Assessment of a 178-mm Minimum Length Limit on Bluegill at Purtis Creek State Park Lake, Texas

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Abstract: We compared relative abundance, size distribution, growth, and harvest of bluegill *(Lepomis macrochirus)* before and after implementation of a 178-mm minimum length limit at 144-ha Purtis Creek State Park Lake (PCSPL), Texas. Relative abundance [catch/hour of electrofishing (CPUE)] was significantly lower in post-regulation years (1993–1995, 243/hour) than in pre-regulation years (1990–1992, 520/hour). However, this decline was likely more attributed to recruitment patterns than to regulation effects. There was no significant difference ($P = 0.18$) between pre- and post-regulation bluegill size distribution. The only significant change in pre- and post-regulation mean length-at-age was for age-1 bluegill (134 mm vs. 123 mm, $P = 0.04$). However, this difference is suspect due to low sample sizes and the effect of extended spawning period on the "actual" age of bluegill captured in the fall. Mean bluegill angler total effort, and catch, release, and harvest rates declined significantly ($P < 0.05$) from pre- to post-regulation. Mean weight of bluegill harvested increased significantly (88 to 152 g, $P = 0.02$) but total yield declined (633 kg to 72 kg, $P = 0.03$) after the regulation was implemented. We were unable to detect any benefits to the bluegill population or to anglers. Thus, we recommend removal of the regulation.

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Frequently, poor size distribution in sunfish (*Lepomis* spp.) populations is attributed to density dependent factors (Snow 1968). This poor size distribution has led to attempts at controlling high abundance and slow growth in sunfish populations through mechanical removal (Grice 1958), chemical control (Hooper and Crance 1960, Beyerle and Williams 1967, Burres 1971), or predator management (Farabee 1974, Novinger and Legler 1978, Lundquist 1990). Other researchers have attempted to increase food supply by supplemental feeding (Schmittou 1969) or through habitat management (Pierce et al. 1965, Wahlquist 1970, Savino et al. 1985).

Although management of largemouth bass *(Micropterus salmoides)* using size and bag limits has been popular since the 1970s (Redmond 1974, Anderson 1980), and examples of the deleterious effect of overharvest on other centrarchid species exist (Goedde and Coble 1981, Coble 1988), actual harvest limits on sunfish populations have not been described. Coble (1988) suggested several reasons why sunfishes are not managed through harvest regulations: (1) removal of restrictive harvest regulations in the 1940s, (2) belief that "stunting" is a common problem, (3) belief that natural and fishing mortality are compensatory, (4) belief that variation in year class strength and growth rate have more effect on stock structure than harvest.

More recently, harvest regulations have been used on other panfish species, such as yellow perch *(Perca flavescens)* and white crappie *(Pomoxis annularis)*, to improve size distribution and angler benefit (Hartman et al. 1980, Colvin 1991, Webb and Ott 1991). Purtis Creek State Park Lake (PCSPL) was initially opened to the public in fall 1988 with a 50-boat limit. This limit was proposed by the Parks Division of Texas Parks and Wildlife Department (TPWD) to improve the angling experience. Despite limited entry, total angling effort in the first 9 months following establishment of a creel survey was very high (>971 hours/ha). Considerable effort was directed toward bluegill (>50 hours/ha) which resulted in a high initial harvest rate (nearly 1 fish/hour). These effort and harvest rates were much higher than those reported for other Texas reservoirs at that time.

Based on the perception that directed effort was high enough on small sunfishes to reduce recruitment into the more desirable (larger) size ranges, and the recent success of harvest regulations on crappie populations in Texas (Webb and Ott 1991), a 178-mm minimum length limit was implemented for all sunfishes at PCSPL 1 September 1992. Based on the results of Colvin (1991) and Webb and Ott (1991) we expected rapid increases in relative abundance of bluegill <178-mm, angler catch rate, release rate, and mean weight of bluegill harvested. Directed effort, harvest rate, and yield were expected to decline initially then rebound as smaller fish recruited into the larger sizes. We did not anticipate any change in electrofishing catch rate of bluegill ≥ 178 mm or growth rate. Our objective was to compare bluegill relative abundance, size distribution, growth, and harvest in PCSPL before and after imposition of the minimum length limit.

