HYPOTHETICAL EFFECTS OF FISHING REGULATIONS IN MURPHY FLOWAGE, WISCONSIN

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ABSTRACT

This paper summarizes the hypothetical effects of bag, season, and size limits on the harvest of panfish, northern pike, and largemouth bass in Murphy Flowage, Wisconsin. Complete angler records were obtained through a compulsory registration-type creel census for 15 years. There were no bag, season, or size limits in effect at any time during the study. The hypothetical reduction in harvest with various regulations was calculated from detailed harvest records.

The present bag limits in effect in most of Wisconsin would have had little effect on the observed harvest in Murphy Flowage. A 50-fish daily bag limit on panfish in aggregate would have reduced the observed harvest 2.9% in summer and 13.8% in winter. A 5-fish daily bag on gamefish would have reduced the northern pike harvest 0.5% in summer and 1.5% in winter, while the harvest of largemouth bass would have been reduced 2.5% in summer, with no effect in winter.

A year-round open season would have had very little effect on the harvest. A maximum of 7% of the northern pike and 4% of the largemouth bass were taken during the normal closed season, 1 March to the 1st Saturday of May. A later opening date could have a marked effect on the harvest, especially on largemouth bass since 50% of the annual harvest was taken by the end of June.

Size limits alone or in combination with later opening dates had the most potential for reducing the observed harvest. An 18-inch limit on northern pike would have reduced the harvest 22% and a 10-inch limit on largemouth bass would have reduced bass harvest 27%. A slot-length limit of 18-22 inches on northern pike would have reduced the harvest 40% while a 12- to 15-inch limit on largemouth bass would have reduced bass harvest 30%.

Some important considerations in the use of length limits are: (1) the possibility of losses of the protected sizes due to hooking mortality, (2) possible alteration of the sex ratio of northern pike populations, (3) lack of control of forage species by bass if their preferred diet of crayfish is abundant, and (4) the possibility of reduced growth rates.

Other in-depth exploitation and mortality studies in Murphy Flowage have shown that the difference in total mortality with fishing and without fishing is relatively small. Therefore, it was concluded that liberalized regulations within the range of fishing pressure and exploitation experienced in Murphy Flowage were not a detriment to the fish populations, and that the hypothetical results of various regulations closely approximated those that would have been obtained with normal regulations.

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INTRODUCTION

Fishing regulations have been a tool for the management of fish populations in Wisconsin lakes since the 1850's and during this time numerous regulation changes have been made (J. Klingbiel, Wis. Dep. Nat. Resour., unpubl.). In the 1950's regulations were relaxed. Most length limits were dropped and seasons were extended, while in the 1960's and early 1970's some length limits were re-established in several counties. Bag limits for game fish have remained quite stable — 5 fish/day for northern pike and largemouth bass since 1949. Bag limits for panfish have varied from 25 of each species, to 50 in aggregate, to no limit, in different years and locations.

In more recent years (1978-81), due to increased angling pressure and findings on the effects of angling on fish populations in other regions of the country, there has been a renewed interest in more restrictive regulations in Wisconsin. There is concern that some over-fishing is occurring and that angling quality is declining. This renewed interest has prompted a more detailed analysis of results from Murphy Flowage where there was a compulsory creel census with liberalized regulations for 15 years (1955-69).

This paper summarizes the hypothetical effects of various bag, season, and size limits on the harvest of panfish, northern pike, and largemouth bass in Murphy Flowage, Wisconsin. There were no actual limits in effect except hours of fishing and methods of capture (hook and line). Proforma recast of data is used to simulate outcomes under potential regulations.

Considerable information covering results from the Murphy Flowage studies has been published (Churchill and Snow 1964, Johnson 1969, Snow 1972, Beard 1973, Snow 1974, Snow 1978*b*) including a detailed report on the harvest (Snow 1978*a*).

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 the Barron Hills. Maximum depth of Murphy Flowage was 14 ft, and over 70% 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 estimated total annual biomass of fish at Murphy Flowage approximated 325 lb/acre (25 lb of game fish and 300 lb of panfish). The bluegill, *Lepomis macrochirus* Rafinesque, comprised about 80% of the total biomass of panfish. 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 estimated game fish biomass was comprised of about 65% northern pike, *Esox lucius* Linnaeus, and 35% largemouth bass, *Micropterus salmoides* (Lacepede).

*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.

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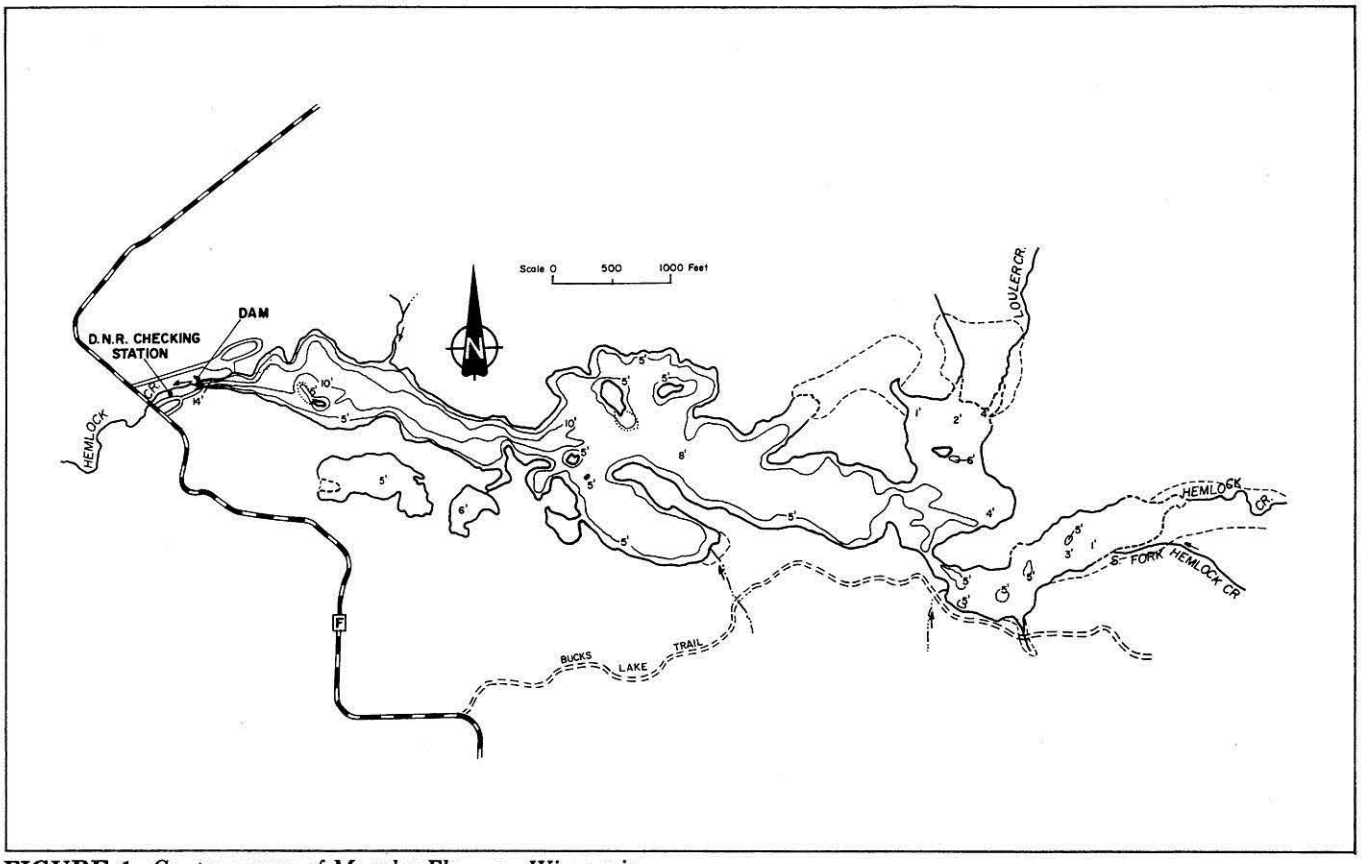

FIGURE 1. *Contour map of Murphy Flowage, Wisconsin.*

SYNOPSIS OF THE SPORT FISHERY

The long-term nature of this study makes it possible to compare various fishing regulations over a wide range of conditions. Fishing pressure, harvest, and fishing quality have displayed considerable annual and seasonal variation throughout the 15-year study.

Aside from the 1st year of the study when fishing pressure was light, the pattern of fishing pressure fell into 3 groups (Table 1). From 1956 to 1959, fishing pressure was over 100 hours/acre. During and after a panfish removal program in 1960 and 1961, the pressure fell within a range of 60.2-74.9 hours/acre (1960-64). The 2nd year after northern pike stocking in December 1963, the pressure declined further to a range of 40.6-56.2 hours/acre (1965-69). The 224% variation in pressure which occurred can be attributed in part to: (1) a decline in fishing quality resulting from the removal program and from the declining growth and increasing abundance of the major panfish species, and (2) an intentional decline in publicity after 1960.

The annual catch rate for all species combined averaged 1.88 fish/hour and varied from a high of 3.28 to a low of 1.25 (Table 1). This extreme annual variation was related in part to changes in the density of fish populations, but was attributed largely to seasonal variation in fishing pressure (Snow 1978*a*). In years when ice conditions were good, the winter hourly catch rate made the annual catch rate higher than in years when ice conditions were bad. The winter catch rate varied from 1.8 to 8.5 fish/hour, while summer catch rates ranged from 1.20 to 1.96.

The total 15-year harvest by anglers was 373,520 fish, which, on an annual basis, amounted to 138.3 fish weighing 30.5 lb/acre (Table 1). The average annual percentage composition (by species) of the numbers of fish caught was: bluegill 83.5, black crappie 4.4, yellow perch 3.9, northern pike 2.1, rock bass 2.2, pumpkinseed 1.9, largemouth bass 1.9, brown bullhead 0.1, and muskellunge 0.01.

