catch rate for northern pike reached the highest levels of the year during that period. The highest catch rate for northern pike occurred between 16 and 31 November — the first two weeks of the ice fishing season. During the remainder of the winter season, the catch rate for northern pike declined steadily until the first half of April when there was a noticeable increase.

Distribution of the Catch Among Anglers

Percent Successful Trips. The percentage of angling trips on which at least 1 fish was caught averaged 63 percent and varied annually from 55 to 71 percent (Table 1). Seasonally, 61 percent of all trips were successful in summer compared to 73 percent in winter. In semimonthly intervals, the percentage successful trips varied from a low of 8 percent during 1-15 April to a high of 82 percent during 16-31 January. During the period of highest pressure (16 May-15 September), the percentage successful trips varied from 58 to 73 percent. In the ice fishing season, the percentage successful trips varied from 60 to 82 percent and for the period from 16 November to 16 February was consistently higher than that during any open water fishing period.

Size of Catch. The number of fish caught per trip averaged 7, varying from 5 to 12 per trip annually and 0 to 22 per trip in semimonthly intervals. In the open water season, anglers caught an average of 6 fish/trip compared to 15 per trip in the ice fishing season. The maximum number of fish taken by any angler in a single fishing trip was 244 in summer and 272 in winter. Semimonthly, seasonal, and annual trends in fish/trip, of course, are similar to the trends in catch/hour which is covered in another section of this report.

The catch in winter was more evenly distributed among anglers than in summer. Anglers catching over 25 fish/trip accounted for 21 percent of the trips and 69 percent of the total fish in winter and 7 percent of the trips and 44 percent of the total fish in summer. Anglers catching over 10 fish/trip accounted for 41 percent of the trips and 92 percent of the fish in winter and 17 percent of the trips and 69 percent of the fish in summer. Generally the most successful 10 percent of all anglers caught 50 percent of the fish; seasonally, the most successful 10 percent of the anglers caught 45 percent of the fish in winter compared to 53 percent in summer. This is illustrated in Figure 10 where percentage of trips, starting with the most successful is plotted against percentage of catch. For example in winter, if all catches were arranged in order of size, starting with the largest, the first 10 percent of the catches would include about 45 percent of the fish. The next 10 percent of the catches would include about another 20 percent of the fish and so on to the last 27 percent of winter anglers who caught no fish. These results have been remarkably consistent throughout the study.

The extremely disproportionate distribution of the catch among anglers has been reported by other researchers, but for shorter time intervals, for Murphy Flowage and Escanaba Lake, Wisconsin (Churchill and Snow 1964) and also in studies on other waters (McFadden 1956 and Wales and German 1956).

Summer and Winter Comparisons

In proportion to the hours fished, anglers caught more fish in winter than summer. The winter season accounts for 12 percent of the total hours fished and 26 percent of all fish caught, while summer fishing accounts for 88 percent of the total hours and 74 percent of all fish caught. Annually the percent total hours fished in winter varied from 3 to 22 while the percent total fish caught varied from 4 to 53 (Table 5). The winter trend of a higher percentage of fish caught than hours fished was quite consistent in that this condition existed during 13 of the 15 years of study (Fig. 11).

The disproportionately high catch of fish in winter is largely accounted for in the high winter catch rate. In winter, anglers caught an average of 4.20 fish weighing 0.86 lb/hour compared to 1.58 fish weight in 0.36 lb/hour in summer. The catch rate varied from 1.18 to 8.50 fish/hour in winter and from 1.20 to 1.96 fish/hour in summer. The winter catch rate was therefore considerably more variable than the summer rate; however, in only 2 of the 15 years of study was the winter catch rate lower than the summer catch rate (Fig. 12).

On the average, anglers caught fish 2½ times faster in winter than summer; however, there were considerable differences between the various species. Those species that are readily caught in winter (bluegill, black crappie, yellow perch, and northern pike), were caught 3, 2, 6, and 3 times faster in winter than summer, respectively. Those species most readily caught in summer (largemouth bass, rock bass, and pumpkinseed), were caught 10, 23, and 4 times faster in summer than winter, respectively (Fig. 13). Brown bullhead and muskellunge were not caught in winter at any time. Of the species that readily bite in winter, 28 percent were taken in winter; however, less than 2 percent of the remaining species were caught in winter. In Murphy Flowage, the bulk of all fish present was composed of those species that are readily

TABLE 5. *Percentage of fishing pressure and harvest in winter in Murphy Flowage, 1955-69.*

Fishing Statistic	15-year Total	Annual Range
Total hours	12	3 - 22
Total fish caught	26	4 - 53
Fish species caught		
Northern pike	28	1 - 47
Bluegill	27	4 - 53
Black crappie	19	2 - 52
Yellow perch	43	5 - 82
All other species*	2	<1 - 4

*Includes largemouth bass, muskellunge, pumpkinseed, rock bass, and brown bullhead.

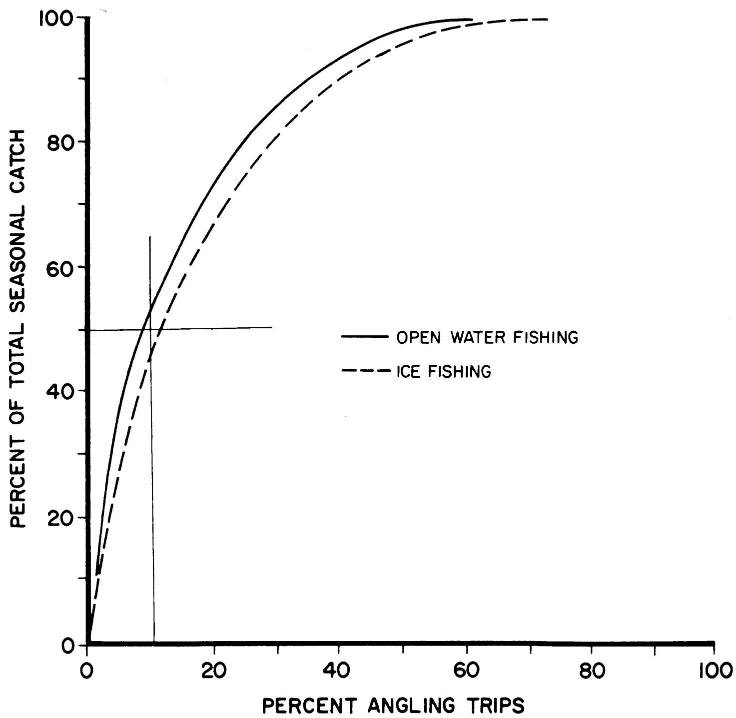


FIGURE 10. *Relationship of total seasonal catch to angling trips to Murphy Flowage, 1957-69.*