Methods

Purtis Creek State Park Lake is a 144-ha reservoir on Purtis Creek (a tributary of the Trinity River in Henderson County). The reservoir was constructed in 1984 by TPWD for recreational and soil conservation purposes. Drainage area is approximately 2,590 km^2, shoreline length is 11.3 km, and shoreline development index is 2.7. Littoral area (water depth <4.7 m) accounts for 80% of the reservoir. Rainfall on the watershed averages 1.1 m/year. Species initially stocked included channel catfish *(Ictalurus punctatus)*, northern strain and coppernose bluegill (*L. macrochirus macrochirus* and *L. m. purpurescens*), redear sunfish *(L. microlophus)*, and Florida strain largemouth bass *(Micropterus salmoides floridanus)*. The reservoir has been opened to public fishing since November 1988 and has 1 public boat ramp.

Bluegill were sampled with a Smith-Root 5.0 GPP electrofishing unit during nighttime, fall 1990–1995. Data collected from 1990 to 1992 represented pre-regulation and 1993–1995 represented post-regulation sampling. Individual specimens (5-fish/2.54-cm class/station) were weighed to the nearest gram and measured to the nearest millimeter. Remaining specimens were counted and recorded by 2.54-cm class by station. Otoliths were collected from a random subsample of bluegill (5-fish/2.54-cm class) for age-and-growth analysis.

Relative abundance was monitored with catch per unit effort (CPUE, defined as catch/hour of electrofishing) of stock-size bluegill (≥ 8 cm, Gabelhouse 1984). Electrofishing CPUE data were not normally distributed (Shapiro-Wilk W test, $P > 0.05$). Therefore, data were log transformed [$\log_{10}$ (n+1)] to more closely approximate a normal distribution. Because sampling stations were fixed, we compared transformed pre- and post-regulation electrofishing CPUE data with repeated measures analysis of variance (ANOVA, Maceina et al. 1994). Samples collected over consecutive years were likely correlated through time, thus we used an autoregressive covariance structure to account for autocorrelation (PROC MIXED, SAS 2000).

Otoliths collected in the field were viewed (whole) in the lab to determine fish age. Because samples were collected in the fall, we compared mean-length-at-age at time of capture to ecological region averages of back-calculated-length at age (Prentice 1987) for the next annulus formation as a standard to determine relative growth rate. For example, mean length of fish at age 1 collected in the fall was compared to mean back-calculated-length at age 2. We evaluated changes in mean-length-at-age between pre- and post-regulation periods with *t*-tests. Age-length keys were prepared using methods described by DeVries and Frie (1996).

Length distributions were pooled into pre- and post-regulation periods. We used a Kolmogorov-Smirnov test ($P = 0.05$) to compare pre- and post-regulation length distribution. Pooled pre-regulation length frequency defined the expected distribution and pooled post-regulation length frequency represented the observed (Zar 1999).

Estimates of fishing effort, catch rate, and size distribution of bluegill were obtained by stratified random angler creel surveys (Malvestuto 1996). Both fixed-access and roving surveys were conducted on 9 days stratified by day type (5 weekend and 4 weekdays) each quarter (Dec–Feb, Mar–May, Jun–Aug, Sep–Nov). For parties using the boat ramp, fixed-access interviews were conducted at the end of their fishing day. For parties fishing from shore, roving interviews were conducted at 3 randomly-selected times during a continuous 6-hour interview period and represented incomplete trip times. Information obtained from each party included number of anglers, hours fished, species sought, number and weight of each species harvested by 2.54-cm group, and number of fish caught and released by species. Harvest was estimated as the product of harvest rate (from angler interviews), total effort (from angler counts), and mean time fished per party (Lambou 1961, Malvestuto 1996). Creel data were segregated into pre-regulation (1 Sep 1989–31 Aug 1992) and post-regulation (1 Sep 1992–31 Aug 1995).

Analyses of catch, harvest, and release rates (number of fish/hours of effort) were conducted using log-linear models (PROC GENMOD, SAS 2000). The negative binomial distribution was chosen over the Poisson distribution because Poisson-based models displayed poor fit, related to overdispersion. Tests of significance between pre- and post-regulation time periods were conducted using Wald Chi-Square statistics. Analyses of average effort were conducted using *t*- tests. Mean weight was compared using an ANOVA. All analyses were conducted using a threshold statistical significance of $P = 0.05$.