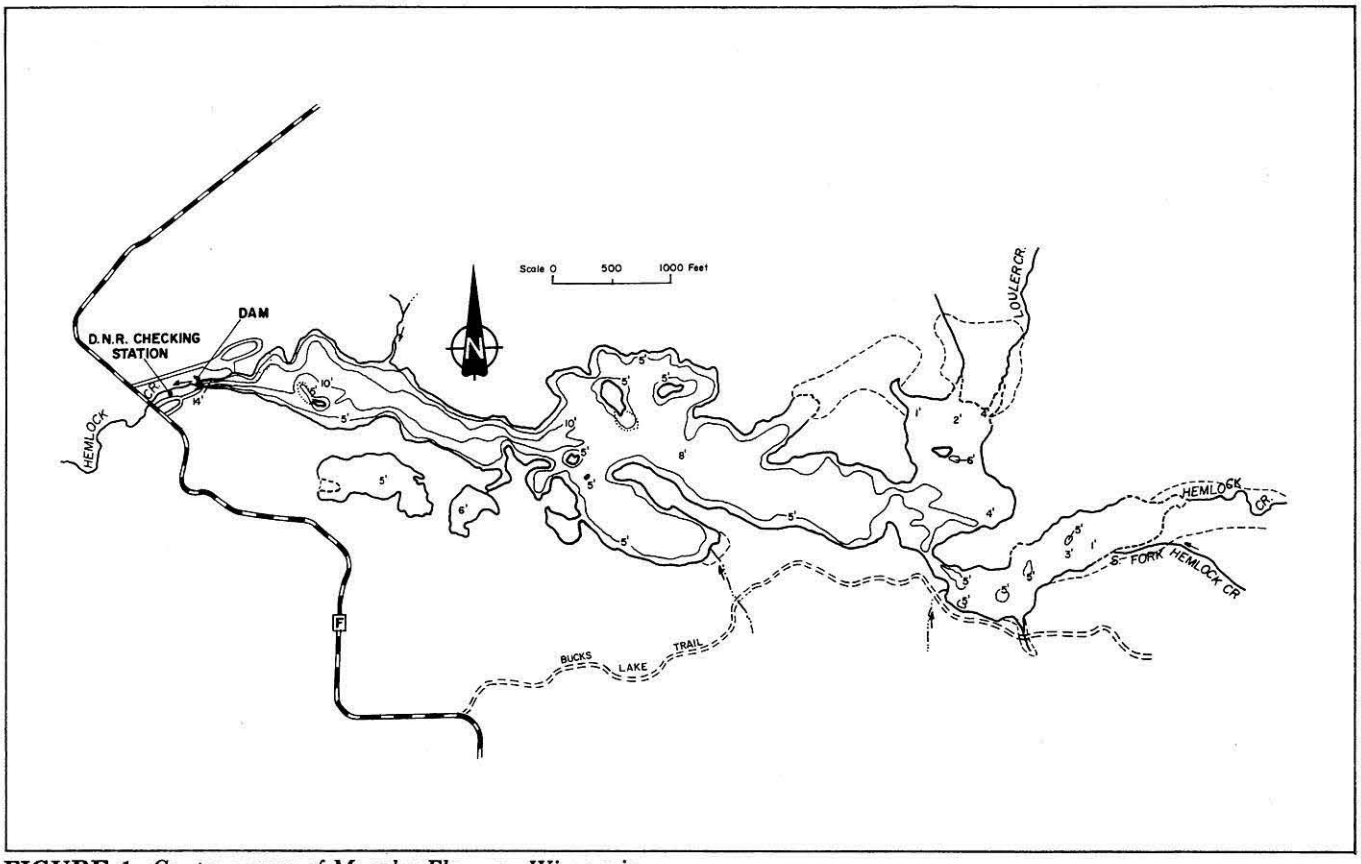

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TABLE 1. *Annual fishing pressure, harvest, and fishing quality for Murphy Flowage, 1955-69.*

	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

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 was 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. Harvest refers to numbers of fish, not pounds or yield. Throughout this paper, the terms "catch" and "caught" refer to fish which were harvested. No records were kept of fish caught and released. During the 1st 2-3 years of this study anglers were encouraged (not required) to keep all fish caught, while in the remaining 12-13 years this idea was not promoted. The individual catch of each angler was recorded as reported; however, when an angling party combined their catch the number of fish harvested was equally divided among all anglers in the party. For further details of the procedures used, see Churchill and Snow (1964), and Snow (1978*a*).

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 2 calendar years, on the average from about 15 April one year to 14 April of the year following. There was no closed fishing season and neither a bag nor size limit was in effect on Murphy Flowage at any time. Angling was permitted from 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.

Management and Publicity

The entire 15-year study was divided into 3 5-year periods from a management viewpoint: (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 partial removal of panfish (22%) occurred in 1960 and 1961 and the stocking of northern pike in December 1963 (47 15.4-inch pike/acre). (3) From 1965 to 1969 — very little publicity was issued; manipulation of the environment by partial 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.

Regulations

Since all fish considered in this report were harvested and there were no controls to compare or evaluate the effects of any regulations, the actual effects of regulations are unknown; i.e., if fish in excess of the regulation considered were returned to the water, the actual effects may have been different. This report simply shows the proportion of the total observed harvest that would have been reduced or would have been returned to the water if the tested regulation had been in effect. The same information is also expressed as the percent of the total observed harvest that would have been legal

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under the hypothetical conditions. These methods are similar to those used in an evaluation of waterfowl regulations in Wisconsin (Bartonek et al. 1964).

Machine tabulation of data on size of catch was not started until the 3rd year of study and continued through the 10th year. Data from the first 2 years were tabulated by hand for single species but not in aggregate. Therefore, data presented on size of catch and bag limits cover a full 10 years for bluegill, northern pike, and largemouth bass and 8 years for evaluation of panfish bag limits in aggregate. Evaluation of size and season limits on northern pike and largemouth bass was also only considered for the first 10 years of study. Most other regulations considered cover the full 15-year period.

Some aspects of the effects of liberalized regulations have been evaluated in previous reports, including sections on average length and the number of larger fish harvested (Snow 1978*a*).

RESULTS

PANFISH

The daily bag limit for panfish in other waters for several years had been either 25 fish of each species/day or 50 in aggregate for bluegills, perch, crappies, and pumpkinseeds. Aside from bluegills and perch, a 25-fish daily bag limit would have had little effect on the harvest in Murphy Flowage. Only 0.2% of the anglers in summer and 3.6% in winter kept more than 25 perch/trip. Their harvest in excess of 25/trip comprised 0.9% of the total in summer and 12.0% in winter (Table 2).

Bluegills were very abundant and comprised about 84% of the harvest. As expected a bag limit would have had a greater impact on the harvest of bluegills than on that of other panfish species. A 25-fish bag limit would have affected the catch of 8.9% of the anglers catching bluegills in summer and 30.0% in winter. With this bag limit the harvest would have been reduced 12.1% in summer and 30.2% in winter (i.e., 87.9 and 69.8% of the harvest would have been legal) (Table 2 and Fig. 2). The curve in Figure 2 is derived from 10-year totals representing over 179,000 bluegills caught in the summer and over 75,000 caught in winter (Table 2) and can be used to estimate the hypothetical effect of any bag limit desired. For example, with a bag limit of 10 bluegills 37% of the harvest would have been legal in winter and 61 % in summer. Annual variations in the effects of a 25-fish bag limit are very slight; however, there was somewhat more variation in winter than summer (Fig. 3). The extreme annual variation in the harvest of bluegills in either season is a reflection of fishing pressure.

Because bluegills comprised such a high percentage of the total population, the results on aggregate bag limits for panfish are quite similar to those presented for bluegills. A 50-fish bag limit for panfish in aggregate would have reduced the observed harvest 2.9% in summer and 13.8% in winter (Fig. 4). The harvest for an individual angler was occasionally quite high. The maximum catch recorded for 1 angler trip was 272 in winter and 244 in summer.

TABLE 2. *Distribution among anglers of the harvest from Murphy Flowage, 1955-64.*

		Percent of Anglers Catching					Percent of Fish Caught by Anglers Catching				Percent Total Harvest Over*		
	Total Anglers	1-5	6-25	26-50	Over 50	Total Fish	1-5	6-25	26-50	Over 50	5	25**	50
Open Water													
Brown bullhead	210	97.6	2.4			309	85.8	14.2					
Yellow perch	2,736	89.3	10.5	0.2		7,225	60.3	36.0	3.7			0.9	
Pumpkinseed	2,733	94.7	5.2	0.1		5,548	79.1	20.3	0.6			0.1	
Bluegill	17,042	43.0	48.1	7.6	1.3	179,453	11.8	54.9	24.9	8.4		12.1	2.2
Rock bass	3,131	94.9	5.1			6,454	78.0	22.0					
Black crappie	4,001	93.6	6.3	0.1		8,995	73.4	25.2	1.4			0.2	
Northern pike	2,880	99.4	0.6			4,619	97.6	2.4			0.6		
Largemouth bass	3,455	98.9	1.1			5,142	94.8	5.5			2.5		
Muskellunge	32	100.0				32	100.0						
Winter													
Yellow perch	1,074	73.9	22.5	2.9	0.7	6,202	27.6	44.7	20.9	7.7		12.0	2.1
Pumpkinseed	159	100.0				192	100.0						
Bluegill	3,477	19.0	51.0	19.7	10.3	75,611	2.7	32.6	32.1	32.6		30.2	8.9
Rock bass	19	100.0				23	100.0						
Black crappie	1,033	93.1	6.8	0.1		2,336	74.9	23.9	1.2			0.9	
Northern pike	1,077	99.0	1.0			1,853	90.6	9.4			1.5		
Largemouth bass	82	100.0				86	100.0						

* Percent of total catch taken in excess of 5 game fish or 25 and 50 panfish/angler trip for anglers catching more than those amounts.
** Includes "over 50" category.

under the hypothetical conditions. These methods are similar to those used in an evaluation of waterfowl regulations in Wisconsin (Bartonek et al. 1964).

