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Evaluation of Largemouth Bass Slot Length Limits in Two Small South Dakota Impoundments

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ABSTRACT - A largemouth bass (*Micropterus salmoides*) slot length limit of 300-380 mm was imposed in 1989 on two small (<20 ha) impoundments in Jones County, South Dakota. Fish population characteristics were assessed through 1993. In Murdo Lake, size structure of largemouth bass increased throughout the study period. Largemouth bass incremental growth and condition increased, while relative abundance of stock length (≥ 200 mm) fish decreased. Proportional stock density (PSD) of bluegills (*Lepomis macrochirus*), black crappies (*Pomoxis nigromaculatus*), and yellow perch (*Perca flavescens*) declined throughout the study. In Knox Pond, a slot length limit was simulated by manual removal of 200-300 mm largemouth bass that had been collected by electrofishing. The size structure of the largemouth bass population substantially increased. Largemouth bass PSD increased from 0 in 1989 to 47 in 1992. In 1993, largemouth bass longer than 380 mm were captured for the first time. Incremental growth and body condition of stock length largemouth bass increased, while relative abundance and biomass declined. Largemouth bass slot length limits appear to be viable tools for improving the size structure of largemouth bass populations in small South Dakota impoundments.

Key words: Largemouth bass, *Micropterus salmoides*, harvest regulations, slot length limit

Length limits are effective tools for largemouth bass (*Micropterus salmoides*) management (Redmond 1986). Slot length limits, designed to protect fish within a specified length range, have been applied to high-density, slow-growing largemouth bass populations to increase the size structure of largemouth bass (Gabelhouse 1984a, Eder 1984). Slot length limits are designed to allow harvest of small fish, protect fish within the slot length range, and increase the abundance of larger fish, thereby retaining or creating a balanced population (Anderson 1976).

The harvest of largemouth bass below the protected slot is important to the success of the length-limit regulation. The removal of small largemouth bass allows increased growth of the remaining largemouth bass in the population. Therefore, the success of a 300-380 mm slot length limit depends on the willingness of anglers to harvest fish less than quality length (300 mm). Eder (1984) found that a harvest rate of 19 largemouth bass/ha/year that were shorter than 300 mm successfully increased bass population size structure in a Missouri impoundment. Gabelhouse (1984a) found that inadequate removal of largemouth bass less than 300 mm caused a slot length limit to function much like a 380-mm minimum length limit in a Kansas impoundment, thereby slowing growth of smaller largemouth bass. The number of small largemouth bass to be harvested depends on the density of small fish remaining in the system, and only surplus bass should be removed (Hackney 1978, Gabelhouse 1987).

The implementation of largemouth bass slot length limits can also have effects on panfish communities due to changes in largemouth bass density and size structure. Eder (1984) found that after implementation of a largemouth bass slot length limit, bluegill (*Lepomis macrochirus*) growth, condition, and size structure decreased. Decreases in density of small largemouth bass can reduce predation on small bluegills, causing increased competition and reduced growth among the remaining bluegills. Conversely, Gabelhouse (1987) found that the density of 200 mm and longer bluegills actually increased after implementation of a largemouth bass slot length limit in a Kansas pond. Apparently, the initial density of small largemouth bass was sufficiently high to overly restrict bluegill recruitment and to compete with bluegills for an invertebrate prey base. Thus, effects of largemouth bass slot length limits on panfish communities are not fully understood. The objectives of this study were to evaluate slot length limits as a tool to improve largemouth bass size structure in small South Dakota impoundments, and to document the effects on panfish communities.

STUDY SITES

Murdo Lake, an 18.2-ha public impoundment located in Jones County, South Dakota, had an approximate aquatic macrophyte coverage of 50% and contained a moderately dense, slow-growing largemouth bass population in 1989 (Lindgren 1991). Macrophyte coverage was approximately 50% during subsequent sampling years. The fish community consisted primarily of largemouth bass, bluegill, black crappie (*Pomoxis nigromaculatus*), and yellow perch (*Perca flavescens*). Northern pike (*Esox lucius*) and channel catfish (*Ictalurus punctatus*) were also present in the lake at low densities. Water conductivity ranged from 1488 to 2850 µS/cm over the course of this study.

Knox Pond, a 2.4-ha private impoundment also located in Jones County, had an aquatic macrophyte coverage of 60% and contained a high-density, slow-growing largemouth bass population in 1989 (Lindgren 1991). Little fishing occurred at Knox Pond. Black bullhead (*Ameiurus melas*) was the only other fish species present in Knox Pond; abundance was low and most bullheads were longer than 300 mm (Saffel et al. 1990). Water conductivity ranged from 480 to 740 µS/cm at Knox Pond.

A 300-380 mm slot length limit was imposed on both Murdo Lake and Knox Pond in the spring of 1989. A public meeting was held at Murdo, SD, and the consensus was to improve largemouth bass size structure in Murdo Lake, recognizing that panfish size structure might decline.

