Largemouth Bass Fishery Responses to Length Limits

By Gene R. Wilde

Length limits are among the most widely used and valuable tools available to fishery managers for the protection and manipulation of freshwater game fishes. Although various length limits have been used to manage freshwater fishes (Brousseau and Armstrong 1987), most are of two types: minimum-length limits and slot-length limits. *Minimum-length limits* require that fish below some minimum size be released, while allowing fish larger than the minimum to be harvested. Minimum-length limits are recommended for fish populations characterized by low rates of recruitment and natural mortality, good growth rates, and high fishing mortality (Anderson 1980; Novinger 1984). In the early part of this century, managers used minimum-length limits to protect fish until reproductive size was reached (Anderson 1980; Redmond 1986), but this practice fell into disuse during the 1940s and 1950s (Redmond 1986). Minimum-length limits again gained popularity with fishery managers in the 1960s and 1970s, based on the theoretical results of Ricker (1945) and Saila (1957) who suggested a greater biomass of fish could be produced and harvested by allowing small, rapidly growing fish to reach a larger size. Minimum-length limits currently are used to protect the reproductive potential of fish populations, prevent overexploitation, increase angler catch rates but not necessarily harvest rates (Novinger 1984), create trophy fisheries, and promote predation on prey fishes (Noble and Jones 1993; Ross 1997).

Anderson (1974, 1976) first proposed and used slot-length limits. Fish within a protected-size range, or *slot*, must be released; fish smaller than the lower limit of the protected-size range or larger than the upper limit may be kept by anglers. This length limit is similar to that proposed by Martin (1958), who suggested that largemouth bass (*Micropterus salmoides*) between 1 lb and 2 lbs not be harvested to promote predation on sunfish (*Lepomis* spp). Slot-length limits are recommended for populations with high recruitment and low growth rates, and are expected to result in increased numbers of protected-size fish, promote growth of smaller fish by reducing intraspecific competition through angler harvest, and increase production of trophy fish (Anderson 1976). By protecting largemouth bass or other predatory fish until they are large enough to become effective predators on sunfish and shad

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(*Dorosoma* spp.), slot-length limits also offer a means for manipulating prey fish populations (Anderson 1976).

Reviews of largemouth bass length limits (Bonneau and Conley 1974; Fox 1975; Redmond 1986) generally emphasize the historical development and use of length limits and which states have implemented or plan to implement different length limits. Descriptions of largemouth bass fishery responses to length limits are based on case histories chosen to illustrate "typical" responses. This approach is severely limited, as Novinger (1984) noted. Without a careful counting of, or comparison between, length limits that worked and those that did not, it is impossible to objectively determine which fishery responses can be attributed to various types of length limits.

Among the stated goals of minimum-length and slot-length limits are increasing the relative or absolute abundance of large (reproductively mature or trophy) fish and increasing angler catch and harvest. Based on these goals, I constructed a number of testable hypotheses that allow an objective evaluation of the effects of length limits on largemouth bass fisheries:

H1: the relative abundance of stock-size ($\geq$ 8-in long) fish that are also $\geq$ 12 in long (proportional stock density, PSD) will increase;

H2: the relative abundance of stock-size fish that are also $\geq$ 15 in long (relative stock density, RSD) will increase;

H3: abundance of largemouth bass (population size) will increase;

H4: weight of fish harvested by anglers will increase;

H5: number of fish harvested by anglers will increase;

H6: angler catch rates for largemouth bass, whether harvested or released, will increase.

In each case, the null hypothesis (H0) states that no increase will occur. Note that H1–H6 are one-sided hypotheses, the length limit is expected to result in a positive response (reject H0) or not (accept H0).