Machine tabulation of data on size of catch was not started until the 3rd year of study and continued through the 10th year. Data from the first 2 years were tabulated by hand for single species but not in aggregate. Therefore, data presented on size of catch and bag limits cover a full 10 years for bluegill, northern pike, and largemouth bass and 8 years for evaluation of panfish bag limits in aggregate. Evaluation of size and season limits on northern pike and largemouth bass was also only considered for the first 10 years of study. Most other regulations considered cover the full 15-year period.

Some aspects of the effects of liberalized regulations have been evaluated in previous reports, including sections on average length and the number of larger fish harvested (Snow 1978*a*).

RESULTS

PANFISH

The daily bag limit for panfish in other waters for several years had been either 25 fish of each species/day or 50 in aggregate for bluegills, perch, crappies, and pumpkinseeds. Aside from bluegills and perch, a 25-fish daily bag limit would have had little effect on the harvest in Murphy Flowage. Only 0.2% of the anglers in summer and 3.6% in winter kept more than 25 perch/trip. Their harvest in excess of 25/trip comprised 0.9% of the total in summer and 12.0% in winter (Table 2).

Bluegills were very abundant and comprised about 84% of the harvest. As expected a bag limit would have had a greater impact on the harvest of bluegills than on that of other panfish species. A 25-fish bag limit would have affected the catch of 8.9% of the anglers catching bluegills in summer and 30.0% in winter. With this bag limit the harvest would have been reduced 12.1% in summer and 30.2% in winter (i.e., 87.9 and 69.8% of the harvest would have been legal) (Table 2 and Fig. 2). The curve in Figure 2 is derived from 10-year totals representing over 179,000 bluegills caught in the summer and over 75,000 caught in winter (Table 2) and can be used to estimate the hypothetical effect of any bag limit desired. For example, with a bag limit of 10 bluegills 37% of the harvest would have been legal in winter and 61 % in summer. Annual variations in the effects of a 25-fish bag limit are very slight; however, there was somewhat more variation in winter than summer (Fig. 3). The extreme annual variation in the harvest of bluegills in either season is a reflection of fishing pressure.

Because bluegills comprised such a high percentage of the total population, the results on aggregate bag limits for panfish are quite similar to those presented for bluegills. A 50-fish bag limit for panfish in aggregate would have reduced the observed harvest 2.9% in summer and 13.8% in winter (Fig. 4). The harvest for an individual angler was occasionally quite high. The maximum catch recorded for 1 angler trip was 272 in winter and 244 in summer.

TABLE 2. *Distribution among anglers of the harvest from Murphy Flowage, 1955-64.*

		Percent of Anglers Catching					Percent of Fish Caught by Anglers Catching				Percent Total Harvest Over*		
	Total Anglers	1-5	6-25	26-50	Over 50	Total Fish	1-5	6-25	26-50	Over 50	5	25**	50
Open Water													
Brown bullhead	210	97.6	2.4			309	85.8	14.2					
Yellow perch	2,736	89.3	10.5	0.2		7,225	60.3	36.0	3.7			0.9	
Pumpkinseed	2,733	94.7	5.2	0.1		5,548	79.1	20.3	0.6			0.1	
Bluegill	17,042	43.0	48.1	7.6	1.3	179,453	11.8	54.9	24.9	8.4		12.1	2.2
Rock bass	3,131	94.9	5.1			6,454	78.0	22.0					
Black crappie	4,001	93.6	6.3	0.1		8,995	73.4	25.2	1.4			0.2	
Northern pike	2,880	99.4	0.6			4,619	97.6	2.4			0.6		
Largemouth bass	3,455	98.9	1.1			5,142	94.8	5.5			2.5		
Muskellunge	32	100.0				32	100.0						
Winter													
Yellow perch	1,074	73.9	22.5	2.9	0.7	6,202	27.6	44.7	20.9	7.7		12.0	2.1
Pumpkinseed	159	100.0				192	100.0						
Bluegill	3,477	19.0	51.0	19.7	10.3	75,611	2.7	32.6	32.1	32.6		30.2	8.9
Rock bass	19	100.0				23	100.0						
Black crappie	1,033	93.1	6.8	0.1		2,336	74.9	23.9	1.2			0.9	
Northern pike	1,077	99.0	1.0			1,853	90.6	9.4			1.5		
Largemouth bass	82	100.0				86	100.0						

* Percent of total catch taken in excess of 5 game fish or 25 and 50 panfish/angler trip for anglers catching more than those amounts.
** Includes "over 50" category.

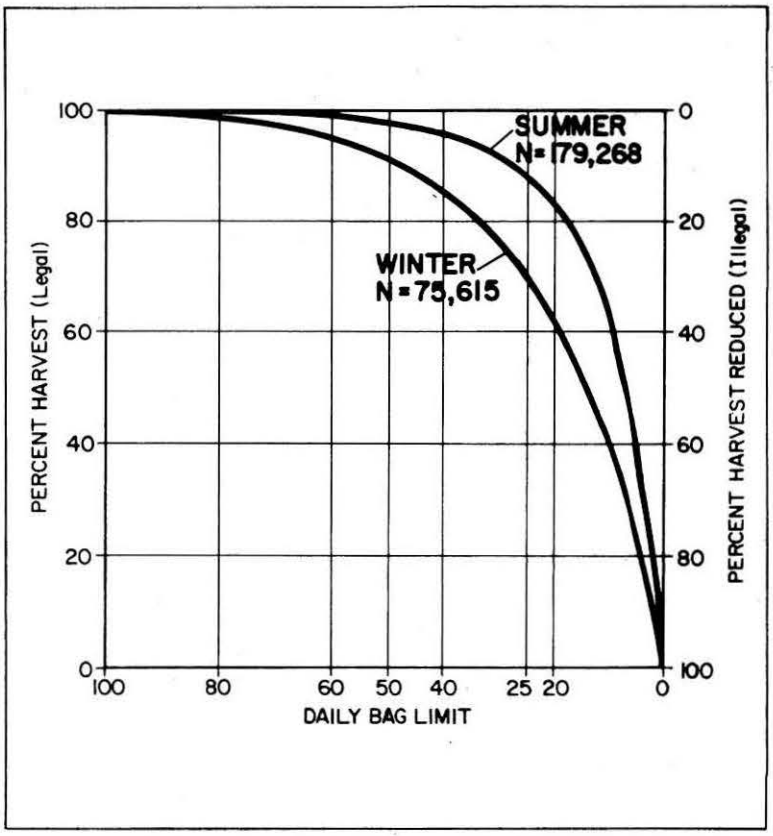

FIGURE 2. *Hypothetical effect of bag limits on the harvest of bluegills in Murphy Flowage (10-year average).*

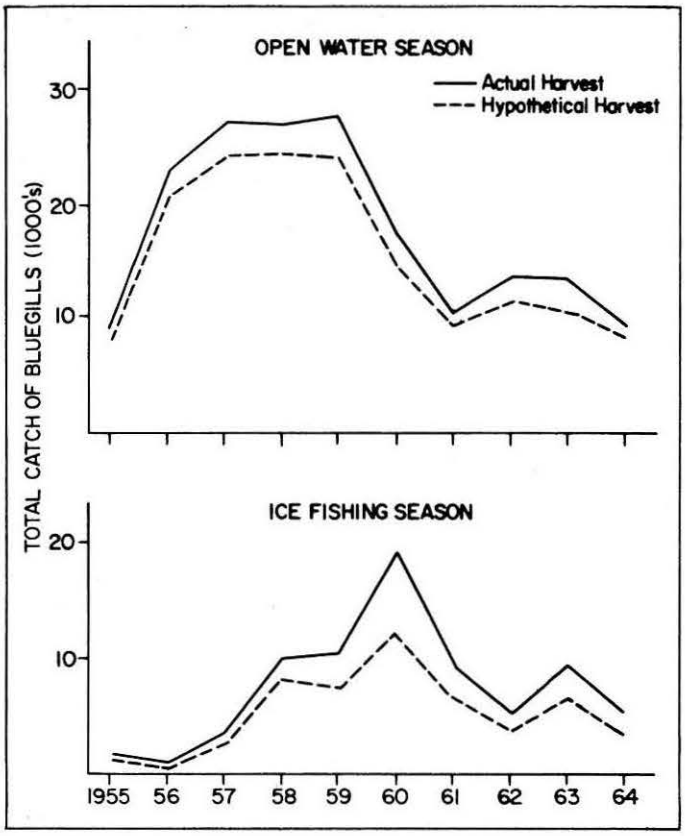

FIGURE 3. *Actual harvest and hypothetical harvest of bluegills with a 25-fish daily bag limit.*

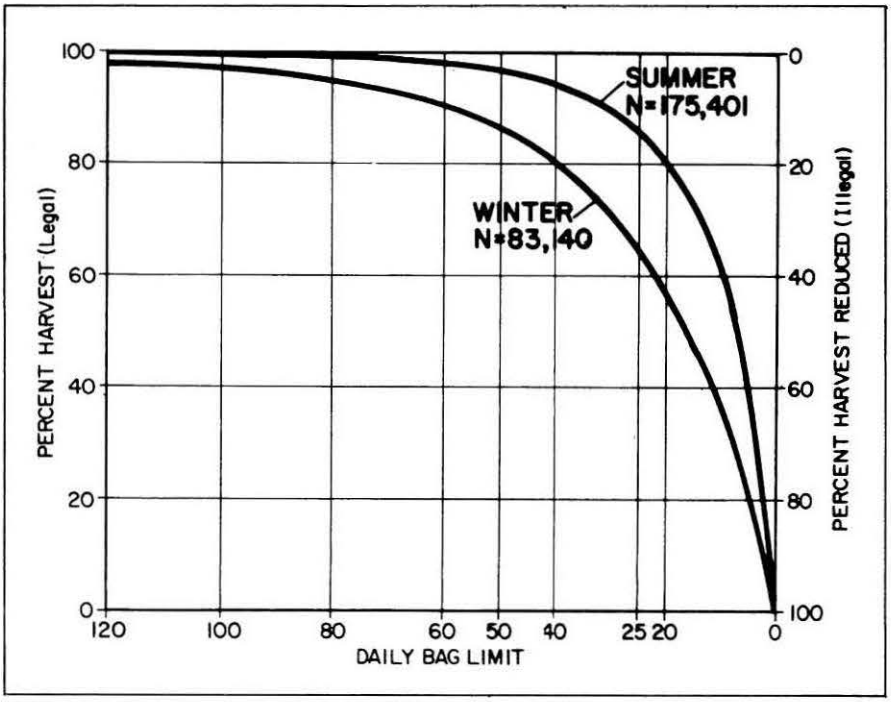

FIGURE 4. *Hypothetical effect of bag limits on the harvest of panfish in Murphy Flowage (8-year average).*

NORTHERN PIKE

Size and Season Limits

Maximum effect on the total harvest of northern pike under various closed seasons used in Wisconsin in recent years is 9% with no size limit. In contrast to this, size limits would result in drastic changes in total catch. With no closed season, size limits from 18 to 24 inches in increasing 2-inch intervals would have reduced the total harvest 22, 43, 62, and 78%, respectively. All the size limits tested would have a greater restrictive effect on the harvest than any closed season used in Wisconsin in recent years (Fig. 5).