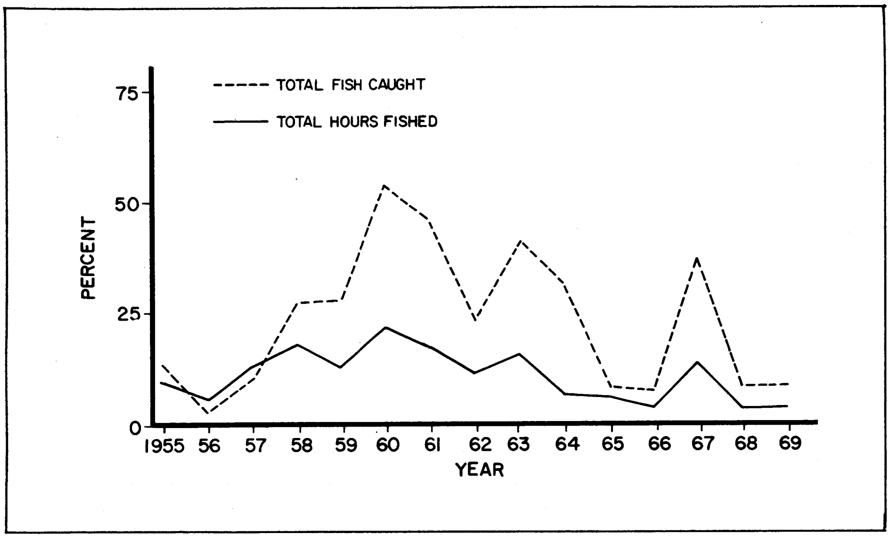


FIGURE 11. *Percent total annual hours fished and fish caught in winter at Murphy Flowage, 1955-69.*

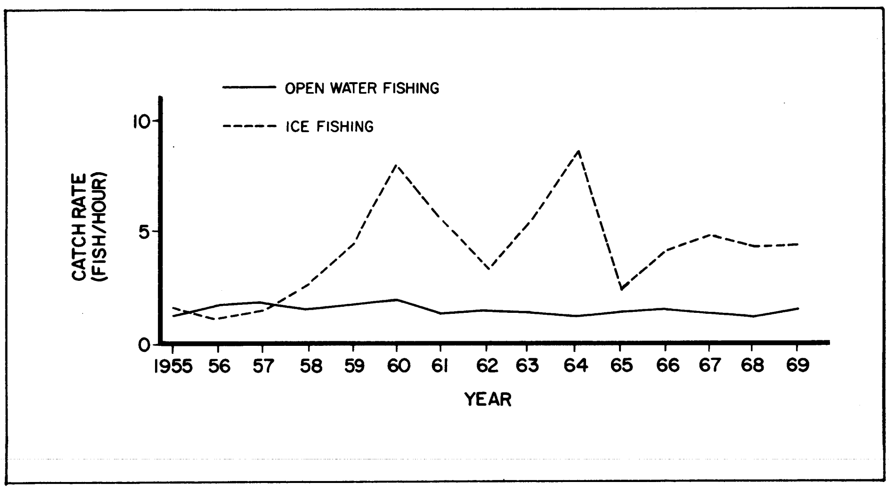


FIGURE 12. *Comparison of catch rate during the open water season to that during the ice fishing season at Murphy Flowage, 1955-69.*

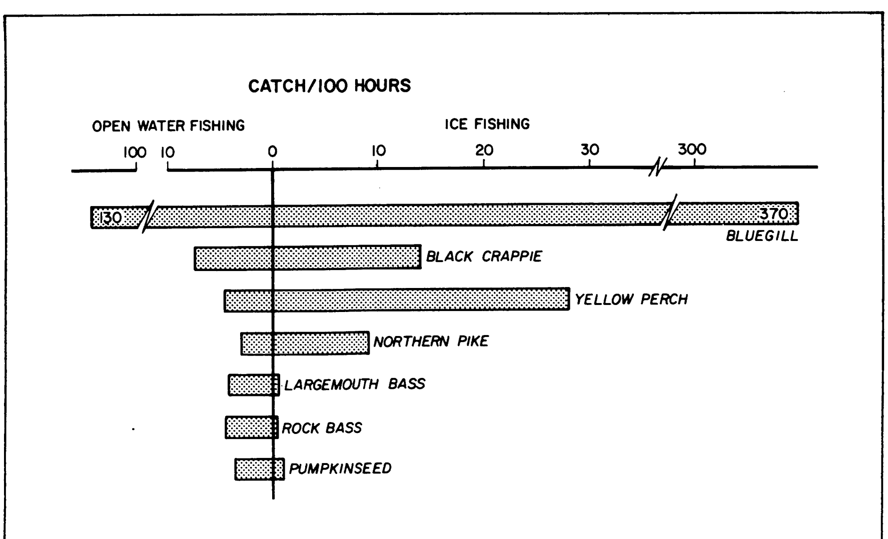


FIGURE 13. *Comparison of the open water and ice fishing catch rates by species for Murphy Flowage, 1955-69.*

caught in winter. Therefore, winter fishing produced the most successful fishing during the year.

Size of Fish Caught

Average Length. There were no consistent trends in average length of fish caught which lasted throughout the entire 15-year study; however, there were trends for some species for intervals of three to nine years duration. Bluegills, the most abundant species in the catch, averaged 6.0 inches in length and varied 0.5 inches annually (5.8 to 6.3), the minimum variation in length of any species harvested (Table 6 and Fig. 14). Among panfish, the black crappie had the highest average length. Average length of black crappies declined from a high of 10.5 inches in 1955 to an average of 7.9-8.4 inches for the period, 1957-69.

The maximum variation and largest general decline in average length among all species occurred for the native northern pike. Pike averaged 21.1 inches and from 1957 to 1965 declined steadily (except for 1963) from an average length of 22.1 to 19.2 inches. After 1965, the average length of native pike increased in 1967 and 1969 to the highest lengths attained throughout the study (Fig. 14).

Although the average lengths of all species varied considerably and displayed various trends, no overall similarity between species in successive years of study was observed. For example, the maximum average length of bluegill, pumpkinseed, black crappie, brown bullhead, and largemouth bass occurred sometime during the first four years of study while the average length of rock bass, yellow perch, and northern pike were at a maximum sometime during the last two years of study. Likewise, the decline in average length of northern pike occurred from 1957 through 1965 while there was a trend for increased size of yellow perch from 1960 to 1969.

Number of "Larger Fish" Caught. In this section the term "larger fish" is an arbitrary figure and refers to fish of the following sizes and larger: bluegill, 8.0 inches; pumpkinseed, 6.5 inches; black crappie, 10.0 inches; rock bass, 8.0 inches; yellow perch, 8.0 inches; largemouth bass, 15.0 inches; and northern pike, 24.0 inches. Total catch is in proportion to hours fished. This relationship is because anglers are more likely to keep big fish than small fish. Therefore, the numbers of "larger fish" caught were compared to hours fished to determine annual changes that have occurred.

Annual comparison of the number of "larger fish" caught and the number of hours fished shows a noticeable difference for bluegill, pumpkinseed, and black crappie the first two to four years (Fig. 15). However, the number of "larger fish" of other species caught was not appreciably different than the hours fished. For example, in 1956 approximately 10 percent of the hours fished produced 30 percent of the bluegills 8.0 inches and larger, 25 percent of all pumpkinseed 6.5 inches and larger, 21 percent of all black crappies 10.0 inches and larger, but only 10 to 12 percent of all other species above the indicated sizes (Fig. 15). Of the total catch of 3,007 bluegills 8.0 inches and larger, 2,294 or 76 percent were caught the first three years of study in only 15 percent of the total hours fished. More bluegills, pumpkinseeds, and black crappies of the sizes indicated in Figure 15 were caught the first two to four years of study than were caught during all the remaining years combined.