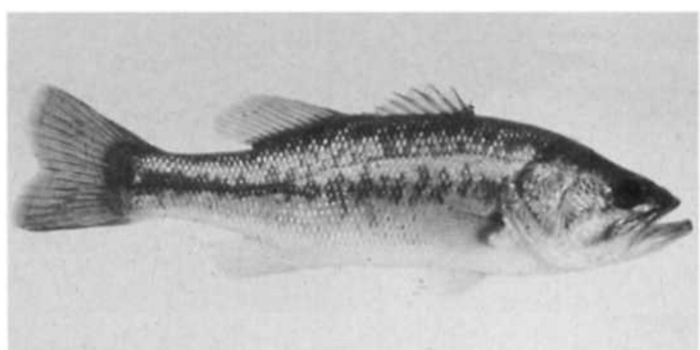
In this paper, I review the published literature and unpublished Federal Aid Program reports, theses, and dissertations that evaluate largemouth bass fishery responses to minimum-length and slot-length limits. I use quantitative information from these studies to test hypotheses regarding responses of largemouth bass fisheries to length limits. I present the results of my review, comment on the effectiveness of length limits, and provide suggestions for future research.

Methods

I set two criteria for inclusion of length limit evaluations in this study. Studies were required to present data for periods both before and after implementation of the length limit and to present information that relates to at least one of the six hypotheses listed above. I did not include data from small, private impoundments (e.g., Novinger 1990) because the potential for controlling access and, consequently, fishing pressure might allow a different response to length limits than is realized in public impoundments. Also, I did not include data for newly impounded reservoirs (e.g., Goddard and Redmond 1986) because it is not possible to distinguish fishery responses to length limits from natural population development and maturation. For purposes of this study, data collected during the year in which the length limit was implemented are considered pretreatment data.

The most frequently reported data were measures of largemouth bass abundance (electrofishing catch rates, mark-and-recapture population estimates, rotenone samples), PSD, and RSD. Creel data, numbers and weight of fish harvested, and angler catch rates were reported less commonly. RSD generally was presented as RSD-15, although a few studies presented RSD-14 (Duval 1991; Follis et al. 1991) or RSD-16 (Chapman et al. 1991); I made no distinction on this basis.

I calculated unweighted means for pretreatment (length limit) and post-treatment data. For a given variable, if the post-treatment mean was greater than the pretreatment mean, consistent with hypotheses H1–H6, I concluded that the response to the length limit in that lake was positive (designated by "+" in Table 1). If the post-treatment mean was less than ("-" in Table 1) or equal to ("=" in Table 1) the pretreatment mean, I concluded there was no response to the length limit. If a minimum-length or slot-length limit had no consistent effect on largemouth bass fisheries, I would expect to observe approximately equal numbers of positive ("+") and nonpositive (sum of "-" and "=") signs for each variable. I used a one-tailed binomial test (Siegel 1956) to determine whether a significant excess of positive signs existed. ◆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Estimates of largemouth bass (*Micropterus salmoides*) abundance made, using electrofishing or other sampling techniques, before and after implementation of a length limit may allow a manager to anticipate changes in angler catch or harvest rates.

My methods of summarizing results from individual studies and using binomial tests to assess hypotheses H1–H6 are conservative but allow the available data to be presented in a standardized form. For each study, numerical data from several years, before and after implementation of a length limit, are reduced to a single qualitative datum, and only the proportions of fisheries that showed a response, rather than the magnitude of

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Table1 summarizes largemouth bass population responses to minimum- and slot-length limits. Positive responses to length limits, in which the post-treatment mean is greater than the pretreatment mean, are indicated by a "+"; cases in which there was no difference between pre- and post-treatment means are indicated by "="; and negative responses are indicated by a "-". Also note: min. = minimum.