Figure 5 can be used to estimate the effect of no size limit and various size limits up to 24 inches in combination with variations in the closed season from 16 February through 15 May. For example, with the most restrictive combination tested, that of a 24-inch limit and a 15 May opening date, only 20% of the total 10-year harvest would have been legal. With no size limit and a 15 May opening date, which most closely approximates the normal regulations in northern Wisconsin for several years, the total harvest would have been reduced by 9% — i.e., 91% of the

total harvest would have been legal. With a 1 May opening date and a 22-inch size limit, the total harvest would have been reduced 64%.

Seasonally, length limits would have had a greater effect on the harvest in winter than summer. With no closed season and an 18-inch size limit 91% of the harvest would have been legal in winter compared to 73% in summer (Fig. 6). Figure 6 can be used to estimate the effects of various size limits, including slot-length limits, on the harvest. With a 24-inch limit 31% of the harvest would have been legal in winter and 18% in summer. A slot-length limit of 18-24 inches would have reduced the harvest 60% (91 minus 31) in winter and 55% (73 minus 18) in summer.*

Bag Limits

A daily bag limit of 5 northern pike has been in effect in most Wisconsin waters for over 30 years. A bag limit of 5 in Murphy Flowage would have reduced the harvest 0.6% in summer and 1.5% in winter. With a bag limit of 2, the harvest would have been reduced 9% in summer, and 18% in winter, while with a bag of only 1 fish/day the harvest would have been reduced 29% in summer and 42% in winter (Fig. 7). It would take a reduction in the daily bag from 5 to 1 to have an appreciable effect on the harvest.

Sex Ratios

The sex ratio of angler-harvested northern pike was considerably different than the ratio found during spring fyke netting. Of 4,498 northern pike sampled with fyke nets from 1958 to 1968, 1,995 or 44% were females, while in a sample of 4,225 angler-caught fish during the same time under no length limits, 2,378 or 56% were females. Anglers harvested female northern pike in a higher ratio than were sampled with nets in spring. In addition the percentage of females in the harvest increased with size. For 16.0- to 17.9-inch fish, females comprised 40% of the spring netting sample and 45% of the harvest, while for fish 26.0 inches and larger, females comprised 71% of the netting sample and 81% of the harvest (Fig. 8). In all, anglers harvested 531 more females than males. Among fish larger than 20.0 inches the harvest consisted of 647 more females than males; among fish 18.0-19.9 inches equal number of males and females were har-

*Northern pike caught in the 18- to 24-inch size range would have to be released.

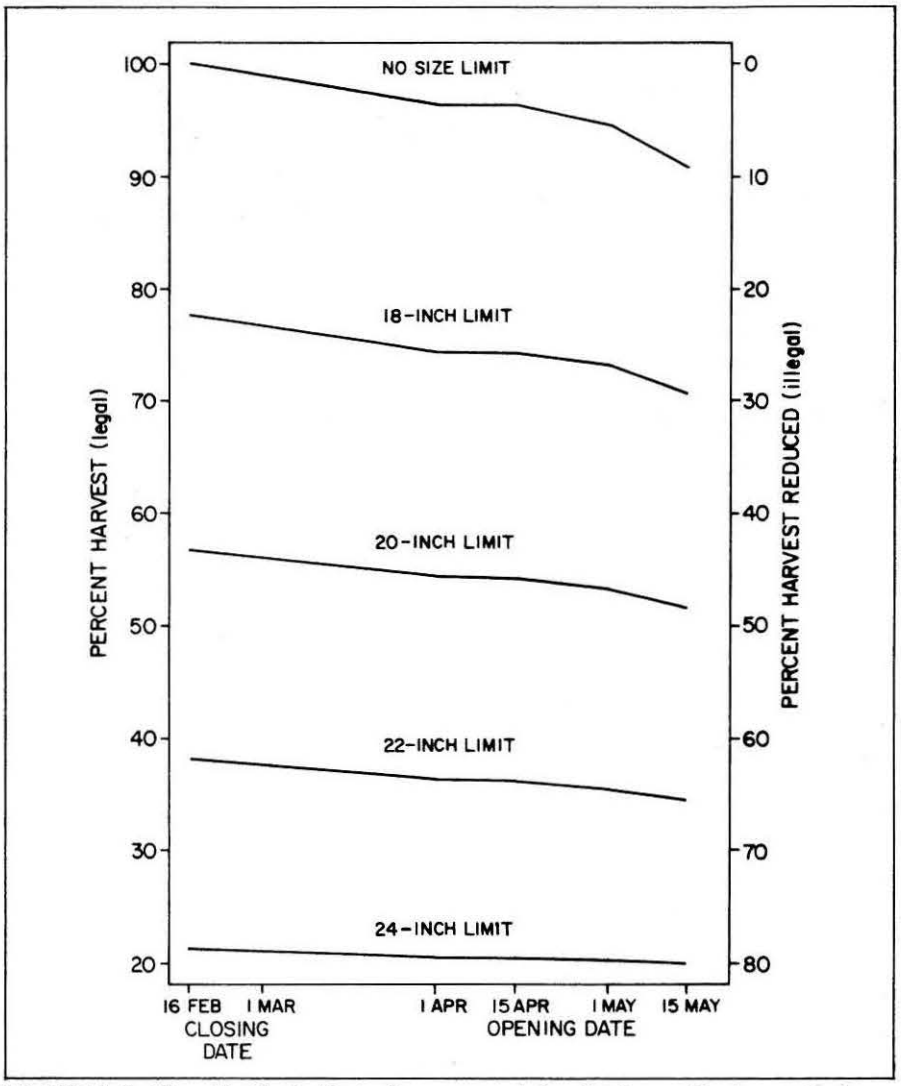

FIGURE 5. *Hypothetical effect of season and size limits on the harvest of northern pike in Murphy Flowage, 1955-64 (N=5,998 fish). The lines connect the cumulative 10-year weighted mean catch for each time period.*

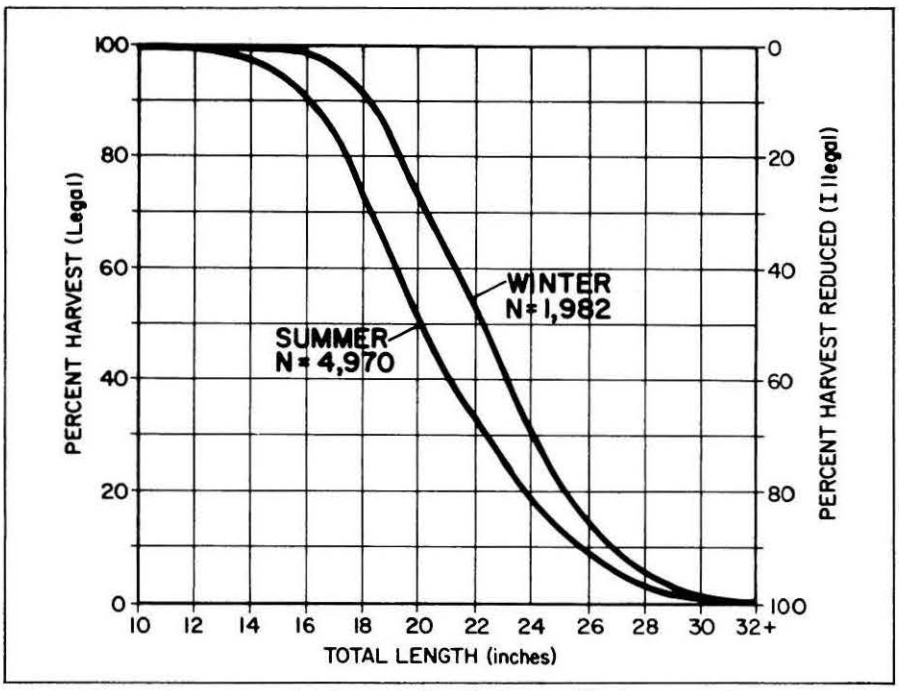

FIGURE 6. *Hypothetical effect of size limits on the harvest of northern pike in Murphy Flowage (15-year average).*

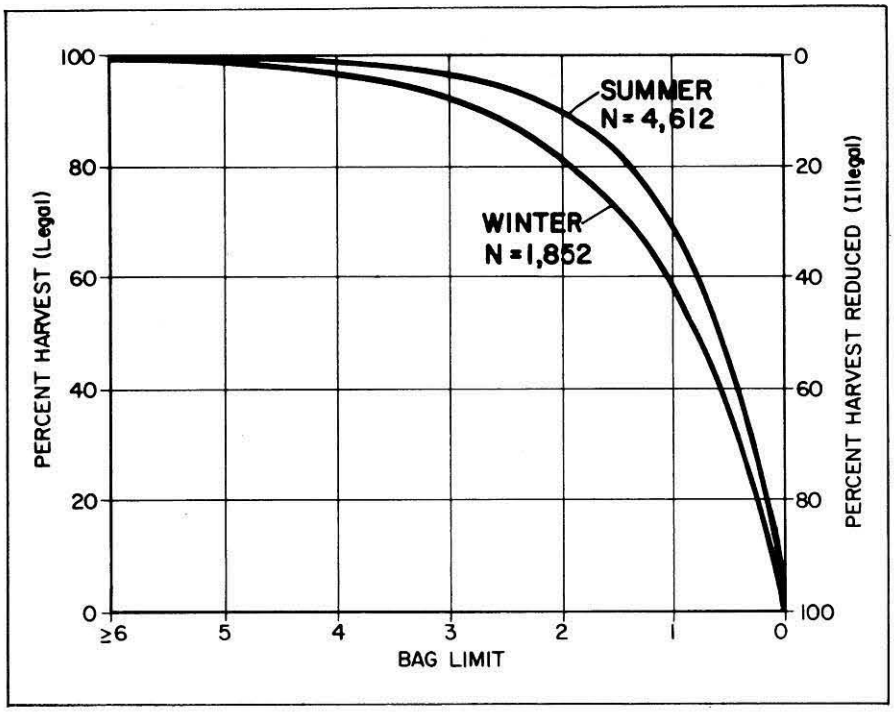

FIGURE 7. *Hypothetical effect of bag limits on the harvest of northern pike in Murphy Flowage (10-year average).*