Results

Electrofishing CPUE of bluegill for pooled pre-regulation years (actual mean = 520/hour) was significantly higher ($P = 0.05$) than for post-regulation years (actual mean = 243/hour). Electrofishing CPUE was highest in 1990 and lowest in 1994 (Table 1). There was no significant change in bluegill length distribution between pre- and post-regulation periods ($P = 0.18$). In fact, very few fish exceeded 178 mm in any year during the study (Fig. 1). Comparisons of growth to ecological region averages indicated PCSPL bluegills exhibited rapid growth (Table 2). However, few fish older than age 2 were sampled (Table 3). No significant difference ($P = 0.27$) was detected between pooled pre- and post-treatment mean lengths-at-age for age-0 bluegill (86 and 81 mm, respectively). A significant difference was detected ($P = 0.04$) between pooled pre-and post-treatment mean-lengths-at-age 1 (134 and 123 mm, respectively). However, no significant difference ($P = 0.68$) was detected for age-2 fish (166 and 169 mm, respectively). The sample sizes of age-3 bluegill were not sufficient to make a valid comparison.

Estimated mean annual total effort by anglers (regardless of species sought) did not significantly change ($P = 0.13$) from 77,875 angler-hours/year pre-regulation to 62,875 angler-hours/year post-regulation. However, pooled annual directed effort for anglers who reported specifically targeting bluegill decreased significantly ($P < 0.01$) from 23,811 angler-hours pre-regulation to 9,355 angler-hours post-regulation (Table 4). Estimates of mean directed catch rate of bluegill decreased significantly (*P*

Table 1. Mean catch rates (CPUE, number of fish/hour) for stock-size bluegill collected during fall electrofishing, 1990–1995, Purtis Creek State Park Lake, Texas. SE in parentheses.

Year	CPUE
1990	699 (99.94)
1991	472 (104.01)
1992	388 (118.83)
1993	318 (83.03)
1994	156 (34.44)
1995	253 (48.37)

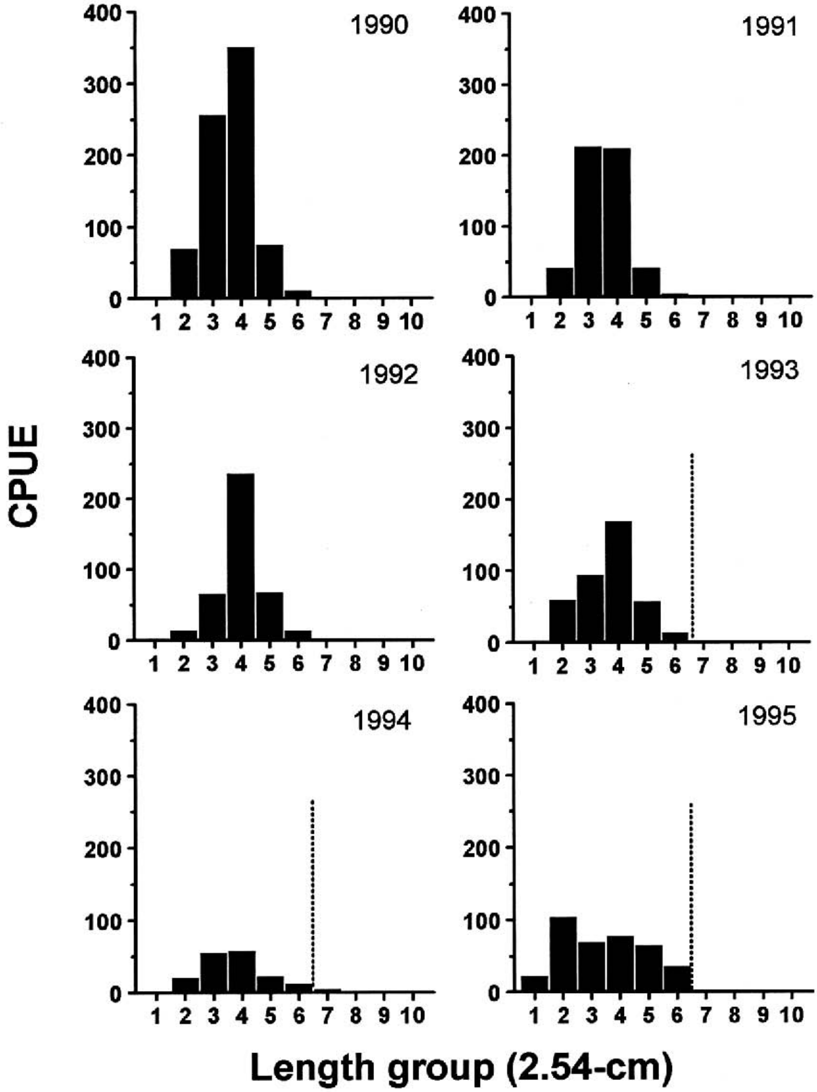

Figure 1. Catch per unit effort (CPUE) of bluegill (by 2.54-cm group) collected by fall electrofishing, 1990–1995, Purtis Creek State Park Lake, Texas. A 178-mm minimum length limit was implemented 1 September 1992.