State	Lake	Surface area (acres)	Length limit	PSD	RSD	Catch per effort	Angler harvest (weight)	Angler harvest (number)	Angler catch rate	Years of data	Source
CA	Merle Collins		12-in min.				-		+	12	Pelzman (1979)
GA	West Point	25,889	16-in min.	-	-		+			10	Ager (1991)
KS	Butler		15-in min.	+	+	+				5	Mosher (1986)
KS	Chase		15-in min.	-	-	+				3	Mosher (1986)
KS	Clark		15-in min.	+	-	+				5	Mosher (1986)
KS	Leavenworth		15-in min.	+	+	+				4	Mosher (1986)
KS	Melvern	7,000	15-in min.	-	+	-				4	Gablehouse (1980)
KS	Milford	16,020	15-in min.	+	-	-				4	Gablehouse (1980)
KS	Wilson		15-in min.	+	=	+				3	Mosher (1986)
KY	Barkley	57,920	12-in min.			-	-	-		9	Crowell (1984)
KY	Barren River	10,000	12-in min.			+	+	+		13	Crowell (1984)
KY	Beaver	170	12-in min.			+	+	+		9	Crowell (1984)
KY	Cave Run	8,270	12-in min.			+	-	-		8	Crowell (1984)
KY	Cave Run	8,270	15-in min.	+	+	+	-	-		7	Buynak et al. (1991)
KY	Grayson	1,510	12-in min.			+	-	-		10	Crowell (1984)
KY	Grayson	1,510	15-in min.	+	-	+	-	-	+	9	Kornman (1990)
KY	Malone	692	12-in min.			+	-	-		14	Crowell (1984)
KY	Smoky Valley	36	20-in min.	+	-	+	-	-	-	11	Kornman (1994)
MO	Deer Ridge	48	12-in min.	+	+					5	Farabee (1974)
MO	Jamesport	30	12-in min.	-	-	+				6	Rasmussen and Michaelson (1974)
MO	Limpp	20	12-in min.	-	-	+				7	Rasmussen and Michaelson (1974)
MO	Pomme de Terre	7,800	15-in min.	+		+			+	7	Dent (1986)
MO	Table Rock	43,100	15-in min.			+	-	-		11	Novinger (1987)
MO	Wakonda	75	12-in min.	+	+					5	Farabee (1974)
MO	Worth County	20	12-in min.	+	-	+				6	Rasmussen and Michaelson (1974)
MS	Mary Crawford		12-in min.	-						4	Nazary (1982)
NC	Badin	5,928	14-in min.	-						3	Van Horn et al. (1986)
NC	Brandt	790	14-in min.	-		+				3	Van Horn et al. (1986)
NC	Chowan River	23,712	14-in min.	+						3	Van Horn et al. (1986)
NC	Gaston	21,736	14-in min.	-						3	Van Horn et al. (1986)
NC	Higgins	282	18-in min.	-	-	-				4	Van Horn et al. (1983)
NC	Norman	32,110	14-in min.	+		-				3	Van Horn et al. (1986)
NC	Oak Hollow	815	14-in min.	-		-				3	Van Horn et al. (1986)
NC	Tar River	1,087	14-in min.	+		+				3	Van Horn et al. (1986)
NC	Tom-A-Lex	785	18-in min.	+	+	-				4	Van Horn et al. (1983)
NC	Tillery	5,187	18-in min.	+	+	-				4	Van Horn et al. (1983)
OH	Knox	494	16-in min.			+		-	+	5	Hall et al. (1986)
OK	Arbuckle	2,347	14-in min.	-						4	Mense (1981)
OK	Birch	1,136	14-in min.	-		+				3	Hamilton (1984)
OK	Tenkiller	12,634	14-in min.	+						4	Mense (1981)
SD	Alvin	100	15-in min.	-	+	-				3	Lindgren and Willis (1990)
TX	Brownwood	7,301	14-in min.	+	+	+		-	+	3	Follis et al. (1991)
TX	Coleman	1,998	14-in min.	+	+	-	+	+	=	3	Follis et al. (1991)
TX	Tradinghouse	1,986	16-in min.	+	+		-	-	+	3	Mitchell and Sellers (1991)
VA	Kerr	48,881	14-in min.	-	-					9	Duval (1991)
VA	Smith Mountain	20,607	14-in min.	+	+					9	Duval (1991)
WI	Browns	395	16-in min.	+	+	-		-	-	6	Mayers (1988)
WI	Pretty	64	16-in min.	+	+	-		-	+	6	Mayers (1988)
WI	Snowden	138	15-in min.	-		+		-	+	5	Schell (1987)
AZ	Alamo		12- to 16-in slot	-	+	+				5	Jacobson (1991)
DE	Andrews	18	12- to 15-in slot	+	+	-			-	5	Martin (1995)
DE	Derby Pond	23	15- to 18-in slot	+	-	+			-	5	Martin (1995)
FL	Stark	236	14- to 20-in slot	-	-	+		-	+	7	Porak et al. (1987)
KS	Atchinson		12- to 15-in slot	+	+	+				5	Mosher (1986)
KS	Barber (lower)		12- to 15-in slot	+	+					6	Mosher (1986)