METHODS

Murdo Lake

Largemouth bass in Murdo Lake were sampled with spring, nighttime electrofishing. Three different electrofishing boats were used at various times. One had a 5000-W, three-phase, 220-V generator; one had a 5000-W, single-phase, 220-V generator; and the other had a 7500-W, single-phase, 220-V generator. Most fish were collected with AC, although DC was occasionally used. Panfish were sampled using 8-10 trap (modified fyke) nets (13-mm bar mesh) set during spring at standard locations. All fish were measured to the nearest mm, and scales and weight (g) were taken from at least five fish per centimeter length group, when available. Size structure, relative abundance, condition, and growth were determined for largemouth bass, bluegill, black crappie, and yellow perch from 1989 through 1993, with 1989 considered the pre-treatment data set. Proportional stock density (PSD), relative stock density of preferred length fish (RSD-P), and relative stock density of quality to preferred length fish (RSD Q-P) were determined for largemouth bass, bluegill, black crappie, and yellow perch based on length categorizations defined by Gabelhouse (1984b). Minimum stock (S), quality (Q), and preferred (P) lengths are 20, 30, and 38 cm for largemouth bass; 8, 15, and 20 cm for bluegill; and 13, 20, and 25 cm for both black crappie and yellow perch. Catch per effort (CPE; number of S-length fish per hour of electrofishing) was calculated as a measure of relative abundance for largemouth bass in Murdo Lake. Catch per effort for panfish was measured as number of S-length fish captured per trap net night. Relative weight (*Wr*) was used as a measure of condition for largemouth bass, bluegill, black crappie, and yellow perch. We used standard weight equations reported by Murphy et al. (1991). Mean *Wr* values were calculated for stock to quality (S-Q), quality to preferred (Q-P), and P length fish. Murphy et al. (1991) recommended calculation of *Wr* for specific length groups to eliminate masking of variability of *Wr* across length.

Growth was determined from back-calculated length at age estimated from scales using the DISBCAL software and a digitizing pad (Frie 1982). We used standard intercepts ("a" values) recommended by Carlander (1982).

Electrofishing CPE data for largemouth bass and *Wr* data for all fish species were tested for normality using the Shapiro-Wilk statistic and inspection of normal probability plots (UNIVARIATE procedure, SAS Institute 1985). Largemouth bass electrofishing CPE data were log-transformed (base 10) to better meet the assumptions of normality. Statistical tests of largemouth bass CPE were done using log-transformed (base 10) data; however, we reported non-transformed means and 95% confidence intervals in this study for clarity. We used analysis of variance and the least significant difference (LSD) multiple range test to detect differences in mean *Wr* among years for all fish species (SAS Institute 1985). We used means and 95% confidence intervals to report trends in CPE data for bluegill, black crappie, and yellow perch. An alpha level of 0.05 was considered significant for all statistical analyses.

Population and biomass estimates for stock-length largemouth bass were determined in 1989 (Lindgren and Willis 1990) using Petersen (single census) mark-recapture techniques (Ricker 1975). Population estimates were made with angling as the marking technique and electrofishing as the recapture technique. A random stratified creel survey was conducted from April through September of 1989, 1990, and 1992 (Neumann et al. 1993) using the standard creel survey analysis program from the South Dakota Department of Game, Fish and Parks (Jacobson and Lucchesi 1989).

Knox Pond

Size structure, condition, and growth of largemouth bass were determined using the same methods as for Murdo Lake. Catch per effort for largemouth bass was determined based on catch during the first complete lap around the margin of the pond using DC electrofishing. Additional largemouth bass were captured to obtain reliable sample sizes for size structure estimates using AC electrofishing because of higher CPE with high-output, pulsed AC electrofishing (Hill and Willis, In Press a). Population size and biomass estimates for S-length and longer fish were determined from 1989 through 1992 using the same methods as for Murdo Lake. Each year after the population estimate was made at Knox Pond, we manually removed approximately 40% of the population estimate; only 200-300 mm largemouth bass were removed. Fish within and longer than the protected slot were returned to the pond.

RESULTS

Murdo Lake

The pre-treatment population size and biomass estimates indicated that Murdo Lake had a moderate-density, slow-growing largemouth bass population in 1989, when density and biomass estimates were 84 bass/ha and 34 kg/ha. Largemouth bass density in Murdo Lake was lower than the average density (410 fish/ha) reported for 10 small South Dakota impoundments (Hill and Willis, In Press b). However, the 1989 biomass estimate was similar to the mean largemouth bass biomass estimate of 43 kg/ha reported by Hackney (1978) for 38 small midwestern impoundments. Largemouth bass PSD in 1989 was 23, and was lower than the recommended PSD range of 40-70 (Gabelhouse 1984b; Willis et al. 1993) for balanced populations. Growth rates were close to or slightly slower than the average reported for largemouth bass in 25 South Dakota waters (Table 1).

Largemouth bass size structure increased following the implementation of the 300-380 mm slot length limit. The PSD increased from 23 to 43 from 1989 to 1993, reaching a high of 57 in 1992 (Fig. 1). The RSD-P values increased from 13 in 1989

Table 1. Mean total length (mm) at annulus for largemouth bass collected from Murdo Lake and Knox Pond in 1989. Sample sizes are in parentheses. Largemouth bass as old as age 9 were collected from Murdo Lake; we included only fish up to age 4 for comparison purposes because age-4 fish were the oldest collected at Knox Pond. The statewide mean was obtained from Willis, Milewski, and Guy (1990).