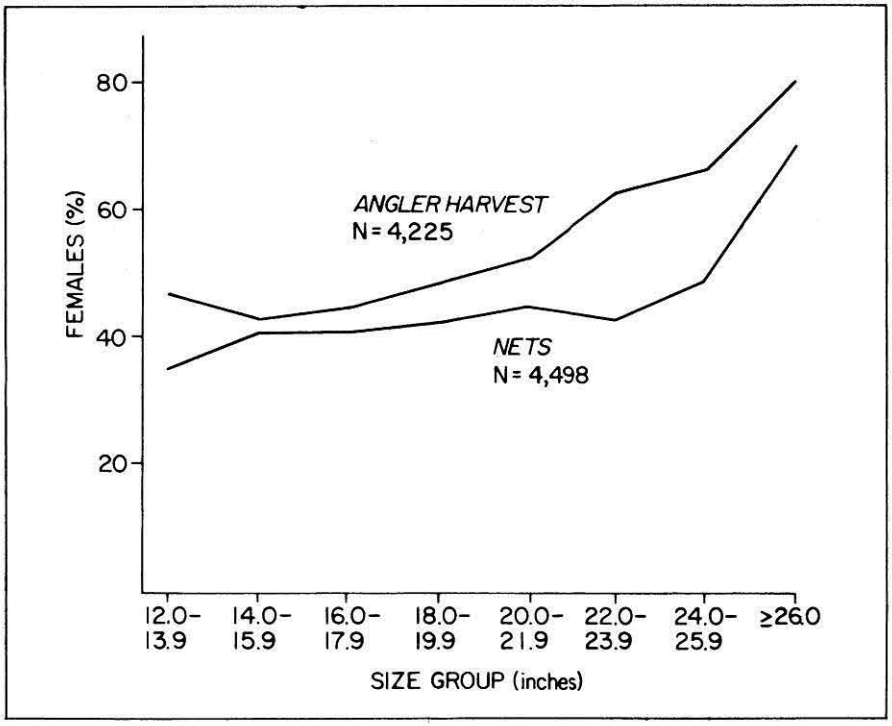

FIGURE 8. *Percent female northern pike taken from Murphy Flowage, 1958-68. Netting samples were taken in April or early May; angling harvest includes the entire angling year.*

vested and among fish 12.0-17.9 inches the harvest of males exceeded the catch of females by 115 fish.

The unrestricted fishing that has been in effect at Murphy Flowage has made it possible to estimate the hypothetical effect of various size limits on the sex ratio of the harvest. The percentages of females in the harvest with hypothetical size limits of 16, 18, 20, 22, and 24 inches were 57, 60, 64, 70, and 74, respectively. With a 22-inch limit, which has been in effect in some areas of Wisconsin, an estimated 70% of the harvest would be females. These results are similar to a New York study where under a 20-inch size limit females made up 70% of the total harvest (Pearce 1962), and to an Ontario study where anglers captured more female than male northern pike and a higher ratio of female fish than were taken by other methods (Casselman 1975). Hypothetically higher size limits result in more selective harvesting of female northern pike.

Population Density and Sizes Harvested

During the first 9 years (1955-63) of liberalized regulations all sizes of northern pike were well represented in the harvest in both the open water and ice fishing (Fig. 9) seasons. The average annual catch from 1955 to 1963 was 630 fish with an annual variation from 364 in 1955 to 801 in 1956. In the last 6 years of study (1964-69) (after northern pike were stocked in December 1963 and during winter drawdowns from 1967 through 1969), the numbers of larger pike in the harvest declined and the average annual harvest of native fish dropped to 213 fish (147-302). In the first 10 years the standing stock of native northern pike (14 inches and larger) increased steadily with some variation from 2.3/acre in 1955 to 16.4/acre in 1965, then declined to 2.8/acre in 1970 (Snow 1978*b*). Population estimates of native northern pike 22 inches and larger varied from a low of 0.24/acre in 1955 to a high of 2.95/acre in 1969, while the number 26 inches and larger varied from a low of 0.04/acre in 1955 to a high of 0.81 in 1967 and 1969. Based on these comparisons, the management techniques used (northern pike stocking and winter drawdown) had a greater impact on the harvest and standing stock of northern pike during the last 6 years than liberalized regulations alone had during the 1st 9 years.

LARGEMOUTH BASS

Size and Season Limits

Maximum effect on the total harvest of largemouth bass under various closed seasons that have been used in Wisconsin would have been a 38% reduction for no size limit and a 16 February-20 June closed season. With a 10-inch size limit and a 20 June opening, 56% of the harvest would have been illegal. With no size limit and a 1 May opening date, which most closely approximates the regulation in northern Wisconsin in recent years, 98.7%

of the harvest would have been legal, while with a 10-inch size limit and a 1 May opening date, 71% of the harvest would have been legal (Fig. 10).

With no closed season and a 10-inch size limit the 15-year harvest would have been reduced 27%, while with a 12-inch limit it would have been reduced 57% (Fig. 11). Figure 11 can be used to estimate the percent that would have been illegal with various slot-length limits. For example a 12- to 15-inch slot-length limit would have reduced the harvest 30%.

Bag Limits

As with northern pike, a bag limit of 5 has been in effect for largemouth bass on other lakes for over 30 years. A daily bag limit of 5 largemouth bass would have reduced the harvest by 2.5%, while a daily limit of 2 fish would have reduced the mean annual harvest by 13.2% and a limit of 1 fish, by 32% (Fig. 12). A bag limit of 5 would have affected the catch of only 1.1% of all anglers catching bass (Table 2), while a limit of 1 would have affected the catch of 28% of all anglers catching bass.

Population Density and Sizes Harvested

A major concern with liberalized bass regulations is a possible decline in abundance of all sizes and a decline in the harvest, especially in the numbers of larger fish harvested. Throughout the entire 15-year study all sizes of bass were well represented in the harvest (Fig. 13). The number of larger bass (16 inches or larger) harvested totaled 577 for an average of 38/year, varying from 13 in 1965 to 56 in 1968.

The number of fish 16 inches and larger in the population, based on estimates from 1959 through 1970 (except 1962 and 1963), varied from 79 in 1970 to 235 in 1961. From 1965 to 1970 there was a steady decline in abundance from 206 to 79 fish (Fig. 14). Population estimates of all bass 8 inches and larger from 1959 to 1970 averaged 7.2/acre (8.1 lb/acre), varied from 3.9/acre (4.4 lb/acre) in 1970 to 10.6/acre (9.7 lb/acre) in 1967, and declined steadily from 1967 to the low level of 1970.

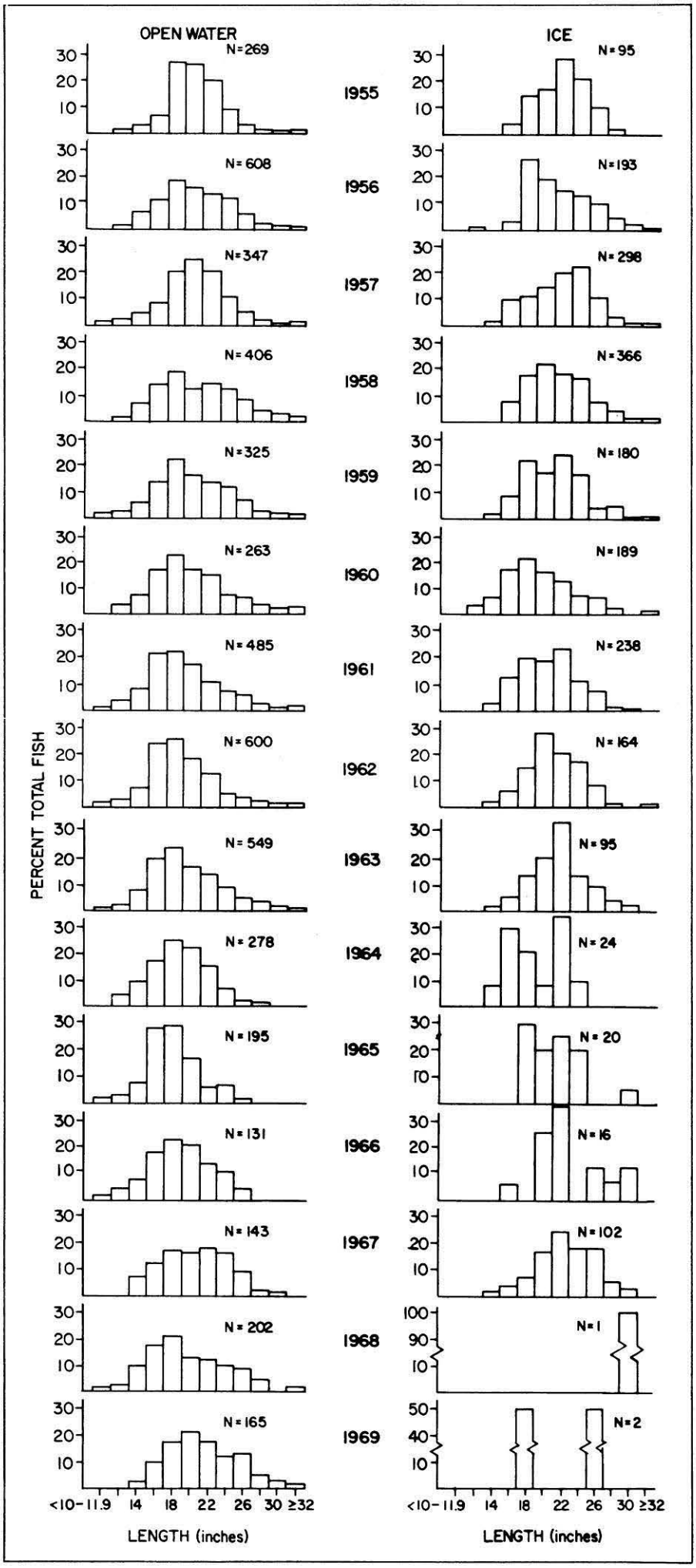

FIGURE 9. *Length-frequency distribution of angler harvest of native northern pike in Murphy Flowage during open water and ice fishing seasons, 1955-62.*