The variations in average length and in numbers of "larger fish" caught are related to one or more of the following factors: (1) increased fishing pressure; (2) variation in year-class strength; (3) growth variations; (4) selectivity by anglers; (5) management practices tested: panfish removal, northern pike stocking, and winter drawdown; (6) liberalized regulations; and (7) natural mortality.

Increased fishing pressure appears to be the immediate cause of the decrease in the catch of larger fish; however, it is probably of only minor importance. If the decline is the result of increased angling, then we must assume that the increased mortality of larger fish from angling caused the decline. However, natural mortality (as will be described later) is higher than mortality from angling. For example, the estimated number of bluegills over 8.0 inches from 1955 through 1958 was approximately 5,200, 2,900, 1,700, and 500, respectively, while the number caught by anglers was 824, 893, 577, and 191 for the same years. Losses by angling thus accounts for a relatively small portion of the total.

The variation in average length and number of "larger fish" caught was more directly correlated to variations in year-class strength and growth rates than to any other factors. In a stable population, recruitment by growth normally replaces losses from natural causes and from angling. In Murphy Flowage increases in year-class strength before and after the project started resulted in large increases in abundance of almost all species and also decreases in growth rate. For example, the estimated number of 4.5- to 5.4-inch bluegills increased steadily from approximately 450/acre in 1955 to 2,300/acre in 1968, while age group IV (one of the most abundant groups

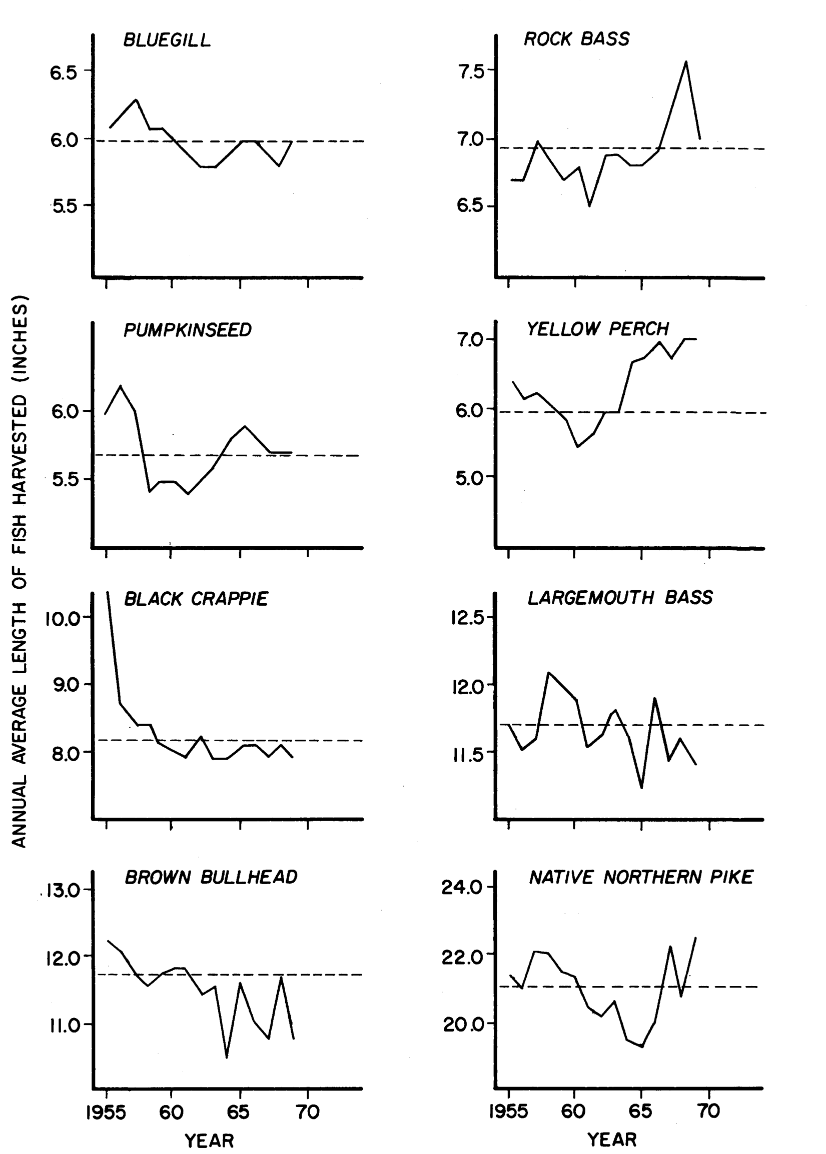


FIGURE 14. *Annual average length of fish harvested in Murphy Flowage, 1955-69. The dashed line indicates the 15-year average length for each species.*

TABLE 6. *Average length (in inches) of fish caught by angling in Murphy Flowage, 1955-69.*

Species	15-year Average	Range of Annual Average
Bluegill	6.0	5.8 - 6.3
Pumpkinseed	5.7	5.4 - 6.2
Black crappie	8.2	7.9 - 10.5
Rock bass	6.9	6.5 - 7.6
Yellow perch	6.0	5.5 - 7.1
Brown bullhead	11.8	10.4 - 12.2
Largemouth bass	11.7	11.2 - 12.1
Northern pike		
Native	21.1	19.2 - 22.4
Stocked*	17.6	17.1 - 30.0**

*Represents returns from 8,534 northern pike stocked in December 1963 at an average length of 15.4 inches.