Table 1 continued.

State	Lake	Surface area (acres)	Length limit	PSD	RSD	Catch per effort	Angler harvest (weight)	Angler harvest (number)	Angler catch rate	Years of data	Source
KS	Barber (upper)		12- to 15-in slot	+	+					3	Mosher (1986)
KS	Brown	62	12- to 15-in slot	-	+	+	-	-	-	6	Gablehouse (1984)
KS	Cowley	84	12- to 15-in slot	-	-	+	-	+	+	6	Gablehouse (1984)
KS	Crawford		12- to 15-in slot	+	+	+				7	Mosher (1986)
KS	Douglas		12- to 15-in slot	+	=	+				6	Mosher (1986)
KS	Jewell		12- to 15-in slot	+	+	-				5	Mosher (1986)
KS	Leavenworth		12- to 15-in slot	-	-	+				2	Mosher (1986)
KS	Lyon	135	12- to 15-in slot	+	-	+				8	Mosher (1986)
KS	McPherson	46	12- to 15-in slot	+	-	+	+	-	-	6	Gablehouse (1984)
KS	Montgomery	105	12- to 15-in slot	-	-	+	-	-	+	6	Gablehouse (1984)
KS	Nebo		12- to 15-in slot	-	+	-				4	Mosher (1986)
KS	Nemaha	248	12- to 15-in slot	+	-	+	+	-	-	6	Gablehouse (1984)
KS	Osage		12- to 15-in slot	+	-					7	Mosher (1986)
KS	Pottawatomie		12- to 15-in slot	+	+					6	Mosher (1986)
KS	Woodson		12- to 15-in slot	-	-	-				5	Mosher (1986)
KY	Elmer Davis	149	12- to 16-in slot	+	+	-				9	Prather (1990)
MO	Watkins Mill	100	12- to 15-in slot	+	+	+	-	-	-	7	Eder (1984)
MS	Barnett	33,000	15- to 20-in slot	+			+	+		4	Nazary (1982)
MS	Claude Bennett		11- to 15-in slot	-						4	Nazary (1982)
MS	Lamar		11- to 15-in slot	+						4	Nazary (1982)
MS	Mike Conner		11- to 15-in slot	+						4	Nazary (1982)
NC	Falls of the Neuse	12,864	12- to 16-in slot	+	+	+				5	Chapman et al. (1991)
NC	Sutton	1,099	12- to 16-in slot	-	+	+			+	5	Wynne et al. (1995)
NC	Tuckertown	2,529	12- to 16-in slot	+	+	-				4	Chapman et al. (1991)
OK	Arbuckle	2,347	12- to 15-in slot	+		+		-		8	Summers(1987, 1990)
OK	Birch	1,136	12- to 15-in slot	+		+	-	-	-	6	Hamilton (1984)
OK	Dripping Springs	1,050	14- to 21-in slot	+	+	+				9	Wright and Bowen (1990)
OK	Fuqua	1,482	14- to 22-in slot			+				4	Cofer (1995)
OK	Pine Creek	3,857	13- to 16-in slot	+		+				3	Harper and Routledge (1990)
OK	Tenkiller	12,900	13- to 16-in slot	+	+	+				6	Smith (1988)
SD	Knox	6	12- to 15-in slot	+	+	-		-		5	Neumann et al. (1994)
SD	Murdo	45	12- to 15-in slot	+	+	-		-		5	Neumann et al. (1994)
TX	Calaveras	3,458	14- to 18-in slot	+				-		5	Garrett (1983)
TX	Monticello	2,001	14- to 18-in slot	+		-				6	Dean et al. (1993)
WI	Beulah	835	12- to 16-in slot	-	+	+		-	+	6	Mayers (1988)
WI	Rockland	40	12- to 16-in slot	+	+	-		-	+	6	Mayers (1988)