	Length at annulus							
	1		2		3		4	
Murdo Lake	93	(119)	175	(94)	248	(53)	307	(42)
Knox Pond	81	(109)	154	(109)	208	(73)	240	(41)
Statewide mean	91		184		251		305	

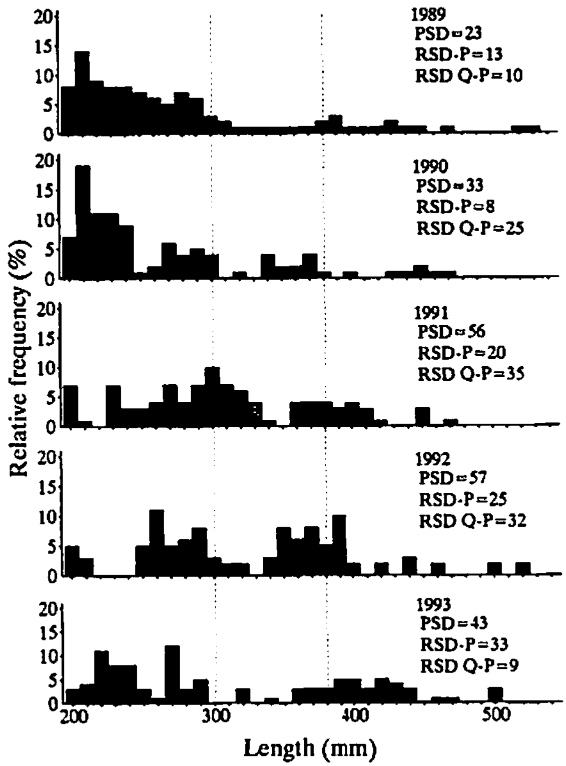

Figure 1. Length frequency, proportional stock density (PSD), relative stock density of preferred-length (RSD-P) and quality-to preferred-length (RSD Q-P) largemouth bass collected from Murdo Lake, South Dakota, 1989-1993 (1989, N=173; 1990, N=79; 1991, N=72; 1992, N=63; 1993, N=75).

to 33 in 1993. The RSD Q-P values increased throughout the study period, but then decreased to pre-treatment levels in 1993 when a strong 1991 year class was recruited to stock length (Fig. 2). Increases in growth of largemouth bass were not observed until 1992, when the length increment added (plotted as a function of initial length) increased above pretreatment levels (Fig. 3), which reflects growth during the 1991 growing season. Although we were initially uncertain of the reliability of CPE data given the various types of electrofishing boats used during the study, there was a significant decline in largemouth bass CPE throughout the study period (r^2=0.78, P=0.05) (Table 2).

There were significant differences among years for mean *Wr* of S-Q, Q-P, and P length largemouth bass (Table 2). Relative weight of S-Q length largemouth bass

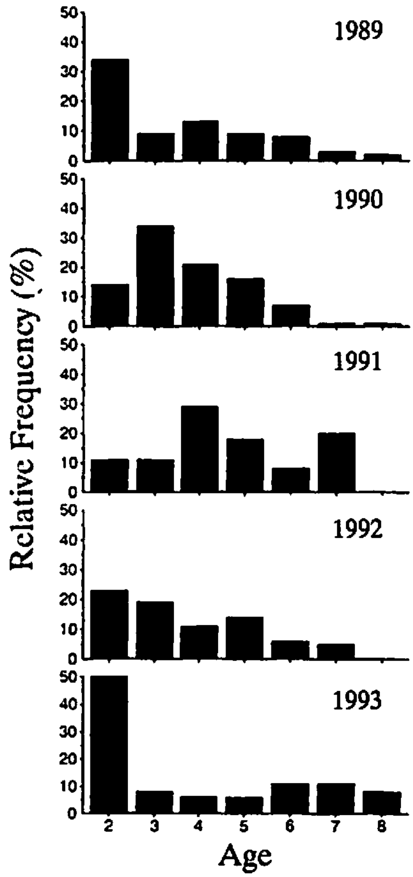

Figure 2. Age structure of stock length (≥ 200 mm) largemouth bass collected by spring electrofishing from Murdo Lake, South Dakota, 1989-1993.

during 1991, 1992, and 1993 was significantly greater than 1989 and 1990. Relative weight of Q-P length fish was significantly greater during 1992 and 1993 compared to 1989. Relative weight of P length fish in 1993 was significantly greater than in 1989.

Mean *Wr* of stock length largemouth bass and bass PSD were initially below the recommended target ranges (Murphy et al. 1991) for balanced populations (Fig. 4). By the end of the study, both *Wr* and PSD had increased to levels at or near the targets.

The panfish community also changed after implementation of the slot length limit. The PSD of bluegills, yellow perch, and black crappies declined throughout the study (Table 2). The RSD-P of bluegills increased from 0 in 1989 to 19 in 1992.