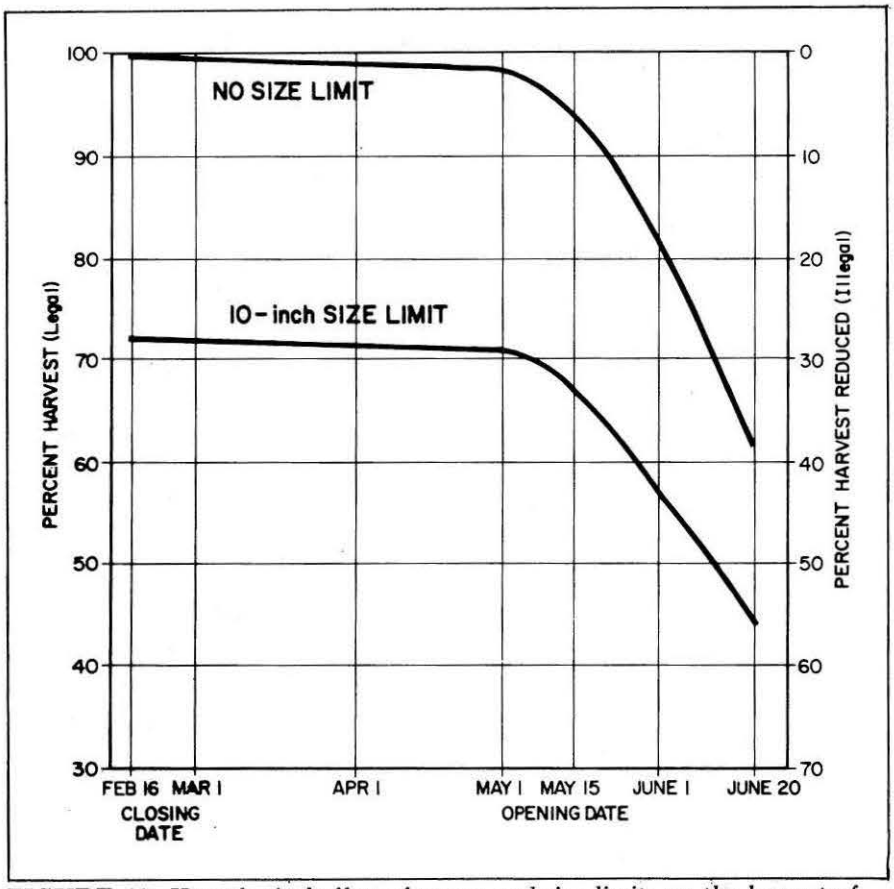

FIGURE 10. *Hypothetical effect of season and size limits on the harvest of largemouth bass in Murphy Flowage, 1955-64 (N=5,142). The curve is fitted to the cumulative 10-year weighted mean catch for each time period.*

The variations in harvest from 1964 to 1969 and the decline in abundance from 1967 to 1970 appear to be the direct or indirect result of management techniques tested rather than the result of liberalized regulations. Large numbers of northern pike stocked in December 1963 resulted in a drastic decline in the harvest of native northern pike from 1964 to 1969 (Snow 1978*b*). For unknown reasons the harvest of bass of all sizes also declined in 1964 and 1965.

The decline in abundance of bass from 1968 to 1970 was directly related to winter drawdowns in 1967, 1968, and 1969 which resulted in a decline in aquatic vegetation (Beard 1973) and a change in the main food item of bass from crayfish to bluegills (Snow 1971). These changes, especially the decline in crayfish which was the main food item for bass, were the probable cause of the much larger harvest of all sizes of bass in 1968.

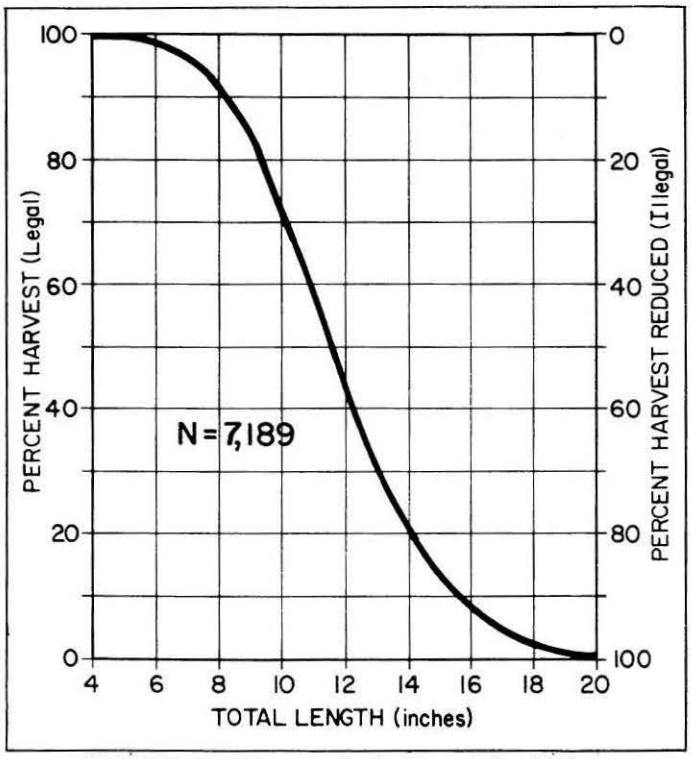

FIGURE 11. *Hypothetical effect of size limits on the catch of largemouth bass in Murphy Flowage, 1955-69. Open water and ice fishing seasons are combined (only 103 fish were taken ice fishing) (N=7,189).*

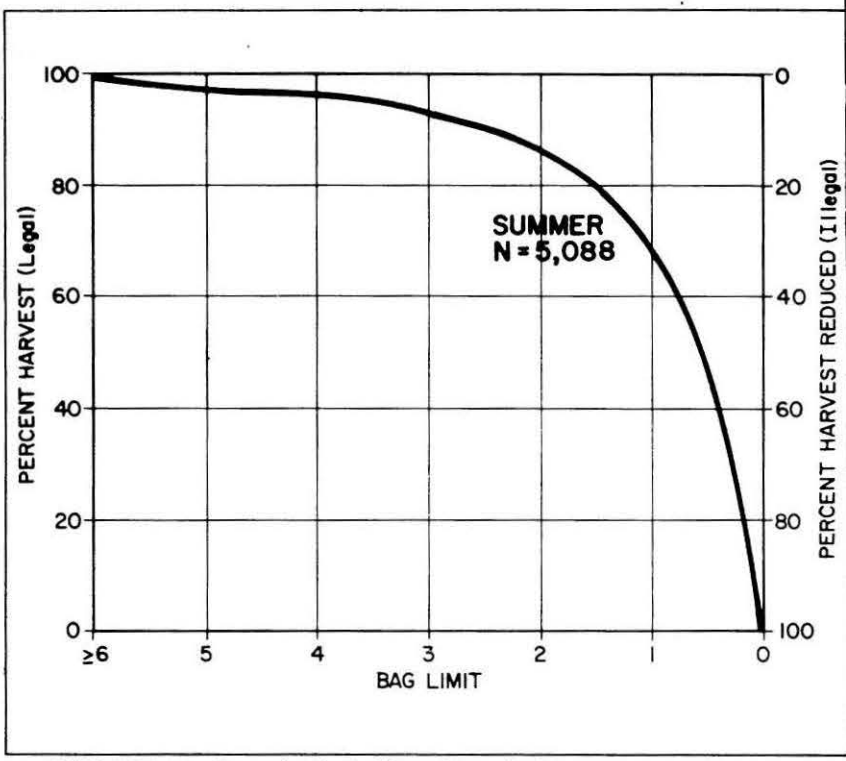

FIGURE 12. *Hypothetical effect of bag limits on the harvest of largemouth bass in Murphy Flowage, 1955-64.*