(from page 15)

the response, are tested. Differences among studies in sample collection methods, sampling intensity, and experimental design (including the specific minimum-length or slot-length limit used) suggest the need for such an approach. My results are robust with respect to these differences and indicate whether consistent fishery responses occurred; however, they provide no estimate of the rate or magnitude of fishery responses to length limits.

Results

Summaries of 91 largemouth bass length limit evaluations are presented in Table 1. These summaries include data for 88 lakes (3 were evaluated for 2 different length limits each) in 16 states located across the United States but were concentrated in the Southeast and Midwest. The lakes ranged in surface area from 6 to 57,920 acres (median = 943 acres). Data presented in these studies spanned four decades, from the 1960s through the 1990s. Included are 49 evaluations of minimum-length limits and 42 of slot-length limits. Minimum-length limits were of 6 types: 12-in (n = 13), 14-in (n = 14), 15-in (n = 13), 16-in (n = 5), 18-in (n = 3), and 20-in (n = 1) minimum length. I evaluated 10 slot-length limits and found that the most commonly studied slot-length limit (23 of 42 studies) was a 12- to 15-in slot; seven studies evaluated a 12- to 16-in slot; and the remaining limits were represented by only 1–3 studies each.

Both PSD (24 of 40 lakes) and RSD (15 of 27 lakes) increased in most largemouth bass populations after implementation of minimum-length limits, but neither increase was significant (P = 0.078 and P = 0.319, respectively). Minimum-length limits did result in a significant increase in population size (24 of 36 lakes; P = 0.034). However, if evaluations of 12-in minimum length limits are omitted, there was still no significant increase in PSD (21 of 34 lakes;

$P = 0.115$) and RSD (13 of 22 lakes; $P = 0.143$) and largemouth bass population size no longer showed a significant increase (16 of 27 lakes; $P = 0.221$). Minimum-length limits failed to increase either numbers (an increase in 3 of 17 lakes) or weight (4 of 14 lakes) of largemouth bass harvested by anglers but did result in increased angler catch rates (8 of 11 lakes; $P = 0.033$).

minimum-length limits increase angler catch rates; whereas slot-length limits restructure largemouth bass populations. However, neither limit accomplishes both.

Slot-length limits resulted in increased largemouth bass PSD (30 of 41 studies; $P = 0.025$) and RSD (21 of 32 lakes; $P = 0.056$) as well as increased population size in 23 of 33 lakes ($P = 0.018$). Weight (3 of 8 lakes) and numbers (2 of 15 lakes) of largemouth bass harvested failed to increase under slot-length limits. I found no evident pattern in angler catch rates, which increased in less than half (6 of 13) of the lakes for which creel data were available.

Discussion

Minimum-length limits generally failed to achieve the goals stated for their use. There is no evidence of a consistent increase in the proportion of larger fish (H1, H2). Population size (H3) increased when 12-in minimum length limits were included in the analysis but not when they were excluded. Nor does any evidence exist of an increase in the weight (H4) or number (H5) of fish harvested by anglers. However, minimum-length limits did increase angler catch rates (H6). In contrast, slot-length limits resulted in an increase in the relative abundance of quality ($\geq$ 12 in; H1) and preferred-size ($\geq$ 15 in; H2) largemouth bass, and in largemouth bass population size (H3). In combination, these results indicate that slot-length limits generally resulted in a greater abundance of largemouth bass $\geq$ 12 and 15 in. Although slot-length limits successfully restructured largemouth bass populations, I found no evidence of any increase in angler harvest or catch (H4, H5, and H6). These results present managers with a dilemma: minimum-length limits increase angler catch rates, whereas slot-length limits restructure largemouth bass populations. However, neither limit accomplishes both.