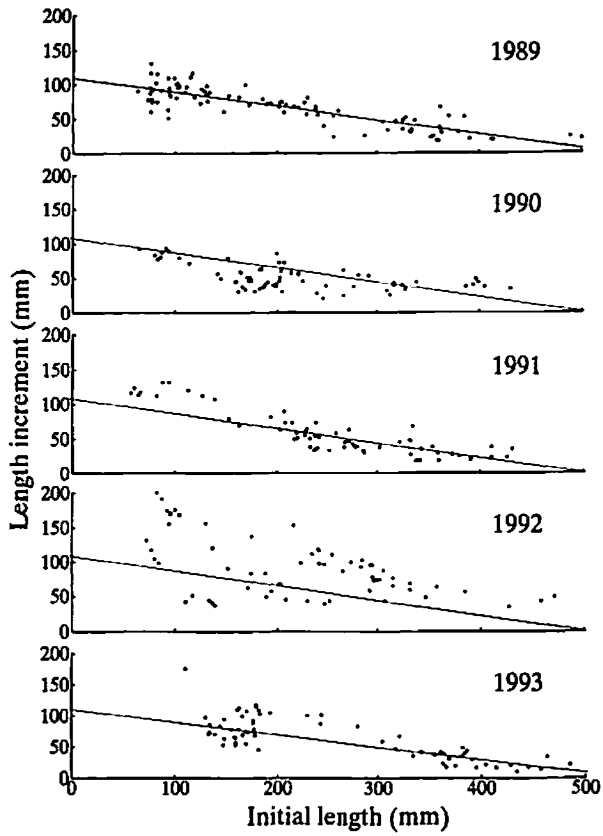

Figure 3. Incremental growth (length increment added during the last complete growing season plotted as a function of initial length at the beginning of that growing season) for stock length (≥ 200 mm) largemouth bass collected from Murdo Lake, South Dakota, 1989-1993. The original regression line for 1989 is repeated each year as a reference to pretreatment conditions.

The RSD-P of black crappies increased from 0 in 1989 to 52 in 1992. Both species showed declines in RSD-P in 1993. No changes in RSD-P of yellow perch were observed. Catch rates of stock length bluegills increased from 1989 to 1992 and then declined in 1993 (Table 2). Catch per effort of stock length yellow perch increased from 1989 to 1993, while CPE of black crappies decreased.

There were significant differences among years for mean *Wr* of S-Q, Q-P, and P length bluegills, black crappies, and yellow perch (Table 2). Mean *Wr* of S-Q length bluegills was greater in 1993 than 1990 and 1991. Mean *Wr* of Q-P length bluegills was greater in 1992 and 1993 than any other year. Mean *Wr* of P length

Table 2. Changes in population parameters for fish species collected from Murdo Lake and Knox Pond, South Dakota, 1989-1993. PSD = proportional stock density, RSD-P = relative stock density of preferred-length fish, CPE = catch per effort (number of stock-length fish/hour of electrofishing for largemouth bass and number per trap net night for panfish), *Wr* = relative weight, S = stock length, Q = quality length, P = preferred length. Values in parentheses are 95% confidence intervals.

Site	Species	Parameter	1989	1990	1991	1992	1993
Murdo Lake	Largemouth bass	PSD	23 (±9)	33 (±12)	56 (±13)	57 (±14)	43 (±13)
		RSD-P	13 (±5)	8 (±6)	20 (±11)	25 (±12)	33 (±12)
		CPE	19.9 (±5.5)	32.9 (±16.6)	12.1 (±4.1)	8.8 (±7.6)	6.1 (±2.7)
		S-Q *Wr*	88 (±3)	88 (±3)	104 (±4)	114 (±3)	107 (±4)
		Q-P *Wr*	97 (±5)	99 (±5)	100 (±6)	110 (±5)	110 (±7)
		P-M *Wr*	103 (±4)	102 (±7)	89 (±6)	103 (±6)	110 (±3)
	Bluegill	PSD	100	83 (±7)	64 (±9)	41 (±10)	64 (±9)
		RSD-P	0	0	0	19 (±4)	9 (±5)
		CPE	3.1 (±6.4)	12.7 (±5.9)	13.7 (±10.9)	53.5 (±38.3)	14.8 (±8.7)
		S-Q *Wr*		97 (±9)	102 (±6)	107 (±6)	113 (±6)
		Q-P *Wr*	88 (±4)	95 (±3)	100 (±4)	117 (±3)	119 (±4)
		P-M *Wr*				120 (±3)	113 (±5)

Table 2. Continued.