Table 2. Mean length-at-age at time of capture of bluegill collected by fall electrofishing, 1990–1995, Purtis Creek State Park Lake, Texas. Texas Post Oak Savannah/Blackland Prairies ecological region mean back-calculated lengths-at-age are listed for comparison. Because sampling was conducted in the fall, comparisons of length-at-age were made to mean back-calculated length-at-age for the next subsequent age. A 178-mm minimum length limit was imposed 1 September 1992. SE in parentheses.

	Age at fall sampling			
Year	0	1	2	3
1990	87 (4.16)	135 (5.82)	171 (5.62)	190([a])
1991	90 (3.75)	139 (5.06)	151 (4.00)	
1992	68 (1.36)	128 (2.78)	180 ([a])	
1993	88 (5.28)	128 (2.78)	168 (3.94)	200 ([a])
1994	77 (5.57)	125 (5.78)	180 (5.00)	199 (4.00)
1995	74 (2.99)	118 (5.08)	163 (5.63)	
	Age at annulus formation			
	1	2	3	4
Ecological region average[b]	72	99	119	134

a. Inappropriate to calculate SE for single observation.
b. Data from Prentice (1987).

Table 3. Age distribution of bluegill collected by fall electrofishing, 1990–1995, Purtis Creek State Park Lake, Texas. A 178-mm minimum length limit was implemented 1 September 1992.

	Age			
Year	0	1	2	3
1990	503	259	6	1
1991	396	112	8	
1992	15	387	1	
1993	242	141	17	1
1994	70	90	15	5
1995	43	132	86	

< 0.01) from 2.23 fish/angler-hour (53,070 fish in 23,811 angler-hours) pre-regulation to 0.94 fish/angler-hour (8,813 fish in 9,355 angler-hours) post-regulation. Mean directed release rate of bluegill also decreased significantly ($P < 0.05$) from 1.51 fish/angler-hour (36,050 fish in 23,811 angler-hours) pre-regulation to 0.87 fish/angler-hour (8,098 fish in 9,355 angler-hours) post-regulation. Resulting mean annual directed harvest rate of bluegill showed a similar significant decline ($P = 0.001$) from 0.71 fish/angler-hour (17,019 fish in 23,811 angler-hours) pre-regulation to 0.07 fish/angler-hour (715 fish in 9,355 angler-hours) post-regulation. Size distribution of

Table 4. Estimated directed effort and associated estimates of catch, release, and harvest rates, total effort, mean fish weight, and total yield of bluegill, Purtis Creek State Park Lake, Texas, 1990–1995. A 178-mm minimum length limit was implemented 1 September 1992. SE in parentheses.

	Anglers seeking bluegill				All anglers			
Year	Effort (hours)	Catch (fish/hour)	Release (fish/hour)	Harvest (fish/hour)	Effort (hours)	Total harvest	Mean fish weight(g)	Yield (kg)
1990	8,382	1.739	0.809	0.930	65,078	7,795	102	880
	(1,657)	(0.337)	(0.323)	(0.129)	(7,081)	(1,903)	(12)	(223)
1991	7,614	2.577	2.317	0.260	92,610	3,848	84	333
	(1,999)	(0.350)	(0.301)	(0.087)	(14,666)	(1,201)	(6)	(111)
1992	7,814	2.415	1.488	0.927	75,938	8,140	81	686
	(2,544)	(0.751)	(0.537)	(0.279)	(8,100)	(3,006)	(4)	(258)
1993	2,566	0.904	0.861	0.043	64,875	602	167	100
	(787)	(0.351)	(0.355)	(0.033)	(9,697)	(246)	(17)	(47)
1994	2,338	0.782	0.628	0.154	63,798	516	170	85
	(564)	(0.138)	(0.114)	(0.069)	(8,663)	(205)	(18)	(32)
1995	4,451	1.048	0.993	0.055	57,721	255	122	26
	(864)	(0.218)	(0.232)	(0.028)	(7,456)	(107)	(18)	(23)

bluegill harvested pre-regulation was primarily fish < 178 mm (Fig. 2). Minor illegal harvest was documented in the first year following implementation of the regulation but all harvest was fish ≥ 178 mm in subsequent years. Mean weight of all bluegill harvested increased significantly ($P = 0.02$) from 87 g pre-regulation to 152 g post-regulation. However, increase in mean weight was unable to compensate for decrease in the total harvest of fish and pooled mean yield decreased significantly ($P = 0.03$) from 633 kg pre-regulation to 72 kg post-regulation.