My results for minimum-length limits contrast with those of Terre and Zerr (1994), who studied the responses of largemouth bass populations to a 14-in minimum-length limit in 28 Texas reservoirs. They reported an increase in electrofishing catch rates for largemouth bass $\geq$ 10 in (22 of 28 lakes) and $\geq$ 14-in long (23 of 28 lakes) as well as the relative abundance of largemouth bass $\geq$ 14 in (RSD-14; 18 of 28 lakes). Their results provide strong evidence of a positive effect of length limits that is not apparent in Table 1. Three explanations for this are possible. First, the study by Terre and Zerr may have occurred during years (1985–1988) in which, by chance, environmental conditions favored a positive response to the length limit. Second, the statewide minimum-length limit studied by Terre and Zerr simply may have been more appropriate, based on population characteristics, than the minimum length limits summarized in Table 1. Successful use of minimum-length limits depends on a low recruitment rate and high growth and mortality rates (Anderson 1980; Novinger 1984); if largemouth bass populations do not exhibit all of these characteristics they may not respond as expected to minimum-length limits. Third, abiotic and biotic conditions in Texas generally may be favorable for managing largemouth bass fisheries with minimum-length limits. In particular, growth rates in Texas may be especially favorable for use of minimum-length limits. Largemouth bass growth rates are positively related to temperature and growing-season length (Miranda and Durocher 1986; McCauley and Kilgour 1990) and are greater in the southern United States, including Texas, than in northern states. No obvious difference exists between fishery responses to length limits in southern and northern lakes in Table 1; however, small sample sizes as well as differences among lakes in fertility, presence of cover, and other characteristics may mask any possible relationship between latitude and fishery responses.

Novinger (1990) examined responses of largemouth bass populations to a 12- to 15-in slot-length limit in 14 small, midwestern impoundments. PSD increased in 10 of 14 impoundments, and electrofishing catch rates generally increased for each of 3 size classes of largemouth bass (< 8 in, 9 of 14 ponds; 8–11.9 in, 12 of 14 ponds; and $\geq$ 12 in, 12 of 14 ponds). These results provide further evidence that slot-length limits can increase the size of largemouth bass populations and the relative abundance of fish $\geq$ 12 in (PSD).

Several studies (e.g., Gablehouse 1984; Summers 1990; Martin 1995) have reported that slot-length limits failed to restructure largemouth bass populations because anglers did not harvest sufficient numbers of fish smaller than the lower limit of the protected-size range. In effect, these limits functioned as minimum-length limits. Fisheries managers are increasingly concerned that this angler behavior may compromise the effectiveness of slot-length limits.

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However, my results show that slot-length limits successfully restructured largemouth bass populations, suggesting that, although this is a problem on some lakes, it may not be a general concern. Results from Novinger (1990) support this suggestion. He reported that anglers released a substantial percentage of largemouth bass smaller than the lower limit of the protected-size range, yet he still observed changes in the relative and absolute abundance of fish $\geq$ 12 in long.

The hypotheses tested herein predict potential changes in largemouth bass population size structure, abundance, and angler catch statistics in response to implementation of length limits. However, predictions based on two additional reasons for using length limits—manipulating predator-prey relationships and increasing growth rates of abundant, stunted individuals—were not tested because insufficient information is available. This is especially unfortunate with respect to the alleviation of stunting, or *stockpiling*, because this is possibly the most important reason for recommending a slot-length limit rather than a minimum-length limit.