**Upper extreme represents only one pike.

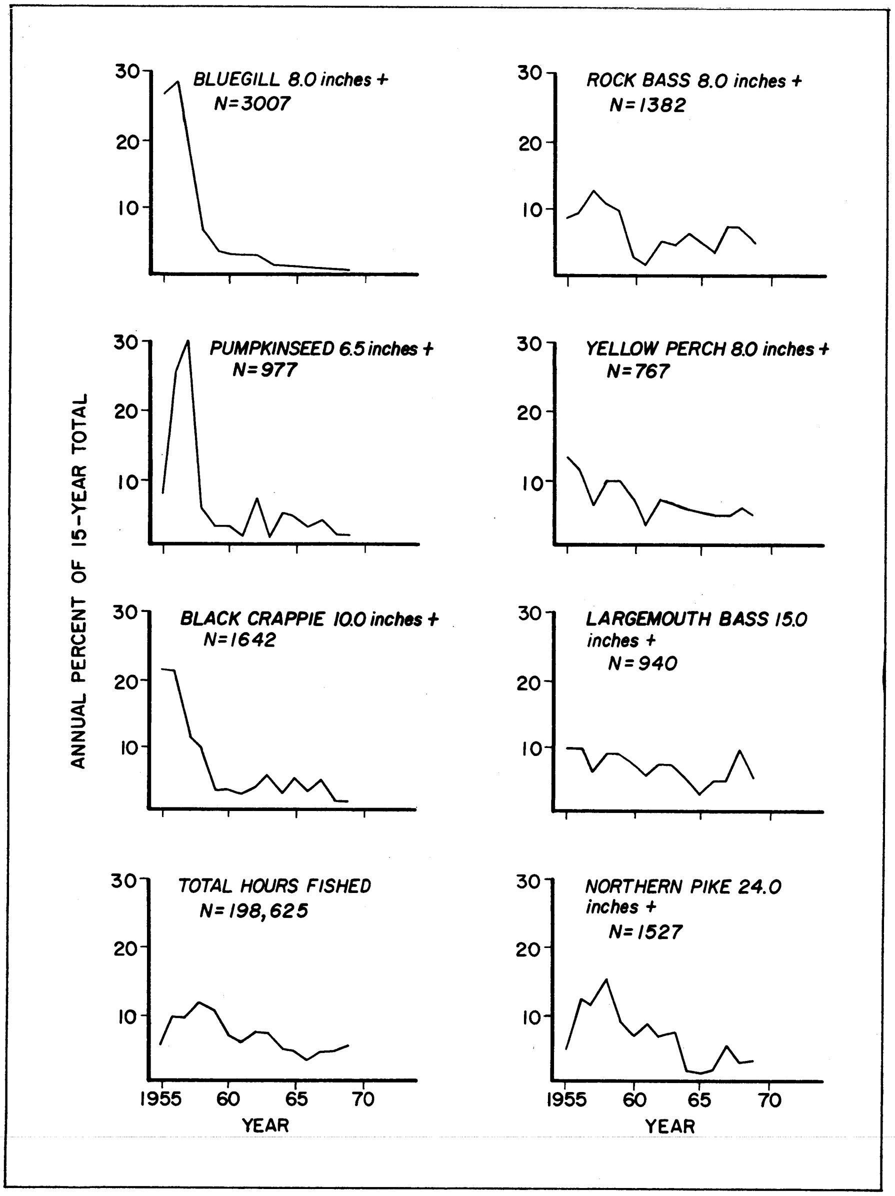


FIGURE 15. *Annual percent of the 15-year total hours fished and fish caught of the indicated size and larger in Murphy Flowage, 1955-69.*

caught) declined in mean length from 7.2 inches in 1954 to 4.8 inches in 1965. Because of the declining growth, recruitment into the larger size groups was minimal.

Selectivity by anglers may also have been a factor related to variation in average size of fish caught. During the early years of study, anglers were encouraged to keep all fish caught, more so than in later years. Although this could have affected the average size, it is believed to have had only a minimal effect because of the relatively large numbers of fish caught.

Of the three management techniques used, panfish removal in 1960 and 1961, northern pike stocking in 1963, and winter drawdown from 1967 through 1969, the first one probably had a greater effect on the size of fish caught than any other. Removal of approximately 23 percent of the panfish each year, in addition to fish taken by anglers, apparently was related to the declines in average length of panfish caught between 1960 and 1963 (Fig. 14).

The northern pike stocked in 1963 seemingly had no effect on the size of any species caught except northern pike. The lowest average lengths and smallest number of larger pike caught occurred the first three years after stocking (Snow 1974).

Drawdown during the winters of 1967-69 had no apparent effect on the number of larger fish caught, except largemouth bass in 1968 and also no effect on the average size of fish caught, except possibly rock bass in 1968 and yellow perch in 1968 and 1969 (Fig. 14). A known decline in the abundance of aquatic vegetation (Beard 1973) and an apparent decline in the abundance of crayfish, the main food item of largemouth bass, coincided with the capture of more larger bass in 1968 (Snow 1971); however, the average length of bass caught in 1968 was slightly below the 15-year average (Figs. 14 and 15).

While it is not the intent to evaluate size limits in this report (this will be covered in a separate publication), it should be pointed out that any size limit such as those in effect in various areas of Wisconsin (18.0 to 22.0 inches for northern pike and 10.0 inches for largemouth bass) would result in higher average lengths of fish caught than those reported here.

FISHING PRESSURE AND HARVEST

The pounds of fish harvested in Murphy Flowage was directly related to the level of fishing pressure. High significance existed for winter and summer catches as well as for the total annual catch.

The relationship is expressed in linear form after logarithmic transformation of hours per acre fished and pounds per acre harvested. This is shown in Figure 16 which contains the equations and is expressed on a log-log scale with the standard errors of the estimate. The regression slopes indicate that for the middle ranges of fishing effort, a ten hour/acre increase in the average could be expected to raise the catch by 3.5 lb/acre in summer, 8 lb/acre in winter, and 4 lb/acre on an annual basis. Coefficient of determination values (r^2) indicate that fishing effort accounts for 97 percent, 93 percent, and 89 percent of the variability of the harvest respectively in summer, winter, and annually. Although r^2 values are high, it should not necessarily be postulated that there is a full causal relationship between harvest and pressure. Since this research study was not designed as a test of pressure as a sole dependent variable, one can conclude only that pressure and harvest are related under a whole complex of circumstances.

The relationship between pressure and harvest would not necessarily be expected to hold well for lakes with differing characteristics. However, an application of the equation developed for 103 large reservoirs (over 500 acres) by Jenkins and Morais (1971) accurately predicts the catch for the average pressure on Murphy Flowage (31.6 lb/acre predicted and 30.5 lb/acre actual). The upper and lower range of pressure

TABLE 7. *Average annual mortality (in percent) of Murphy Flowage fishes, 1955-69.**

Species	Avg. Total Mort. (A)	Exploitation: Angling (u)	Exploitation: Panfish Removal (1960 & 1961 only)	Natural Mort. (v)
Panfish				
Bluegill	61 (49-74)	12 (4-24)	23 (21-25)	46 (32-59)
Pumpkinseed	72 (59-87)	8 (3-18)	31 (28-34)	60 (43-76)
Black crappie	55 (31-74)	11 (5-22)	17 (15-18)	42 (26-65)
Yellow perch	61 (34-90)	5 (2- 6)	4 (2- 7)	55 (28-86)
Rock bass	44 (24-62)	18 (6-28)	26 (26-26)	23 (5-46)
Brown bullhead	50 (23-68)	2 (0- 3)	33 (22-43)	48 (23-67)
Avg.	57	9	22	46
Game Fish				
Largemouth bass	48 (30-65)	27 (14-45)	–	21 (0-45)
Northern pike	66 (47-90)	26 (3-50)	–	40 (9-86)
Avg.	57	27	–	30
Avg. All Species	57	14	22	42

*The annual range in mortality is shown in parentheses.

values give estimates within 13 and 23 percent of their equation. Further studies in smaller bodies of water would be a valuable aid in helping the fish manager predict harvest levels.

EXPLOITATION AND MORTALITY

Harvest as analyzed in previous sections is an important angling statistic; however, it does not indicate what proportion of the available fish were harvested (exploitation). Average annual exploitation of all panfish species combined was 9 percent and was lowest for the brown bullhead at 2 percent and highest for the rock bass at 18 percent (Table 7). The most abundant species, the bluegill, was exploited at an average annual rate of 12 percent with annual variations from 4 to 24 percent.

In addition to exploitation by angling, panfish were also exploited by netting and electrofishing in 1960 and 1961. Average removal for the two years varied from 4 to 33 percent (Table 7). When exploitation by removal in 1960 and 1961 is included, the average exploitation rates for panfish increase by 1 to 4 percent.

The exploitation rate for northern pike and largemouth bass averaged 26 and 27 percent, respectively, and varied annually from 14 to 45 percent for largemouth bass and 3 to 50 percent for northern pike.