Discussion

Bluegill ≥ 178 mm at PCSPL were rare prior to establishment of the regulation and continued to be rare after the regulation was established. Implementation of a 178-mm minimum length limit did not appear to improve size distribution or compensate for natural mortality of bluegill <178 mm. Instead, electrofishing CPUE data indicated that relative abundance of stock-size bluegill steadily declined from 1990 through 1995, which implies that natural mortality had a more substantial influence on population dynamics than harvest.

Beard et al. (1997) found that in slow growing bluegill populations in the Midwest, angling effort as low as 70 hours/ha reduced the number of trophy fish and overall density. They suggested that reduction in angling pressure (possibly including a closed season during spawning) rather than harvest regulations would be needed to increase the proportion of large bluegill in Midwest reservoirs. At its highest (in 1990), directed effort for bluegill at PCSPL (59 hours/ha) was well below 70 hours/ha and had declined to only 2.4 hours/ha in 1994, but no change in bluegill size distribution was detected and relative abundance continued to decrease significantly. Since growth

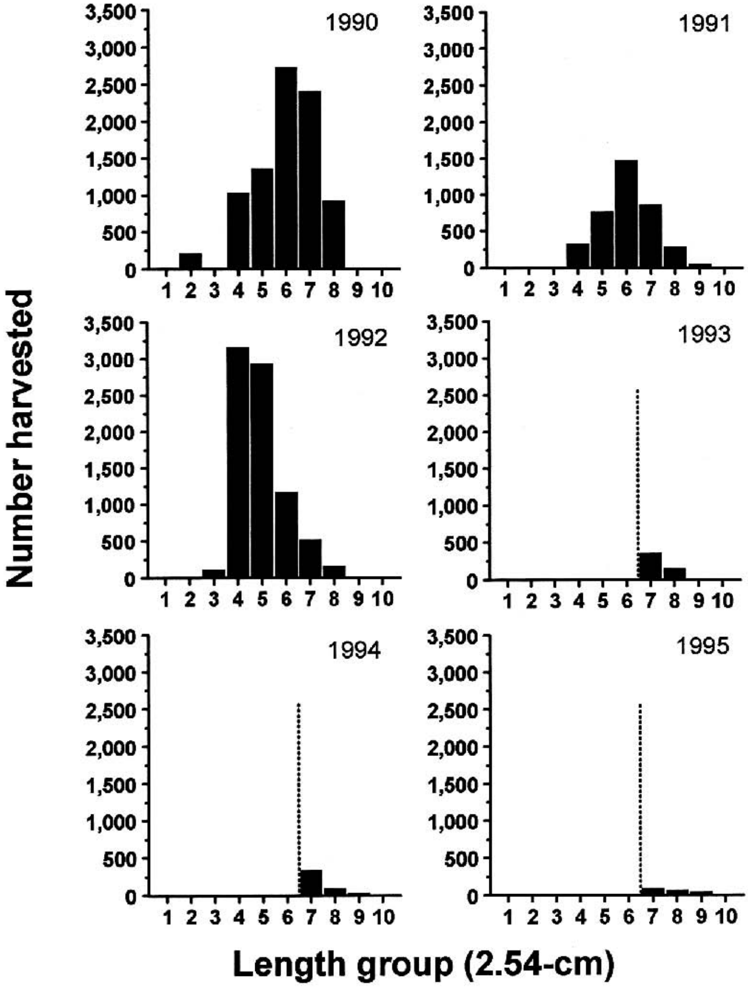

Figure 2. Estimated length-frequency of all bluegill (by 2.54-cm group) harvested by anglers 1990–1995 from Purtis Creek State Park Lake, Texas (based on expanded values). A 178-mm minimum length limit was implemented 1 September 1992.

rates for bluegill at PCSPL were high compared to ecological region averages, benefits proposed by Beard et al. (1997) should have been exhibited even sooner.