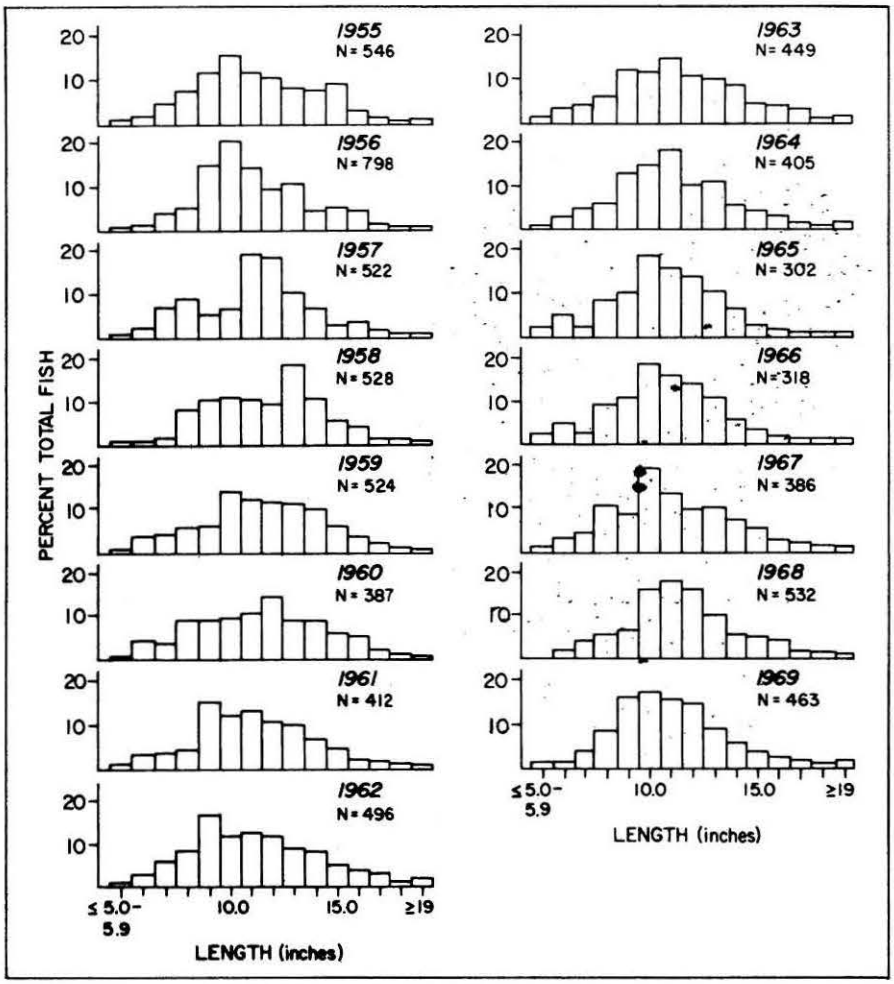

FIGURE 13. *Length-frequency distribution of the largemouth bass harvest in Murphy Flowage during open water seasons, 1955-69. (Only 1.4% of the total 15-year harvest was taken during ice fishing seasons.)*

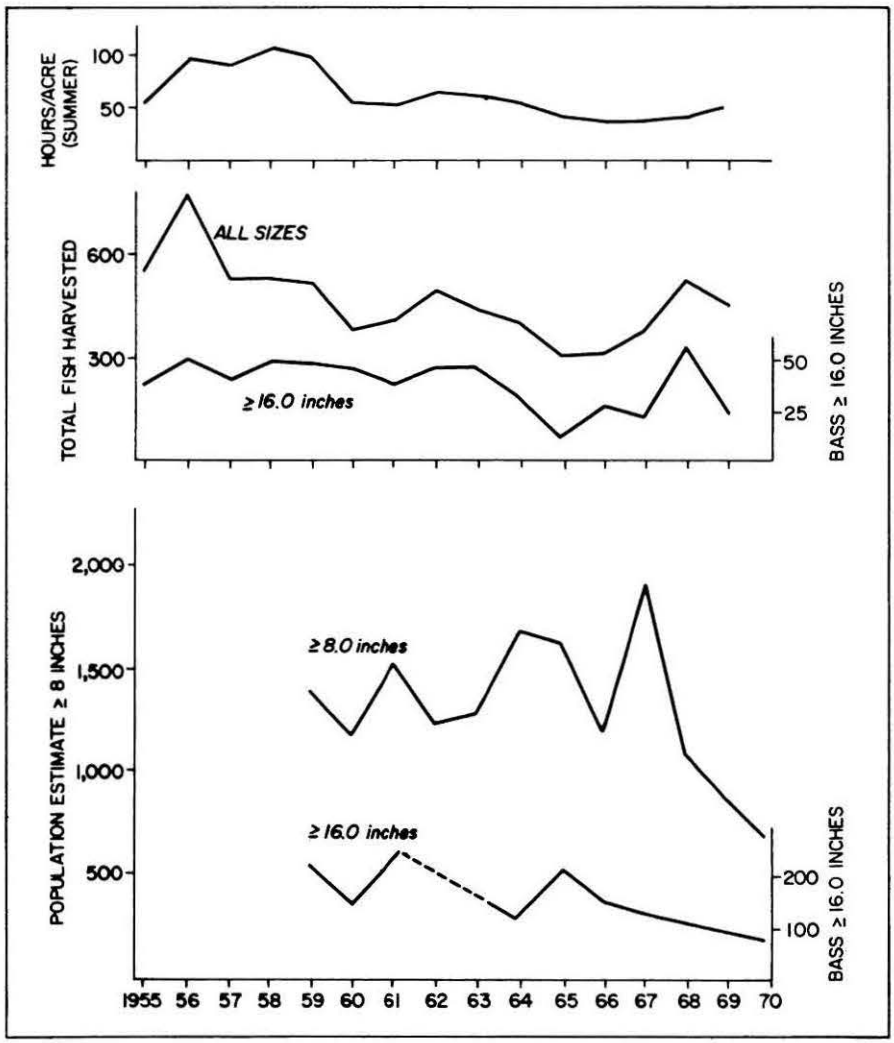

FIGURE 14. *Total pressure and harvest of largemouth bass 16 inches and larger and all sizes, 1955-69, and estimated abundance of largemouth bass in Murphy Flowage 8 and 16 inches and larger, 1959-70. (No estimates were made of bass 16 inches and larger in 1962 and 1963.)*

DISCUSSION AND CONCLUSIONS

The results presented here considered the proportion of the observed harvest that could not have been legally taken under various bag, season, and size limitations. This was done on a proforma basis as no comparison study of harvest under these restrictions was made. It can be questioned whether or not these results actually represent results that would have been obtained with regulations in Murphy Flowage, since the existence of restrictions could affect the harvest in ways that could not be evaluated by this method. In other waters additional factors could further affect results that might be realized. However, this evaluation of the Murphy Flowage results yields the best known guidelines for the application of regulations to other Wisconsin waters.

EVALUATION IN MURPHY FLOWAGE

Several parameters were considered in evaluating the effects of unrestricted fishing in Murphy Flowage. Exploitation rates for most species in Murphy Flowage were usually quite low and except in a few years for game fish, losses of fish by angling (exploitation) were a relatively small portion of total mortality (Snow 1978*a*).

Northern pike were exploited at levels of 45-50% the 1st 4 years of liberalized fishing and 25-30% the next 5 years, yet during this time the population density increased steadily (Snow 1978*b*). During the last 6 years of study exploitation rates varied from 3 to 11% and the population density, after reaching a peak following experimental stocking in the 9th year, declined to lower levels the last 4 years.

Exploitation rates for largemouth bass averaged 28% (20-33%) the first 9 years, declined to an average of 17% (14-20%) the next 4 years, then reached a high of 45% in each of the last 2 years after a winter drawdown. Population density of bass was quite stable until the drawdown when the abundance of all sizes over 8 inches declined to the lowest level during the study (Fig. 14).

Another important consideration is the decline in angling quality of bluegills, pumpkinseeds, and black crappies the 1st 2-3 years of study. For example, more bluegills over 8 inches total length were taken by anglers during the 1st 2 years than in all the remaining years combined. Lack of recruitment into the larger sizes was attributed to increases in abundance of smaller bluegills and declining growth which began before liberalized regulations started (Snow 1974, 1978*a*). The estimated number of bluegills over 8 inches from 1955 to 1958 was 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 account for a relatively small portion of the total; the remaining were lost to natural mortality.

The species composition and relative abundance of all species was remarkably stable through the 15 years of study (Snow 1978*a*). For example, bluegills dominated the population and harvest at all times. In contrast to this the harvest in Escanaba Lake (Kempinger et al. 1975) was dominated by 4 different species at various times during a 24-year period. Conclusions from Escanaba Lake, where liberalized regulations were in effect and methods were identical to those used in Murphy Flowage, indicated that the liberalized angling regulations had no detrimental effect on the fish population during the 1st 17 years (a 22-inch limit on northern pike was implemented in the 18th year).

In Murphy Flowage fishing pressure, harvest, and exploitation varied considerably under the liberalized regulations. However, the different management techniques used during the last 10 years appeared to have a greater impact on the population and harvest than the liberalized regulations alone during the 1st 5 years of study. Based on these comparisions, it is unlikely that the increased harvest and exploitation related to liberalized regulations resulted in a decline in the abundance of fish or the availability of desirable fish for the angler. The unrestricted fishing allowed a higher harvest for more anglers than would otherwise have been possible in Murphy Flowage.

COMPARISON WITH OTHER WATERS

Bag Limits

Based on comparison of the results from Murphy Flowage, the present daily bag limits in effect in Wisconsin — 50 panfish in aggregate (except rock bass) and 5 of each species of game fish — probably have little effect on the harvest. With the possible exception of small ponds (Smith et al. 1975) the results of other studies indicate that bag limits have little effect on the harvest (Churchill 1957, Kempinger et al. 1975, Redmond 1974, Powell 1975, Schneider and Lockwood 1979). There is little supportive data for bag limits, yet 47 of the 48 contiguous states have had them in effect for 1 or more species in recent years (Fox 1975). One purpose served by a daily bag limit is to keep the more proficient anglers from taking excessive numbers of fish. The bag limit also serves as a goal to aim at, the achievement of which has a positive psychological effect on the angler. For these reasons daily bag limits do have some value; however, their application from a biological viewpoint in the management of panfish, northern pike, and largemouth bass populations is questionable.

Season Limits

Very little fishing occurred in Murphy Flowage and many other waters in March, April, and the 1st few days of May, which has been the normal closed season in Wisconsin (Churchill 1957, Snow 1978*a*) and in Michigan lakes studied by Schneider and Lockwood (1979). Therefore an open season during this time period would have little effect on the harvest. However, an opening date later than the 1st part of May could have a marked effect on the harvest, especially for largemouth bass. In Murphy Flowage 50% of the total annual harvest of largemouth bass was taken by the end of June and 38% by 20 June. Studies in 3 Michigan lakes have shown similar results; 21-51% were caught by 24 June (Schneider and Lockwood 1979). If overexploitation is a problem, more restrictive seasons might be utilized to reduce the harvest. In contrast to northern pike which are more readily caught in winter, the highest catch rate per hour for largemouth bass is during May and June (Snow 1978*a*). Any later opening date than that presently in effect (1st Saturday in May) would eliminate bass fishing during the most successful time of the year. Unless it can be demonstrated that the harvest is ex-

cessive and that overfishing has occurred, more restrictive seasons for bass are not recommended. Based on results in Murphy Flowage, a year-round open season would have resulted in very little change in the harvest compared to the present closed season (1 March - 1st Saturday of May) for both northern pike and largemouth bass.