Since the total harvest is dependent upon the fishing pressure (Fig. 16), exploitation would be expected to follow the same annual trends as pressure; however, this situation did not exist for all species. Bluegills, pumpkinseeds, black crappies, and northern pike were exploited most heavily in years when pressure was average or above, mainly from 1955 through 1963. Exploitation of largemouth bass was also relatively high during this period, but was highest in 1968 and 1969 when pressure was considerably less. The unexpected increase in exploitation for largemouth bass in 1968 and 1969 was attributed to a decline in crayfish, their major food item, and to increased accessibility to anglers due to a decline of aquatic vegetation associated with a winter drawdown (Snow 1971). The variations in exploitation of rock bass and yellow perch followed no trend which could be associated with pressure or other factors, except that the two years of lowest exploitation of rock bass by anglers were 1960 and 1961 — the years of panfish removal.

Natural mortality for panfish averaged 46 percent and varied from 23 percent for rock bass to 60 percent for pumpkinseed. Natural mortality of bluegills averaged 46 percent and ranged from 32 to 59 percent while the natural mortality for largemouth bass averaged 21 percent and for northern pike 40 percent (Table 7). The average for all species combined was 42 percent.

Average mortality from natural causes for most species was several times greater than mortality from angling (exploitation); however, there was considerable variation among species. The exploitation rate of largemouth bass, northern pike, and rock bass more closely approaches the natural mortality rate than for any other species (Table 7). However, the largemouth bass is the only species for which the rate of exploitation exceeded the natural mortality rate.

Total annual mortality averaged 57 percent for all species combined and also for panfish and game fish when figured separately. Among panfish, total mortality was highest for pumpkinseed at 72 percent and lowest for rock bass at 44 percent (Table 7). Total mortality for bluegills averaged 61 percent and varied annually from 49 to 74 percent. Total mortality for largemouth bass averaged 48 percent and for northern pike, 66 percent.

Although mortality may seem high at Murphy Flowage, it is generally within the range of mortality in other waters as reported in a summary by Bennett (1971).

Analysis of exploitation (u), natural mortality (v), and total mortality (A) provides a better understanding of the relationship between these parameters and also a means to predict what the mortality would be at various levels of exploitation including what the mortality would be in the absence of angling.

The figures and narrative to follow are based on the assumption that the relationship between natural mortality and exploitation is linear. However, a recent paper on population ecology of mallards by Anderson and Burnham (1976) questions the validity of the additive approach in determining esti-

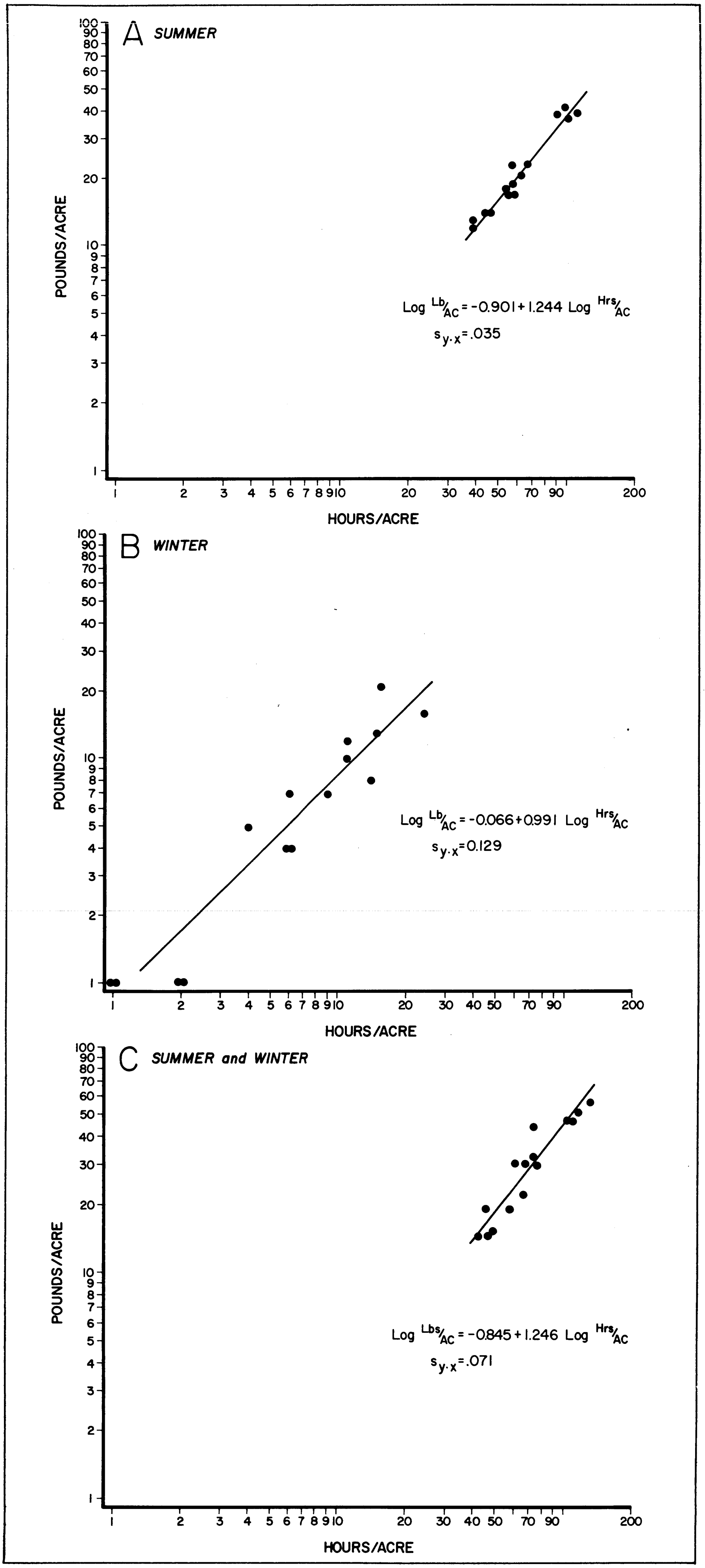


FIGURE 16. *Regression of harvest on pressure in Murphy Flowage, 1955-69, for: (A) summer, (B) winter, and (C) both seasons combined.*

mates of mortality and suggests that the relationship between natural mortality and exploitation is in fact curvilinear. The application of these hypotheses to fisheries biology is not known at this time. Because of its use and support in fisheries literature (McFadden 1961; Youngs 1972; Forney 1972), the linear additive approach has been used in this paper.

The relationship between exploitation and natural mortality can take several forms of which three hypothetical examples are shown in Figure 17. The ideal relationship between exploitation and natural mortality from the standpoint of management goals is the situation where the entire catch is taken from potential losses (A of Fig. 17). Under these conditions the catch has no effect on the number of fish surviving or dying because the entire catch is taken from fish which would have died from natural causes within the same year.

The least desirable relationship between exploitation and natural mortality is the situation where the total catch is taken from potential survivors (B of Fig. 17). Under these conditions, the catch has no effect on natural mortality and total mortality inceases at the same rate as exploitation.

In contrast to these two examples, the realistic or expected form of the relationship between exploitation and natural is the situation where a portion of the catch is taken from potential survivors and a portion taken from potential natural losses. Furthermore, natural mortality is likely to approach zero before the exploitation rate reaches 100 percent. Beyond this point which is 75 percent in this example (C of Fig. 17), the entire remaining catch is taken from potential survivors.