Without overharvest as an explanation for decrease in relative abundance, other causative factors must be considered. Although Coble (1988) also predicted benefits from length and bag limits in protecting sunfish populations from overharvest, these benefits would not be realized if released fish succumb to hooking mortality (Waters and Huntsman 1986). However, based on other studies we would expect hooking mortality to be minimal (Muoneke and Childress 1994). Furthermore, directed effort, catch, and release rates all declined significantly post-regulation, so fewer bluegill were being subjected to hooking mortality.

Bennet (1971) discussed the decline in productivity (and fishery quality) in reservoirs with age. Purtis Creek State Park Lake was impounded and stocked in 1984 and opened to public angling in fall 1988. The beginning of the present study in 1990 was 6 years after impoundment and corresponds to the period of "reduced recreational value" as described by Bennet (1971). This time period also represented a period of substantial habitat change as terrestrial vegetation and timber inundated when the reservoir was impounded progressively decomposed.

The possibility also exists that decreased abundance of bluegill may be related to intensive management of largemouth bass. Purtis Creek State Park Lake is managed with a catch-and-release only regulation for largemouth bass. This regulation has provided a very high quality fishery with catch rates of largemouth bass ≥ 355 mm well above the statewide average (Storey and Ott 1992). Largemouth bass of this size are capable of capturing and swallowing bluegill in the same size range as those protected from harvest by the regulation (Lawrence 1958). With loss of escape cover as a result of decomposition of terrestrial vegetation, bluegill of all sizes could be expected to be even more susceptible to predation and even fewer would survive to 178 mm.

Growth of bluegill at PCSPL was higher than ecological region averages. The only significant change detected in pre-and post-regulation length-at-age was for age-1 fish. However, this difference is suspect due to low sample sizes and bluegill propensity to spawn multiple times each year (Bennet 1971) resulting in greater variability in "actual" fish age. For example, a bluegill assigned as age-0 when collected in October would have had 5 months of growth if spawned in May but only 3 months of growth if spawned in July. In the past, bluegill management has emphasized reducing density with the assumption that this would increase growth rates and improve size structure (Grice 1958, Hooper and Crance 1960, Beyerle and Williams 1967, Burres 1971, Farabee 1974, Novinger and Legler 1978, Lundquist 1990). At PCSPL, growth rate appears independent of significant changes documented in relative abundance of bluegill. It is likely that bluegill growth at PCSPL was operating at its maximum rate across the range of relative abundance and level of intraspecific competition present during our study and supports the possibility of a high rate of predation from largemouth bass.

Some explanation for the lack of bluegill ≥ 178 mm may be the apparent lack of bluegill over age-3 (and in most cases age-2). If bluegill do not survive past age-3 at PCSPL they cannot be expected to grow into larger size classes. Bennet (1971) lists approximate life spans for several species. For largemouth bass, lifespan is listed as 14–16 years in the north and 9–12 years in the south. Bluegill lifespan is listed as 5–8 years without reference to latitude, and bluegill up to 10 years old were reported by Beard et al. (1997) for slow growing Midwest populations. Assuming a commonality between southern bluegill and southern largemouth bass populations, bluegill lifespans of 4–6 years would be expected. The rapid growth rate and long spawning season of bluegill at PCSPL might have resulted in high natural mortality and short lifespans as have been reported for largemouth bass in the tropics (Waters 1999). Another possibility is that older (larger) fish are present but are not spatially susceptible to electrofishing. Reynolds and Simpson (1978) reported that bluegill >152 mm were less susceptible to electrofishing, as larger fish occupied water too deep to sample effectively. Anglers at PCSPL harvested bluegill >178 mm (in low numbers) each year even when we were unable to document occurrence by electrofishing. Electrofishing might have been more effective at documenting the occurrence of bluegill >178 mm if sampling had been specifically directed toward known spawning areas in the spring.