Carline et al. (1984) compiled information for largemouth bass populations in 10 Missouri lakes after implementation of a 12-in minimum-length limit. They noted that, when these lakes were arranged in order of increasing surface area (range = 15–240 acres), there was a general tendency for densities of sublegal largemouth bass to increase, while their growth rates decreased. For lakes listed in Table 1, for which surface area is available, I compared differences in largemouth bass PSD, RSD, and population size in response to length limits in large ($\geq$ 247 acres in surface area) and small (< 247 acres) lakes using a likelihood ratio test (*G*-test; Sokal and Rohlf 1981). I found no consistent differences ($P > 0.5$) between large and small

In the future, fishery managers will be challenged with using length limits in a creative manner to provide specific fishing opportunities and experiences for various angler groups.

lakes in largemouth bass population responses to minimum-length limits: PSD increased in 15 of 25 (60%) large lakes and 5 of 9 small lakes (56%); RSD increased in 9 of 14 large lakes (64%) and 4 of 8 small lakes (50%); and population size increased in 13 of 22 (59%) large lakes and 6 of 8 (75%) small lakes. For slot-length limits, I found no differences ($P > 0.5$) between large and small lakes in largemouth bass PSD, which increased in 9 of 12 (75%) large lakes and 9 of 13 (69%) small lakes, and population size, which increased in 10 of 12 (83%) large lakes and 8 of 13 (61%) small lakes. There was a significant difference ($P = 0.016$) in RSD, which increased in 6 of 6 (100%) large lakes but only 7 of 13 (54%) small lakes. My analysis fails to show any consistent relationship between lake size and population responses to length limits as noted by Carline et al. (1984); however, their observations may be specific to 12-in minimum-length limits or very small lakes (surface area < 50 acres) that are poorly represented in Table 1.

State fishery management agencies increasingly are adopting statewide minimum-length limits for largemouth bass. Fox (1975) questioned the soundness of this approach. He suggested that, ideally, a specific length limit should be applied to a lake in response to a very specific set of conditions and that this limit should then be periodically reevaluated and possibly modified in response to population changes initiated by the length limit. With the exception of Terre and Zerr's (1994) study, comprehensive assessments of the effects of statewide minimum-length limits are wanting. However, given the limited success of the minimum-length limits listed in Table 1 in accomplishing common fishery management goals (H1–H6), I cannot be very optimistic that statewide minimum-length limits generally will benefit largemouth bass fisheries. Nevertheless, use of statewide limits will probably continue to increase because of the relative ease in administering and enforcing these limits. Minimum-length limits also are well accepted by fishery managers and anglers. This acceptance may explain the apparently superior performance of slot-length limits in achieving fishery management goals. Anglers are less supportive of slot-length than minimum-length limits (Wilde and Ditton 1991). Consequently, managers may be more deliberate in diagnosing the need for, and recommending implementation of, slot-length limits. This may result in a better match between population characteristics and regulation, ensuring a more favorable population response, than usually occurs when a minimum-length limit is used. By implication, the general failure of minimum-length limits in achieving desired goals may result from attempts to manage largemouth bass populations characterized by recruitment, growth, and mortality rates that are inappropriate for minimum-length limits.

Reasons advanced by fishery managers for using minimum-length and slot-length limits have evolved rapidly since the 1960s. Based on studies by Ricker (1945) and Saila (1957), managers initially used length limits with the hope that these limits would maximize the weight of fish harvested by anglers. Although there was never any formal assessment of the success of this use of length limits, a consensus apparently quickly emerged that length limits did not increase harvest. Increased angler harvest rates no longer are used as a reason for recommending length limits. By the late 1970s, managers used minimum-length and slot-length limits to increase angler catch rates, as sublegal or protected-size fish were caught and released, and possibly caught again (Novinger 1984). This change was motivated by an expanding angler population that increased

creel data should be included as an integral part of length limit evaluations

pressure on finite fishery resources and by a growing awareness among fishery managers that many factors contribute to an angler's fishing experience (Hendee 1974; Driver 1985; Fedler and Ditton 1994). Among largemouth bass anglers, for example, harvest is only one motive, and not a very highly rated one at that, for fishing (Fedler and Ditton 1994; Wilde and Ditton 1994). Increased understanding of the ecological basis for fishery management also led to the expanded use of length limits as a method of manipulating predator-prey relationships among fish (Anderson 1976, 1980, 1984). In the future, fishery managers will be challenged with using length limits in a creative manner to provide specific fishing opportunities and experiences for various angler groups.