Example C in Figure 17 is the approximate relationship found for the brook trout population of Lawrence Creek, Wisconsin (McFadden 1961). The statistical implications of the relationship between exploitation and mortality have been discussed in detail by McFadden.

All three hypothetical relationships between v and u appear to occur at Murphy Flowage for one or more of the species found; however, the only species for which relationships were significant were northern pike, bluegill, and pumkinseed. The relationship for northern pike approached the idealis-

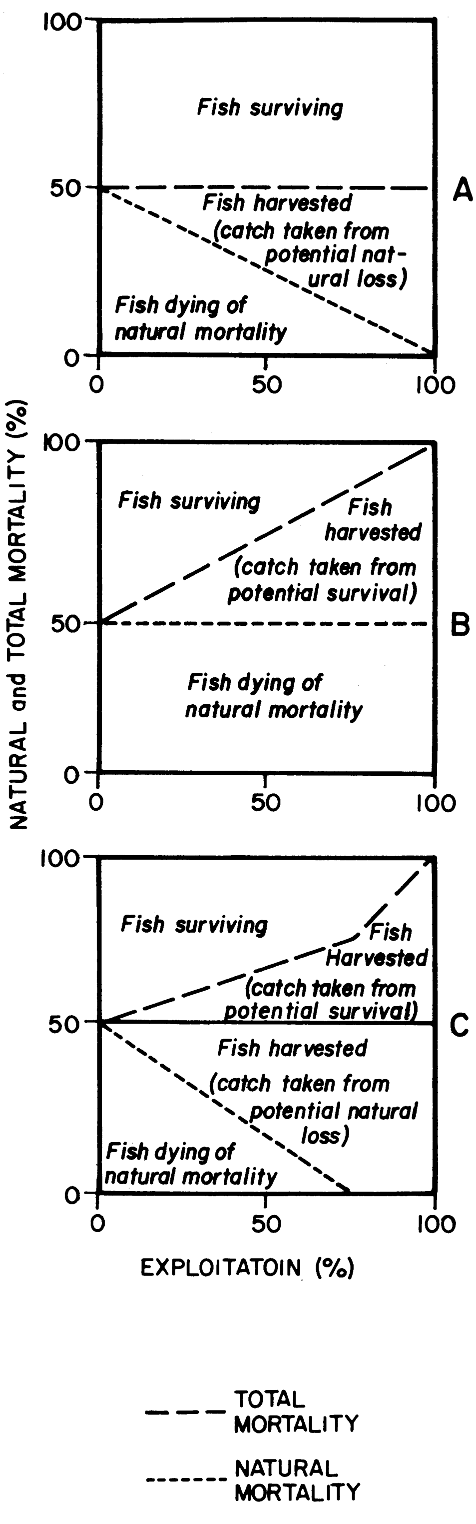


FIGURE 17. *Three hypothetical examples of the relationship between exploitation and mortality.*

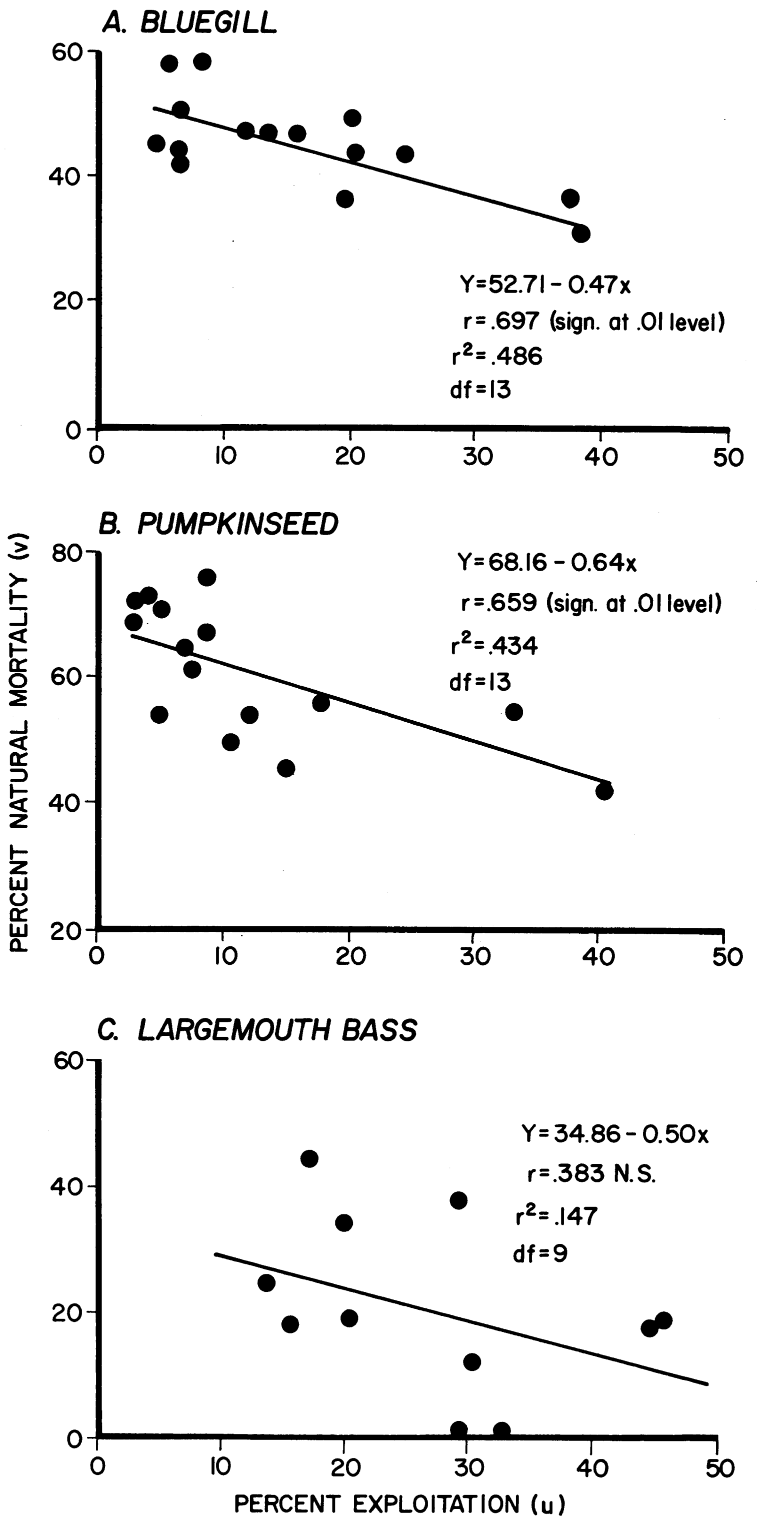


FIGURE 18. *Relationship between exploitation (u) and natural mortality (v) for: (A) bluegill, (B) pumpkinseed, and (C) largemouth bass in Murphy Flowage, 1955-69.*