Management Implications

The results of our study appear to agree with Coble (1988) that angling mortality and natural mortality of bluegill are compensatory. Our results agree with Anderson (1978) and Novinger and Legler (1978) that the Proportional Stock Density (PSD) of bluegill and largemouth bass are mutually exclusive and it is probably unreasonable to expect to manage for large individuals of both species in the same system. Establishment of the 178-mm minimum length regulation adversely affected directed effort, although not enough to reflect the potential benefits proposed by Beard et al. (1997) in their length limit simulation. Reed and Parsons (1999) found that the majority of anglers they contacted on 4 Minnesota lakes would not support regulation changes on bluegill fisheries. Although anglers at PCSPL were not specifically questioned regarding their opinion of the harvest regulations, the decreased effort directed at the bluegill fishery after the regulation was implemented suggests that they would rather fish elsewhere. Despite decreased effort, angler compliance with the regulation was good, only 2 illegal-length bluegill were documented in the creel post-regulation, and both were just below legal length. The decrease in relative abundance, and decline in catch, release, harvest rates, and total yield of bluegill are more likely related to recruitment variability and natural mortality than to regulation effects. Although mean weight of bluegill harvested increased following implementation of the length limit, the implemented regulation was unable to compensate for a decrease in the total harvest of fish and yield decreased. A similar increase in size but decrease in total yield was reported by Hale et al. (1999) after a 254-mm minimum length limit was imposed on crappie in Delaware Reservoir, Ohio. Since the 178-mm minimum length limit is not benefiting Texas anglers or fish populations, we recommend the regulation be removed.

Literature Cited

Anderson, R. O. 1978. New approaches to recreational fisheries management. Pages 73–78 *in* G. D. Novinger and J. G. Dillard, eds. New approaches to the management of small impoundments. Am. Fish. Soc., North Cent. Div. Spec. Pub. 5, Bethesda, Md.

______. 1980. The role of length limits in ecological management. Pages 41–44 *in* S. Gloss and B. Shupp, eds. Practical fisheries management: More with less in the 1980's. N. Y. Chap. Am. Fish. Soc.

Beard, T. D., Jr, M. T. Drake, J. E. Breck, and N. A. Nate. 1997. Effects of simulated angling regulations on stunting in bluegill populations. North Am. J. Fish. Manage. 17: 525–532.

Bennet, G. W. 1971. Management of lakes and ponds, 2nd ed. Van Nostrand Reinhold, N.Y. 283pp.

Beyerle, G. B. and J. E. Williams. 1967. Attempted control of bluegill reproduction in lakes by the application of copper sulfate crystals to spawning nests. Prog. Fish-Cult. 29:150–155.

Burres, R. M. 1971. Improved method of treating ponds with antimycin A to reduce sunfish populations. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 24: 464–473.

Coble, D. W. 1988. Effects of angling on bluegill populations: management implications. North Am. J. Fish. Manage. 8: 277–283.

Colvin, M. A. 1991. Evaluation of minimum-size and reduced daily limits on the crappie populations and fisheries in five large Missouri reservoirs. North Am. J. Fish. Manage. 11:585–597.

DeVries, D. R., and R. V. Frie. 1996. Determination of age and growth. Pages 483–508 *in* B. R. Murphy and D. W. Willis, eds. Fisheries techniques, 2nd ed. Am. Fish. Soc., Bethesda, Md.

Farabee, G. B. 1974. Effects of a 12-inch length limit on largemouth bass and bluegill populations in two northeast Missouri lakes. Pages 95–99 *in* J. L. Funk, ed. Symposium on overharvest and management of largemouth bass in small impoundments. North Cent. Div. Am. Fish. Soc. Spec. Pub. 3. Bethesda, Md.

Gabelhouse, D. W., Jr. 1984. A length-categorization system to assess fish stocks. North Am. J. Fish. Manage. 4:273–285.

Goedde, L. E. and D. W. Coble. 1981. Effects of angling on a previously fished and unfished warm water fish community in two Wisconsin lakes. Trans. Am. Fish. Soc. 110:594–603.

Grice, F. 1958. Effect of removal of panfish and trash fish by fyke nets upon fish populations of some Massachusetts ponds. Trans. Am. Fish. Soc. 87:108–115.

Hale, R. S., M. E. Lundquist, R. L. Miller, and R. W. Petering. 1999. Evaluation of a 254-mm minimum length limit on crappies in Delaware Reservoir, Ohio. N. Am. J. Fish. Manage. 19:804–814.

Hartman, W. L., S.J. Nepszy, and R. l. Scholl. 1980. Minimum size limits for yellow perch *Perca flavescens* in western Lake Erie. Great Lakes Fishery Commission, Tech. Rep. 39. Ann Arbor, Mich. 32pp.

Hooper, A. D. and J. H. Crance. 1960. The use of rotenone in restoring balance to overcrowded fish populations in Alabama lakes. Trans. Am. Fish. Soc.89:351–357.

Lambou, V. W. 1961. Determination of fishing pressure from fisherman or party counts with a discussion of sampling problems. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 15: 380–401.

Lawrence, J. M. 1958. Estimated sizes of forage fishes that largemouth bass can swallow. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 11:220–225.