Site	Species	Parameter	1989	1990	1991	1992	1993
	Black crappie	PSD	100	82 (±8)	84 (±7)	71 (±9)	10 (±10)
		RSD-P	0	1 (±1)	1 (±1)	52 (±6)	8 (±4)
		CPE	4.9 (±7.3)	109.3 (±39.2)	43.6(±25.3)	23.3 (±13.0)	20.3 (±21.0)
		S-Q *Wr*		101 (±3)	93 (±5)	94 (±4)	108 (±4)
		Q-P *Wr*	85 (±3)	89 (±2)	89 (±2)	91 (±4)	78 (±10)
		P-M *Wr*	79 (±7)	79 (±4)	80 (±6)	92 (±3)	84 (±4)
	Yellow perch	PSD	24 (±9)	4 (±4)	2 (±5)	6 (±5)	6 (±5)
		RSD-P	1 (±1)	0	0	0	3 (±2)
		CPE	38.0 (±38.8)	24.0 (±10.4)	21.2(±12.8)	67.4 (±49.0)	71.5 (±72.6)
		S-Q *Wr*	70 (±4)	77 (±3)	80 (±4)	86 (±3)	102 (±3)
		Q-P *Wr*	68 (±3)	71 (±6)	79 (±10)	90 (±5)	79 (±4)
		P-M *Wr*	67 (±8)				85 (±5)
Knox Pond	Largemouth bass	PSD	0	0	3 (±4)	47 (±12)	22 (±10)
		RSD-P	0	0	0	0	9 (±7)
		CPE[a]	306	130	8	29	26
		S-Q *Wr*	77 (±2)	87 (±3)	82 (±4)	109 (±4)	100 (±3)
		Q-P *Wr*			73 (±12)	106 (±4)	91 (±4)
		P-M *Wr*					

[a] Confidence interval could not be calculated because effort was one single lap of the pond

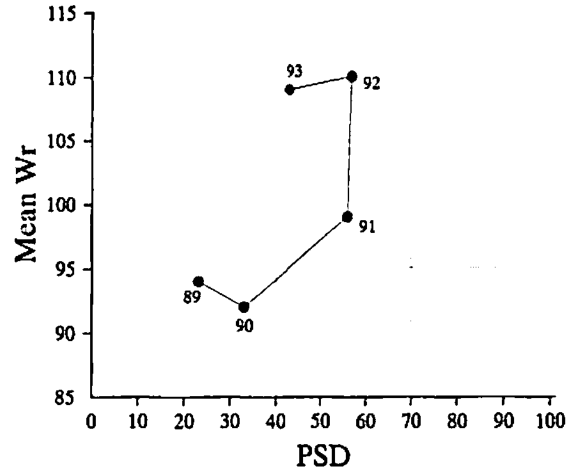

Figure 4. Mean relative weight (*Wr*) and proportional stock density (PSD) of largemouth bass collected from 1989 through 1993 in Murdo Lake, South Dakota. The box bordered by dashed lines represents accepted target ranges for *Wr* and PSD in balanced largemouth bass populations.

bluegills declined from 1992 to 1993. Mean *Wr* of S-Q length black crappies was greater in 1993 than 1990, 1991, and 1992. Mean *Wr* of Q-P length black crappies declined in 1993. Mean *Wr* of S-Q length yellow perch was greater in 1992 and 1993 than any other year. Mean *Wr* of Q-P length fish increased until 1992, but then slightly declined in 1993. Mean *Wr* of P length yellow perch was higher in 1993 than 1989.

The 1989, 1990, and 1992 creel surveys documented 99, 25, and 326 angler hr/ha, respectively (Table 3). Harvest rates for the corresponding years were 59.6, 6.8, and 24.2 S-length largemouth bass/ha. Interview data indicated that anglers harvested 95% and 85% of largemouth bass less than 300 mm long caught in 1989 and 1990, respectively. Due to an oversight, such data were not collected during the 1992 creel survey.

Table 3. Total fishing effort and harvest statistics for largemouth bass at Murdo Lake based on random-stratified creel surveys conducted from April through September 1989, 1990, and1992. Two standard errors are in parentheses.

	Year					
	1989		1990		1992	
Angler hr	1810	(394)	433	(176)	5919	(945)
Angler days	691	(206)	147	(65)	1930	(419)
Angler hr/ha	99	(22)	25	(10)	326	(52)
Total harvest	1087	(1294)	124	(122)	441	(301)
Harvest/ha	59.60	(71.00)	6.80	(6.70)	24.18	(16.50)
Harvest/hr	0.60	(0.70)	0.29	(0.26)	0.07	(0.05)

Knox Pond

The pre-treatment population size and biomass estimates indicated that Knox Pond had a high-density, slow growing largemouth bass population in 1989, when density and biomass estimates were 887 bass/ha and 112 kg/ha. Hackney (1978) reported that the highest density he observed in 38 small midwestern impoundments was 112 kg/ha. The density estimate in Knox Pond ranked second out of 10 small South Dakota impoundments (range 22 to 1481 fish/ha) studied by Hill and Willis (In Press b). The PSD of largemouth bass in Knox Pond was 0 in 1989. Growth rates were slower than the average reported for largemouth bass in 25 South Dakota waters (Table 1).

The size structure of largemouth bass in Knox Pond substantially increased from 1989 to 1993. The PSD increased from 0 in 1989 to 22 in 1993, reaching a high of 47 in 1992 (Fig. 5). The RSD-P increased to 9 in 1993, the first year that largemouth bass longer than 380 mm were collected. Removal of 200-300 mm largemouth bass resulted in declines in population size and biomass (Table 4).