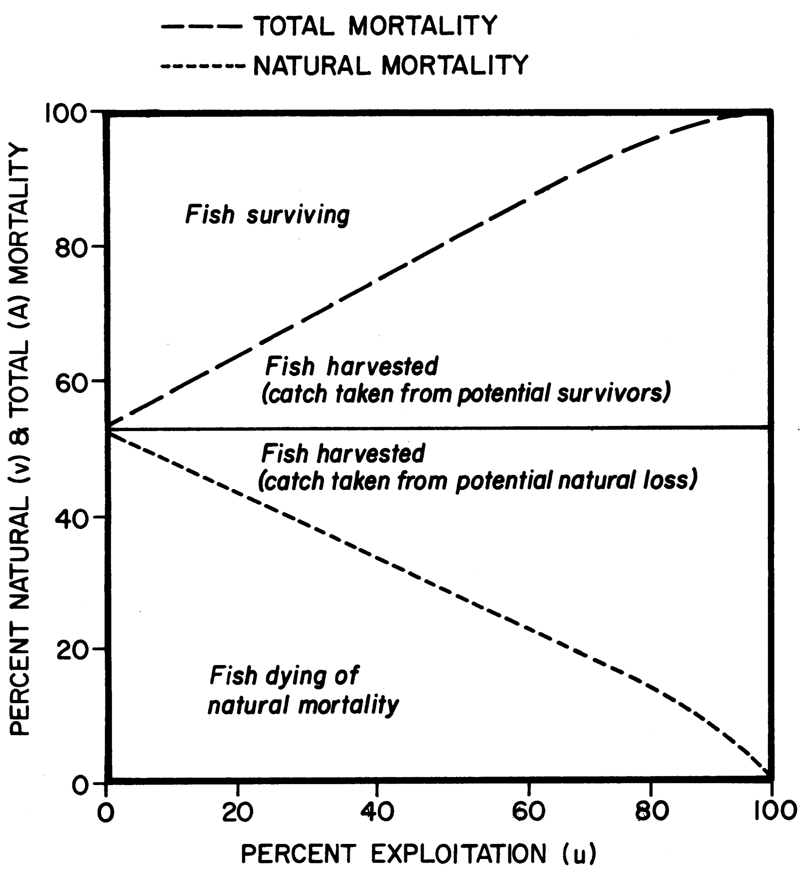


FIGURE 19. *Relationship between exploitation and natural mortality for the bluegill in Murphy Flowage, 1955-70 (based on the regression line in part A of Figure 18).*

TABLE 8. *Estimated annual natural mortality of Murphy Flowage fishes in the absence of fishing.*

Species	Estimated Natural Mortality (%)
Panfish	
Bluegill	53
Pumpkinseed	68
Black crappie	43
Yellow perch	61*
Rock bass	23
Brown bullhead	50*
Avg.	50
Game Fish	
Largemouth bass	35
Northern pike	60
Avg.	48
Avg. All Species	49

*Because of insufficient data for yellow perch and brown bullhead, this figure could not be calculated; however, since exploitation was extremely low, total mortality with fishing was used as an approximation of natural mortality in the absence of fishing.

tic form in which almost all fish caught were taken from potential natural losses (Snow unpubl.).

The black crappie and rock bass approach the least desirable situation for which almost all fish caught were taken from potential survivors (B of Fig. 17); however, neither of these relationships were significant. The range of annual exploitation for those species for which this relationship was significant was considerably greater than for the black crappie or rock bass (Table 6). With a wider range of data it is possible that the relationship between v and u for black crappies and rock bass would approach that of the other centrarchids.

The relationship between v and u which was significant for bluegills and pumpkinseeds but not for largemouth bass is shown in Figure 18. Despite lack of significance for largemouth bass, the relationship for all three species approached the practical situation where a portion of the catch is taken from potential survivors and a portion from potential natural losses (C of Fig. 17). Of each 100 fish in the catch, approximately 50 were from potential survivors and 50 from potential natural losses for bluegills and largemouth bass and approximately 65 from potential survivors and 35 from potential natural losses for pumpkinseeds.

Exploitation rates used in the previous regression analysis ranged from 3 to 50 percent (Table 7). Therefore conclusions relating exploitation and mortality are likely to be more reliable within or near this range of data (3-50) than at extremely high levels of exploitation. This relationship is convenient because an estimate for the natural mortality in the absence of fishing can be made from the intercept on the Y or vertical axis. Furthermore the horizontal projection of the intercept value divides the catch into that portion which would have been expected to survive and that portion which would have been expected to die from natural causes if no angling had occurred. Because total mortality equals the sum of natural mortality and exploitation, paired values of these parameters were used to determine the location of the lines for total mortality. This is the principle upon which the hypothetical examples and the specific examples for bluegill and largemouth bass in Murphy Flowage are based (Figs. 19 and 20).

The estimated natural mortality in the absence of angling averaged 49 percent for all species and varied from a low of 23 percent for rock bass to 68 percent for pumpkinseed (Table 8). When only those species for which the relationship between exploitation and natural mortality was significant are considered (i.e., bluegill, pumpkinseed, and northern pike), the average

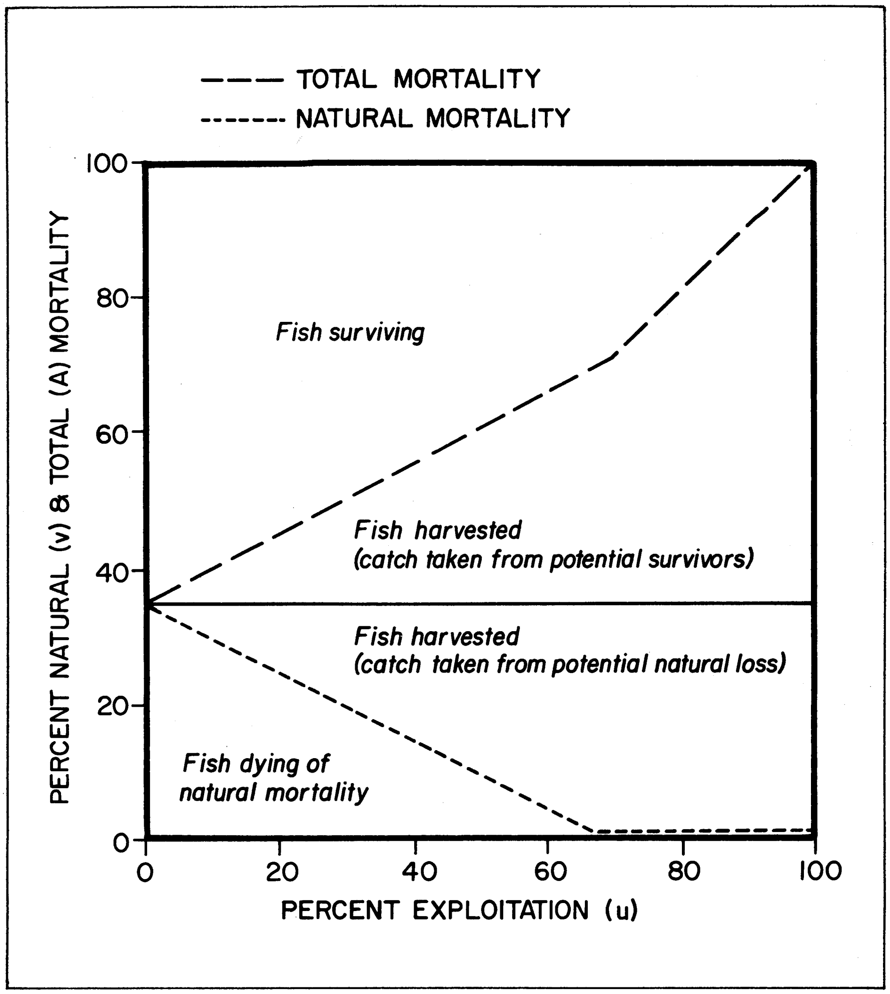


FIGURE 20. *Relationship between exploitation and natural mortality for the largemouth bass in Murphy Flowage, 1959-70 (based on the regression line in part C of Figure 18).*

estimated mortality in the absence of angling increased to 60 percent. Therefore, the average for all species is probably a minimal estimate. If a wider range of data were available for other species, the average mortality with no fishing would probably be higher than 50 percent.