Lundquist, M. E. 1990. Effects of minimum and slot length limit regulations for largemouth bass on the largemouth bass and bluegill fisheries in four lakes in Wisconsin. Masters thesis. Univ. Wisc., Stevens Point. 197pp.

Maceina, M. J., P. P. Bettoli, and D. R. DeVries. 1994. Use of a split-plot analysis of variance design for repeated-measures fishery data. Fisheries 19(3):14–20.

Malvestuto, S. P. 1996. Sampling the recreational creel. Pages 591–620 *in* B. R. Murphy and D. W. Willis, eds. Fisheries techniques, 2nd Edition. Am. Fish. Soc., Bethesda, Md.

Muoneke, M. I. and W. M. Childress. 1994. Hooking mortality: A review for recreational fisheries. Rev. in Fish. Sci. 2:123–156.

Novinger, G. D. and R. E. Legler. 1978. Bluegill population structure and dynamics. Pages 37–49 *in* G. D. Novinger and J. G. Dillard, eds. New approaches to the management of small impoundments. Am. Fish. Soc., North Cent. Div. Spec. Pub. 5, Bethesda, Md.

Pierce, P. C., J. E. Frey, and H. M. Yawn. 1965. An evaluation of fishery management techniques utilizing winter drawdowns. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 17:347–363.

Prentice, J. A. 1987. Length-weight relationships and average growth rates of fishes in Texas. Inland Fisheries Data Series No. 6. Texas Parks and Wild. Dep., Inland Fish. Div. Austin. 61pp.

Redmond, L. C. 1974. Prevention of overharvest of largemouth bass in Missouri impoundments. Pages 54–58 *in* J. L. Funk, ed. Symposium on overharvest and management of largemouth bass in small impoundments. North Cent. Div. Am. Fish. Soc. Spec. Pub. 3. Bethesda, Md.

Reed, J. R. and B. G. Parsons. 1999. Angler opinions of bluegill management and related hypothetical effects on bluegill fisheries in four Minnesota lakes. North Am. J. Fish. Manage. 19:515–519.

Reynolds, J. B. and D. E. Simpson. 1978. Evaluation of fish sampling methods and rotenone census. Pages 11–24 *in* G. D. Novinger and J. G. Dillard, eds. New approaches to the management of small impoundments. Am. Fish. Soc., North Cent. Div. Spec. Pub. 5, Bethesda, Md.

Savino, J. F., R. A. Stein, and E. A. Marschall. 1985. Management of macrophyte communities to enhance largemouth bass and bluegill populations at Clark Lake. Ohio Dep. Nat. Resour., Div. Wildl., Fed. Aid in Sport Fish Restor. Proj. F-57-R-3-7, Columbus. 283pp.

SAS Institute, Inc. 2000. SAS/STAT: Version 8 ed. SAS Inst., Cary, N.C. 1,675 pp.

Schmittou, H. R., 1969. Some effects of supplemental feeding and controlled fishing in largemouth bass-bluegill populations. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 22:311–320.

Snow, H. E. 1968. Stocking of muskellunge and walleye as a panfish control practice in Clear Lake, Sawyer County. Wisc. Dep. Nat. Resour., Res. Rep. 38, Madison. 32pp.

Storey, K. W. and R. A. Ott, Jr. 1992. The largemouth bass catch-and-release regulation at a new reservoir, Purtis Creek State Park Lake, Texas. Proc. Annu. Conf. Southeast Assoc. Fish and Wildl. Agencies 46:377–385.

Wahlquist, H. 1970. Effect of water hyacinths and fertilization on fish food organisms and production of bluegill and redear sunfish in experimental ponds. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 23:373–384.

Waters, D. S. 1999. Spawning season and mortality of adult largemouth bass (*Micropterus salmoides*) in a tropical reservoir. M.S. Thesis, N.C. State Univ., Raleigh. 71pp.

Waters, J. R. and G. R. Huntsman. 1986. Incorporating mortality from catch and release into yield-per-recruit analysis of minimum-size limits. North Am. J. Fish. Manage. 6:463–471.

Webb, M. A. and R. A. Ott, Jr. 1991. Effects of length and bag limits on population structure and harvest of white crappie in three Texas reservoirs. North Am. J. Fish. Manage. 11:614–622.

Zar, J. H. 1999. Biostatistical analysis. 4th ed. Prentice-Hall Book Co., Englewood Cliffs, N.J. 663pp.