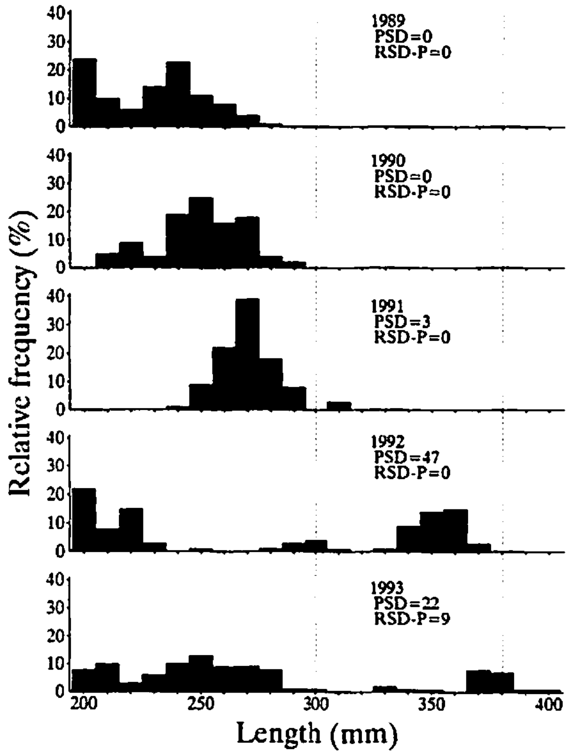

Figure 5. Length frequency, proportional stock density (PSD), relative stock density of preferred (RSD-P) length largemouth bass from Knox Pond, South Dakota, 1989-1993 (1989, N=221; 1990, N=92; 1991, N=77; 1992, N=78; 1993, N=89).

Table 4. Population estimates, biomass estimates, and removal rates of 200-300 mm largemouth bass from Knox Pond, South Dakota 1989 through 1992 (95% confidence intervals for population size and biomass estimates are in parentheses).

Year	Population estimate		Biomass (kg/ha)		Removal (number)	Percent removed
1989	1153	(214)	112	(21)	549	48
1990	458	(90)	52	(10)	183	40
1991	167	(34)	16	(3)	66	40
1992	191	(39)	31	(6)	41	21

Removal rates of 200-300 mm largemouth bass ranged from 48% in 1989 to 21% in 1992. In 1992, only 21% of the total sample of 200 mm and longer largemouth bass was within the length range of 200-300 mm. Initial increases in growth of largemouth bass were observed in 1991, when the length increment added (plotted as a function of initial) length increased above pre-treatment levels (Fig. 6). Growth remained higher than pre-treatment levels from 1991 through 1993. Catch rates (Table 2) and population estimates (Table 4) for stock length largemouth bass decreased throughout the study, likely due to manual removal of largemouth bass.

Mean *Wr* values were significantly different among years for S-Q (F=56.94, P=0.0001) and Q (F=21.21, P=0.0001) length largemouth bass (Table 2). Mean *Wr* of S-Q length largemouth bass was highest in 1992 and 1993. Mean *Wr* of Q length largemouth bass was highest in 1992 and 1993. Mean *Wr* of stock length and longer largemouth bass and PSD increased to levels in or near the recommended target ranges for largemouth bass (Fig. 7).

Few black bullheads were observed at Knox Pond throughout the study, and those few typically exceeded 30 cm. We observed no increase in black bullhead recruitment throughout the course of this evaluation.

DISCUSSION

Slot length limits appear to be viable fisheries management options to improve size structure of largemouth bass in small South Dakota impoundments. In Murdo Lake and Knox Pond, the slot length limit increased the size structure, growth, and condition of largemouth bass. While we did not rely on CPE estimates as an index to density because different electrofishing gears were used to sample largemouth bass, the decline in CPE was consistent with other observed parameters (i.e., increased growth and condition also reflected reduced density). Increases in growth of largemouth bass were observed during this study, although increments added by bass in Murdo Lake in 1993 were only slightly larger than for the pre-treatment data set. Even if no change in growth had occurred, we believe that the

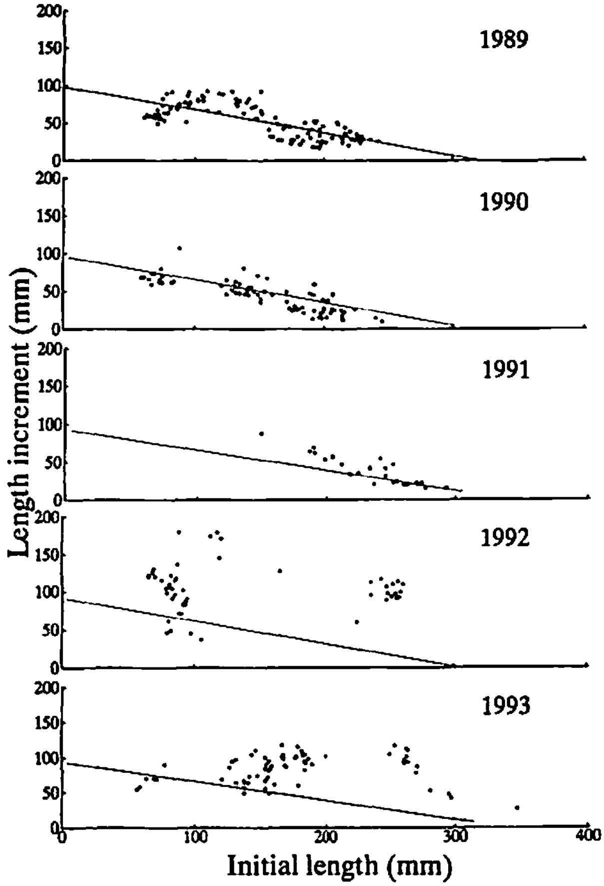

Figure 6. Incremental growth of stock length (≥ 200 mm) largemouth bass collected from Knox Pond, South Dakota, 1989 - 1993. The original regression line for 1989 is repeated each year as a reference to pretreatment conditions.