Size Limits

Size limits have received the most attention and probably have the most potential alone or in combination with season limits for managing fish populations. Many studies have been conducted to evaluate size limits of both northern pike and largemouth bass; however, largemouth bass has received the most attention because of its wide geographical distribution in the United States and high public interest.

Because of differences in species composition, growth, food supply, mortality, and size and age structure of populations it is difficult to evaluate the effects of size limits in different waters. The use of size limits in some waters was judged successful while in other waters it was unsuccessful.

An 18-inch limit on northern pike in Bucks Lake, Wisconsin (Snow and Beard 1972) and a 22-inch limit in Escanaba Lake (Kempinger and Carline 1978) were both ineffective management techniques. A significant reduction in harvest was noted in both Bucks Lake and Escanaba Lake. Both length limits protected a high proportion of the northern pike populations through Age IV despite much slower growth in Bucks Lake. The 18-inch limit covered several northwestern Wisconsin counties and was not implemented as a specific management proposal for Bucks Lake. The 22-inch limit in Escanaba Lake was established to determine if the harvest of large northern pike could be increased by applying a length limit. The technique was at least in part unsuccessful in achieving the desired goal because of reduced growth rates after the size limits became effective. The population density of fish below the size limit increased dramatically in Escanaba Lake and decreased steadily in Bucks Lake, while the numbers above the size limit generally increased in both studies. Changes in the populations in both lakes were attributed more to differences and trends in size and age structure and forage abundance at the time the limits were implemented than to the size limits themselves.

A comparison of size limits in several Michigan lakes (Schneider and Lockwood 1979) yielded limited success in that the results were in line with a model developed by Latta (1972). However, the results in some lakes were similar to results in Bucks Lake and Escanaba Lake in that the catches were highest with a 14-inch limit or no limit and markedly lower with a 20- or 24-inch limit. The degree of response was related to growth. In faster growing populations, which had few pike less than 20 inches, the 20-inch limit did not change harvest appreciably and more growth potential was realized. Schneider and Lockwood (1979) also reported that catch statistics gave no indication that pike populations were affected by size limits, that in 2 lakes with mark and recapture studies there was no clear-cut response in the pike populations, and that growth of pike could not be linked to size limits.

Studies in Wisconsin (Snow unpubl.) and other regions (Bregazzi and Kennedy 1980, Kipling and Frost 1970, Casselman 1975) indicate that the normal male:female sex ratio of northern pike populations is 1:1. Females normally grow faster and attain larger sizes than males. Unless males have a higher mortality rate than females as suggested by Kipling and Frost (1970), any size limit could affect the sex ratio of the population (Fig. 8). This should be considered in the potential use of size limits as a management tool.

The comparisons of size limits for northern pike cover populations with different characteristics, some of which may be comparable to the hypothetical results obtained in Murphy Flowage, and others which are obviously not comparable. Bucks Lake, which had a very slow-growing, dense, and stable population and one in which pike was the only predator, is not comparable to Murphy Flowage. Escanaba Lake had a low density, unstable population with varying growth. The pike population expanded, fluctuated, and declined over a period of 15-17 years. The dominant predator was the walleye while smallmouth bass, largemouth bass, and muskellunge were present, sometimes in relatively large numbers, over the years. Despite these differences the hypothetical effects of size limits in Murphy Flowage were similar to the Escanaba Lake data after the 22-inch limit was terminated and the unlimited regulations were reestablished. The Murphy Flowage results for northern pike suggest that the effects of the hypothetical regulations on populations would be most comparable to stable populations with pike as a major predator with average to moderate growth rates.

A 12-inch size limit on largemouth bass was successful in the recovery of an overharvested bass population in Pony Express Lake (Ming and McDannold 1975). These authors referred to another study using a 12-inch size limit in a similar Missouri lake which was unsuccessful (Choate 1970). They further pointed out that the 2 studies were conducted in similar lakes and under similar conditions with the only difference being the relative numbers of bass in the population. Both bass populations were overharvested; however, the lake where the size limit was successful had a relatively abundant year class under 12 inches while the other lake did not.

Schneider and Lockwood (1979) compared length limit results for largemouth bass from 6 Michigan lakes against a 10-inch limit for periods of 5-7 years. The results roughly followed the prediction of Latta's model (1974) and were also comparable to the hypothetical results from Murphy Flowage for all sizes except a reduction to an 8-inch limit. For example, Latta predicted a 75% decrease in harvest with a 14-inch limit while the decrease in Murphy Flowage was 72%. A decrease from a 10-inch to an 8-inch limit resulted in a predicted increase in harvest of 50% for Latta's model and 26% for the Murphy Flowage results. These comparisons suggest that the hypothetical results for largemouth bass from Murphy Flowage are comparable to many lakes in the North Central States.

A relatively new concept concerning size limits is the use of slot-length limits (Anderson 1976, Anderson and Weithman 1978). The idea is to protect the predator population while growth is at a maximum, and at the same time control forage species and provide quality fishing for predator species. The sizes protected depend on growth rates and possible forage abundance. A 12- to 15-inch slot-length limit has been tested for largemouth bass in Philips Lake, Missouri. Results were more favorable than a minimum length of 12 inches alone (Anderson 1976). This size range (12-15 inches) includes 30% of the total harvest for bass in Murphy Flowage, while an 18- to 22-inch slot-length limit for northern pike, for example, would include 40% of the northern pike harvest. The effectiveness of slot-length limit needs further evaluation, but theoretically it has more potential for effective management than a normal size limit.

An important consideration in the use of slot-length limits for bass is the presence or absence of crayfish. Results from Murphy Flowage (Snow 1971) indicate that when crayfish are present bass prefer crayfish to small forage fish. Therefore if crayfish are abundant, a slot-length limit may not achieve 1 of its intended purposes, that of controlling forage species.

The use of any type of size limit, especially slot-length limits, involves catch and release fishing and consequently hooking mortality. The extent of hooking mortality is dependent on many factors, such as angler experience, bait used, hook type and size, etc. Hooking mortality as high as 38% has been reported for bass (Rutledge and Pritchard 1977) and 5% for northern pike (Wydoski 1977). Although more research is needed, the limited information to date suggests that hooking mortality can result in rather high mortality of released fish and should be considered when size and length limits are proposed.

These studies as well as several others (Serns 1981, Fox 1975, Anderson and Weithman 1978, Kempinger and Carline 1978) point to the need for knowledge of the size and age structures of the population, including recruitment, mortality rates, growth rate, and angling pressure, before a decision to implement a size limit is made. To be effective, size limits may have to be increased, decreased, or removed as the situation changes over a period of time. A size limit which is an effective management tool in 1 lake may have an adverse effect in another lake. For this reason fish populations ideally should be managed on a lake-by-lake basis. Since this is not practical, and based on the results from Murphy Flowage and comparisons made in this paper, the present no-size-limit regulation provides the most effective use of largemouth bass and northern pike populations in the majority of Wisconsin waters.

SUMMARY AND MANAGEMENT IMPLICATIONS

This paper estimates the hypothetical effects of bag, season, and size limits on the harvest of panfish, northern pike, and largemouth bass in Murphy Flowage. There were no actual limits in effect except hours of fishing and methods of catching (hook and line). Complete angling and harvest records were obtained through a compulsory registration-type creel census for 15 years. The observed harvest under these conditions and the hypothetical reduction in harvest with various regulations constitute the essence of this report. The information presented should be useful to fish managers to estimate the effects of proposed regulation changes for fish populations with similar characteristics in other waters.

A daily bag limit of 25 bluegills would have affected the catch of 8.9% of all anglers catching bluegills in summer and 30.0% in winter. With this bag limit, the harvest would have been reduced 12.1% in summer and 30.2% in winter. The present bag limits in effect in Wisconsin would have had little effect on the observed harvest. A 50-fish daily bag limit on panfish in aggregate would have reduced the observed harvest 2.9% in summer and 13.8% in winter (i.e., 97.1% of the harvest would have been legal in summer, and 86.2% in winter). A 5-fish daily limit on game fish would have reduced the northern pike harvest 0.6% in summer and 1.5% in winter, while the harvest of largemouth bass would have been reduced 2.5% in summer; there would have been no effect in winter.

A year-round open season would have had very little effect on the harvest. A maximum of 7% of the northern pike and 4% of the largemouth bass were taken during the normal closed season, 1 March to the 1st Saturday of May. A later opening date could have a marked effect on the harvest, especially on largemouth bass since 50% of the annual harvest was taken by the end of June.

Size limits alone or in combination with later opening dates have the most potential for reducing the observed harvest. An 18-inch limit on northern pike would have reduced its harvest 22% and a 10-inch limit on largemouth bass would have reduced its harvest 27%. A slot-length limit of 18-22 inches on northern pike would have reduced the harvest 40% while a 12- to 15-inch limit on largemouth bass would have reduced bass harvest 30%.

Some important considerations in the use of length limits are: (1) the possibility of losses of the protected sizes due to hooking mortality, (2) alteration of the sex ratio of northern pike populations, (3) lack of control of forage species by bass if crayfish are present, and (4) the possibility of reduced growth rates.

This study as well as several others point to the need for knowledge of the size and age structure of a fish population before a decision to implement a different regulation is made. To be effective, size limits, for example, may have to be increased, decreased, or removed as the situation changes over a period of time. A regulation which is an effective management tool in one lake may have an adverse effect in another lake. For this reason fish populations ideally should be managed on a lake-by-lake basis.

Other in-depth exploitation and mortality studies in Murphy Flowage have shown that the difference in total mortality with fishing and without fishing is relatively small. Therefore, I concluded that liberalized regulations within the range of fishing pressure and exploitation experienced in Murphy Flowage were not a detriment to the fish populations, and that the hypothetical results of various regulations closely approximated those that would have been obtained with normal regulations.

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