Suggestions for Future Length-limit Evaluations

My analysis provides a fairly comprehensive assessment of the effects of minimum-length and slot-length limits on population abundance and size structure of largemouth bass; however, I cannot offer a similarly comprehensive assessment of the effects of length limits on angler catch and harvest rates because creel data are so infrequently collected and reported. This is both surprising and unfortunate because increasing catch and harvest rates are among the commonly stated goals for managing fish populations with length limits. Estimates of largemouth bass abundance made, using electrofishing or other sampling techniques, before and after implementation of a length limit may allow a manager to anticipate changes in angler catch or harvest rates. However, these sampling techniques provide neither a direct nor a highly reliable estimate of angler catch and harvest rates for all or specific size classes of largemouth bass (Buynak and Mitchell 1993; Betsill, in press). I concur with Dent's (1986) recommendation that creel data should be included as an integral part of length limit evaluations. Evaluations that provide information only on the abundance and size structure of largemouth bass populations may be necessary for administrative purposes such as documenting the effectiveness of regulations but provide no additional insight into the general problem of assessing population responses to length limits and should be otherwise discouraged.

If fishery responses to length limits are related to environmental conditions..., a longer post-treatment (length limit) collection of data (at least three years) may be required to meaningfully assess responses.

The number of years required by a largemouth bass fishery to fully respond to a length limit is unknown; however, most length-limit evaluations apparently anticipate a rapid response. More than 50% (50 of 91) of the studies listed in Table 1 include data for five or fewer years. This roughly corresponds to two (or fewer) years each of pre- and post-treatment data collection, with the remaining year being that in which the limit was implemented. Terre and Zerr (1994) observed increased catch rates of largemouth bass ≥ 10 in and ≥ 14-in long within two years of implementing a 14-in minimum-length limit in Texas. This is, perhaps, a best-case scenario. As noted above, the populations studied by Terre and Zerr showed a more positive response to minimum-length limits than the studies listed in Table 1. If fishery responses to length limits are related to environmental conditions, especially temperature and growing-season length, a longer post-treatment (length limit) collection of data (at least three years) may be required to meaningfully assess responses. Angler behavior provides an additional argument for lengthening the period of post-treatment data collection. Even a small degree of noncompliance can seriously compromise the success of a length limit (Gigliotti and Taylor 1990), and some evidence exists to suggest that angler compliance increases for two to three years after implementation of a length limit (Summers 1990; D. Terre, Texas Parks and Wildlife Department, personal communication). Lengthening the period of post-treatment data collection and allowing adequate time for anglers to adjust to the new length limit may provide a more accurate assessment of fishery responses.

A need for more consistent and extensive collection of pretreatment data also is indicated. In most (77%) of the studies listed in Table 1, pretreatment data were collected for ≤ 2 years. Pretreatment data were collected for only 1 year in 41% of these studies, and in 30% pretreatment data are limited to those collected during the year in which the length limit was implemented.

Finally, there is a critical need for studies of length limits conducted in accord with the principles of experimental design (McAllister and Peterman 1992), with replication of treatments (length limits), inclusion of control lakes to which no treatments are applied, and in which treatments (including controls) are applied *at random* to study lakes. Randomization, in particular, is often neglected; however, in its absence, it is impossible to attribute population changes to the experimental treatment, rather than to preexisting conditions that led managers to recommend a limit in the first place. Fisheries managers have long-recognized the need for such studies (Novinger 1984; Dent 1986), but, unfortunately, they all too often fall victim to a "management data paradox." Successful and innovative fisheries management is based on sound science; however, financial, institutional, and time constraints often result in a tendency to compromise on study design, with the justification that "management data" are being collected. This limits the usefulness and credibility of the very data on which scientific fishery management is based. Furthermore, because inadequately designed studies may fail to yield conclusive results, they represent an inefficient use of financial and other resources.

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