slot limit regulation would still have been successful if largemouth bass size structure increased. We observed increases in largemouth bass size structure and condition, with no slowing of growth. In Murdo Lake and Knox Pond, mean *Wr* and PSD values increased to levels in or near the accepted *Wr* (95-105; Murphy et al. 1991) and PSD (40-70; Gabelhouse 1984b, Willis et al. 1993) target ranges for largemouth bass in balanced fish populations. In 1992 and 1993, PSD values for largemouth bass in Murdo Lake fell within the desired target range; *Wr* values were higher than the target range. Angler harvest of sub-slot largemouth bass apparently

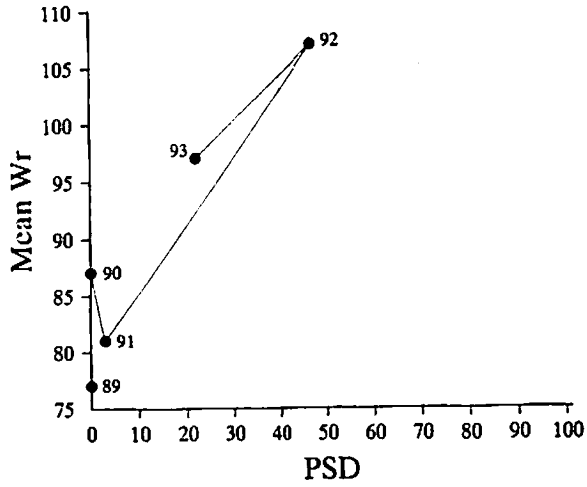

Figure 7. Mean relative weight (*Wr*) and proportional stock density (PSD) for largemouth bass collected from 1989 through 1993 in Knox Pond, South Dakota. The box bordered by dashedlines represents accepted target ranges for *Wr* and PSD inbalanced largemouth bass populations.

was sufficient to increase growth and condition of largemouth bass, resulting in improved size structure. The RSD Q-P for largemouth bass in Murdo Lake increased from 13 in 1989 to 32 in 1992, but declined to 9 in 1993. This decline was probably due to the recruitment of the strong 1991 year class to the S-Q length category in 1993. In Murdo Lake, angler willingness to harvest 200-300 mm largemouth bass was high; anglers harvested 95% of sub-slot fish they caught in 1989, and 85% in 1990. In 1992, anglers harvested 24.2 largemouth bass/ha; 66% of these fish were shorter than 300 mm (16.0/ha). In 1992, angling effort was 326 angler hr/ha as compared to 99 and 25 angler hr/ha in 1989 and 1990. Gabelhouse (1984b) found that anglers harvested a mean of 50% of the sub-slot fish that were caught in five Kansas Lakes, and in some instances angler harvest was inadequate to improve largemouth bass size structure.

In Knox Pond, removal rates of 21-48% of the largemouth bass population estimate were sufficient to allow substantial increases in the number of 300-380 mm bass. Largemouth bass PSD and RSD-P in Knox Pond substantially increased throughout this study. Removal of surplus sub-slot length largemouth bass from Knox Pond decreased bass density, thereby improving growth, condition, and size structure.

Gabelhouse (1987) reported that a 300-380 mm largemouth bass slot length limit imposed on a Kansas pond decreased the catch rates and biomass of 200-300 mm largemouth bass. He also found that catch rates and estimated numbers of 300-380 mm largemouth bass increased substantially from pre-treatment levels. Only modest increases in growth and condition occurred, probably because an inadequate number of small largemouth bass were removed. Eder (1984) found that a 300-380 mm largemouth bass slot length limit in Watkins Mill Lake, Missouri, substantially increased size structure and growth. Prather (1990) reported that a 300-406 mm largemouth bass slot length limit substantially reduced the numbers of largemouth bass less then 300 mm in the population, and after four years, the density of 300-mm largemouth bass reached pre-treatment levels. Abundance and growth of largemouth bass greater than 300 mm increased. Summers (1988) found increases in PSD and density of largemouth bass longer than 380 mm after implementation of a 300-380 mm slot length limit on Arbuckle Reservoir, Oklahoma.