The estimation of natural mortality in the absence of fishing and the relationship between natural mortality and exploitation — in addition to that reported for brook trout by McFadden (1961) — has also been determined for the smallmouth bass population in Oneida Lake, New York, (Youngs 1972; Forney 1972). To the best of my knowledge, this is the first time these relationships have been presented for the species covered in this report.

Although the previous discussion provides a better understanding of mortality parameters, it does not indicate the maximum allowable mortality that can occur without fear of depleting the stock, or stated another way, it does not indicate what survival is necessary to maintain a good fishable population. While these factors have not been determined in the present study, it should be pointed out that during most years of study, the standing crop increased, particularly during and immediately following the years of highest exploitation (1955-60). Therefore, it can be concluded that there were no signs of overexploitation and that on the long-term average, survival plus recruitment into the catchable size range compensated for losses from angling and natural mortality.

MANAGEMENT IMPLICATIONS

The information presented in this report should be useful to fish managers as a standard of comparison and as a guide to anticipate various angling statistics in other waters with similar characteristics. In all comparisons made, it must be remembered that this entire study was conducted with no bag, season or size limits in effect. Therefore, the yield was probably slightly higher in Murphy Flowage than would be expected in waters where more restrictive regulations are in force.

In addition to being used for comparative purposes there are some results which should be reemphasized and which, if considered in management plans, could increase the yield to anglers:

1. Most fish are caught by few anglers — 10 percent of all anglers caught 50 percent of the fish while 37 percent caught no fish. Some means of increasing the percentage of successful anglers could be desirable. Possibly a brochure on fishing techniques distributed with fishing licenses or some other type of educational program would help achieve this goal.

2. On the average, anglers caught fish 2½ times faster in winter than summer; however, there were seasonal differences among species. Northern pike, bluegills, black crappies, and yellow perch are most readily caught in winter and largemouth bass, rock bass, and pumpkinseeds in summer. When the fish population is composed predominantly of those species that are readily caught in winter, the winter season is likely to be the most successful season of the year. Seasonal publicity considering these differences could increase the success rate.

3. Exploitation rates varied considerably for different species; however this had no apparent effect on the future status of that species in the fishery. The proportion of each species in the harvest when compared by numbers and pounds was remarkably stable throughout the 15-year study.

SUMMARY

Fifteen years of liberalized fishing regulations resulted in an average annual pressure of 73.6 hours/acre, a yield of 30.5 lb/acre, and a catch rate of 1.88 fish/hour. Compared to the waters in nearby states, pressure and yield could be considered above average for sparsely populated areas and average for sparsely and densely populated areas combined. Catch rate in fish/hour of effort, however, was higher than that for all other waters compared.

Seasonally, 88 percent of all hours fished and 75 percent of all fish caught occurred during the open water seasons. In semimonthly intervals, maximum pressure occurred the first half of July while maximum yield occurred the first half of June. During the ice fishing season, maximum pressure and yield occurred in the last half of December. The catch rate reached a maximum of 6.5 fish/hour the last half of January during the ice fishing season and 2.6 fish/hour the first half of June during open water fishing.

Annually the catch of panfish averaged 132.8 fish weighing 21.7 lb/acre, and of game fish, 5.5 fish weighing 8.8 lb/acre. Among panfish, bluegills dominated the catch at all times. The numbers of game fish caught were about equally divided between northern pike and largemouth bass; however, by weight, northern pike comprised about 70 percent of the pounds of game fish caught. A remarkable feature of the yield has been the stability in the proportion of species harvested throughout the 15-year study period.

The percentage of successful trips averaged 63 percent annually, 61 percent in summer, and 73 percent in winter. In the open water season, anglers averaged 6 fish/trip compared to 15 fish/trip in the ice fishing season. Generally the most successful 10 percent of all anglers caught 50 percent of all fish caught.

Winter fishing was more productive than summer fishing. The winter season accounted for 12 percent of the total hours fished and 26 percent of all fish caught. The winter catch rate was 4.2 fish/hour compared to 1.6 fish/hour in summer. In Murphy Flowage, the bulk of all fish present was composed of those species that are readily caught in winter (bluegill, black crappies, yellow perch, and northern pike). Therefore, winter fishing produced the highest catch rate and generally the most successful fishing of the year.

The average length of all fish caught annually varied considerably; however, there were no trends for increasing or decreasing average length which lasted throughout the entire study. Although trends lasted for 3 to 9 years duration for various species, no overall similarity between species in successive years of study was observed. For 5 to 8 species caught, maximum average length occurred sometime during the first four years of study while for the remaining 3 species, maximum length occurred during the last 2 years of study.

The number of larger bluegills, pumpkinseeds, and black crappies caught the first 2 to 4 years of study was greater than the number caught during all remaining years combined. During other years and for all other species, the number of larger fish caught was approximately in proportion to the hours fished.

The variations in average length

and in the numbers of larger fish caught are believed to be more closely related to variations in year class strength and growth rates than to fishing pressure, liberalized regulations, or any other factors.

The relationship between fishing pressure and harvest was highly significant both seasonally and annually. An increase in pressure of 10 hours per acre would be expected to increase the harvest by 8 lb/acre in winter and 3.5 lb/acre in summer.

Annual exploitation rate averaged 9 percent for panfish and varied from 2 percent for the brown bullhead to 18 percent for the rock bass. Bluegills were exploited at an average annual rate of 12 percent while game fish were exploited at an average annual rate of 27 percent with variations of 14 to 45 percent for largemouth bass and 3 to 50 percent for northern pike.

Estimated natural mortality averaged 46 percent for panfish, 30 percent for game fish, and 42 percent for all species combined.

Total annual mortality averaged 57 for all species combined and also for panfish and game fish when figured separately.

The relationship between exploitation and natural mortality was highly significant for northern pike, bluegill, and pumpkinseed. Further analysis of the relationship between mortality and exploitation indicates that most of the pike caught were taken from potential natural losses rather than from potential survivors. This indicated that the catch of pike by anglers had little effect on total mortality. For bluegills and largemouth bass, half of the catch was estimated to come from potential survivors and half from potential natural losses.

Estimated natural mortality in the absence of fishing averaged 49 percent for all species combined and varied from 23 percent for rock bass to 68 percent for pumpkinseed.

From a comparison of the total 15-year harvest and exploitation with the estimated total and natural mortality, it was concluded that there were no signs of overexploitation in Murphy Flowage. On the average, survival plus recruitment into the catchable size range compensated for losses from angling and natural mortality.

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