Water levels in Murdo Lake increased approximately 2-3 m in 1992 following a drought in 1989-1991. One may speculate that drought years may have caused reductions in largemouth bass recruitment, thereby reducing largemouth bass density, and that subsequent increases in size structure, growth, and condition would actually be due to unstable recruitment rather than the slot limit regulation. Although we had no formal quantitative evaluation of vegetation cover, aquatic macrophyte coverage remained at approximately 50% during each sampling year. Moreover, largemouth bass age structure was actually quite stable throughout the study period (Fig. 2). In fact, the 1993 age structure indicated that a strong largemouth bass year class was recruited in 1991 (age 2), supporting the argument that reductions in water levels during drought years did not affect largemouth bass recruitment. Thus, increases in size structure, growth, and condition likely were due to the effects of the slot limit regulation.

Changes in the panfish community also occurred after implementation of the slot length limit on Murdo Lake. In general, PSD of bluegills, black crappies, and yellow perch declined throughout the study. In 1989, PSD of both bluegills and black crappies was 100, higher than the accepted PSD ranges for balanced populations (bluegill 20-60 and black crappie 30-60; Willis et al. 1993). The density of 300-mm and shorter largemouth bass prior to implementation of the slot length limit in 1989 apparently was high enough to restrict recruitment of smaller bluegills and black crappies to quality length. Presumably, the reduction in densities of 300-mm and shorter largemouth bass in Murdo Lake after the slot limit was imposed allowed higher recruitment of the remaining bluegills and black crappies into S-Q length range, thus reducing PSD of bluegills and black crappies to levels at or near the accepted PSD target ranges by 1992. Bluegill PSD remained near the accepted range in 1993, but PSD of black crappies declined. The decline in black crappie PSD in 1993 may have been due to high angler harvest of stock length black crappies in 1992; harvest of black crappies in 1992 was 122 fish/ha (Neumann et al. 1993).

Bluegill and black crappie RSD-P peaked in 1992. The PSD of yellow perch was below the accepted PSD range (30 - 60) for balanced yellow perch populations throughout this study (Willis et al. 1993). In general, lower yellow perch size structure can be expected in small South Dakota impoundments containing largemouth bass and multiple-species panfish communities rather than only largemouth bass and yellow perch (Guy and Willis 1991). The RSD-P of bluegill and black crappie in Murdo Lake decreased in 1993, but still remained greater than pre-treatment levels. In some cases, a slot length limit on largemouth bass can result in improved bluegill populations (Gabelhouse 1987), while in others, bluegill quality has declined after the slot limit was imposed (Eder 1984). Eder (1984) reported a decline in bluegill size structure, growth, and condition after a slot limit was imposed, presumably because lowered densities of small largemouth bass did not prey as effectively upon young bluegills. However, Gabelhouse (1987) documented a situation where the density of 200-mm and longer bluegills increased after the largemouth bass were managed with a slot length limit. Apparently, the density of the overpopulated largemouth bass was so high before the slot regulation was imposed that small bass actually competed with bluegills for food. In Murdo Lake, larger sizes of panfish may have been competing with small bass for food. In Murdo Lake, condition of bluegill, black crappie, and yellow perch showed increases, with corresponding declines in PSD, and increases in catch rates (bluegill and yellow perch). Increases in *Wr* of panfish in Murdo Lake may be due to increases in water levels in 1992 which may have increased the food supply for panfish due to the newly-flooded terrestrial vegetation. However, there were no consistent changes in growth for any of the three panfish species in Murdo Lake (Neumann et al. 1993).

Black bullhead recruitment did not increase at Knox Pond, even given the decrease in largemouth bass density. Saffel et. al. (1990) reported an inverse relationship between size structure of largemouth bass and black bullheads in small South Dakota impoundments.

MANAGEMENT IMPLICATIONS

Slot length limits appear to be viable tools for management of largemouth bass populations in small South Dakota impoundments. During this study, largemouth bass relative abundance declined with subsequent increases in size structure, growth, and condition of largemouth bass. The slot length limit successfully accomplished the management objectives of increasing PSD and *Wr* into or near the accepted target ranges for largemouth bass in balanced fish populations. Willingness of anglers to harvest sub-slot length largemouth bass was important. Anglers at Murdo Lake harvested approximately 90% of the 200-300-mm largemouth bass that were caught.

Overabundant small largemouth bass are often a problem in small ponds across the midwest, and selective harvest by anglers can improve the size structure of the bass population. In Knox Pond, 200-300-mm largemouth bass were manually removed at rates of 21-48%/year. These removal rates were adequate to increase the quality of the largemouth bass population. South Dakota ponds are often managed only with largemouth bass (Willis, Beem, and Hanten 1990). We believe that pond owners can improve size structure of crowded largemouth bass populations through harvest of S-Q bass and release of Q-P bass, as we simulated in Knox Pond.

Effects of the slot regulation on panfish populations were not as easy to discern. Bluegill and black crappie PSD values declined from 100 in 1989 to levels in 1992 that were at or near the accepted PSD ranges for balanced bluegill and black crappie populations. Yellow perch PSD was lower than the accepted PSD range for balanced yellow perch populations throughout this study. In general, condition of panfish increased throughout this study. High water levels in 1992 and 1993 may have increased the food supply for panfish. The effects of a slot length limit on panfish in a multiple-species panfish community apparently are variable, and likely depend on the density of largemouth bass remaining in an impoundment.

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