Fisheries Session

Evaluation of a 254-mm Minimum Length Limit, 25-fish Daily Bag Limit on Crappies at Sam Rayburn Reservoir, Texas

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Abstract: As part of a statewide regulation change in 1990, Texas Parks and Wildlife Department adopted 254-mm minimum length and 25-fish daily bag limits on crappies (*Pomoxis* spp.) at Sam Rayburn Reservoir. The objective of the regulation was to increase the size of harvested crappies while maintaining pre-regulation catch rates, harvest rates, and yield. Population and fishery parameters during 3-year unregulated and 8-year regulated periods were compared. Results indicated that mean length and weight of harvested crappies increased significantly (16% and 40%, respectively), while yield was maintained. Significant increases in trap net catch rates of crappies, coupled with a 36% increase in angler catch rates, suggested an increase in stock-length crappie abundance during the regulation period. However, similar increases in trap net catch rates at nearby Toledo Bend Reservoir (regulated with a bag limit only) may indicate that the increase in crappie relative abundance at Sam Rayburn Reservoir was not directly associated with the regulation. Harvest rates, both number and weight per hour, did not change significantly between pre- and post-regulation periods. At Toledo Bend Reservoir, harvest as well as effort levels oscillated over annual periods according to the supply of young, available crappies, suggesting a pattern of growth overfishing. Growth rates remained above average indicating the accumulation of protected-length crappies did not affect growth. Although the 25-fish bag limit was incorporated as part of the crappie regulations at Sam Rayburn Reservoir, it was not biologically effective. Application of the appropriate harvest restrictions should be reservoir-specific, based not only on environmental and biological characteristics, but the preferences of the angling clientele.

Key words: crappie, regulations, minimum length limits, Sam Rayburn Reservoir

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Crappies (*Pomoxis* spp.) are popular game fishes in the United States. A national survey indicated that 22% of anglers ≥16 years of age fished for crappie at least one day in 1996 (U.S. Department of the Interior 1996). A statewide survey of licensed Texas freshwater anglers indicated that only black bass (*Micropterus* spp.)

and catfish (Ictaluridae) were sought more frequently than crappie (Bohnsack and Ditton 1999). Due to their popularity, viable crappie fisheries provide immeasurable recreational benefits to communities and the associated angling-related expenditures can be a major source of income to local businesses (Dorr 1997). Voluntary catch-and-release rates of crappies are relatively low (Quinn 1996) and, as a result, they are the most harvested game fishes in reservoirs of the United States (Miranda 1999). Establishing and sustaining viable harvest-oriented crappie fisheries can be difficult because crappie recruitment is typically variable and influenced by both density-dependent and density-independent factors (Miranda and Allen 2000).

Contemporary research associated with management of reservoir crappie populations has been directed primarily at the environmental and hydrological factors affecting year class strength (e.g., Ploskey 1986, O'Brien 1990, Mitzner 1991, Sammons et al. 2002) and the effects of harvest restrictions (e.g., Colvin 1991, Webb and Ott 1991, Hale et al. 1999, Boxrucker and Irwin 2002). Perhaps the most practical tool currently available to managers of crappie populations is harvest regulation. Since the late 1980s, implementation of crappie regulations has increased in the United States (Quinn 1996). Typically, minimum length limits have been implemented to reduce harvest of small crappies and to increase the size of crappie harvested without substantially reducing yield (Colvin 1991, Webb and Ott 1991, Hale et al. 1999). However, the success of minimum length limits has generally varied across populations and is most attainable where compliance is high, growth is rapid, natural mortality is low, and exploitation prior to the regulation is high (Allen and Miranda 1995).

In 1985, an experimental 254-mm minimum length limit (MLL) and a 25-fish daily bag limit were established on white crappie *(P. annularis)* populations at three Texas reservoirs. The relative stock density of preferred-size white crappie (≥254 mm) increased at two reservoirs, mean weight at harvest increased at one reservoir, and total yield increased at all three reservoirs. As a result, Texas Parks and Wildlife Department (TPWD) adopted, in September 1990, a statewide 254-mm MLL and 25-fish daily bag limit on crappies. As part of this change, these regulations were implemented on Sam Rayburn Reservoir, where previously no harvest restrictions had been imposed on the crappie fishery. The objective of the regulation was to increase the size of harvested crappies while maintaining pre-regulation catch rates, harvest rates, and yield. Because the regulation was instituted as part of a statewide package, no data had been examined to assess the applicability of this regulation at this specific reservoir.

We sought to determine possible effects of the regulations at Sam Rayburn Reservoir by making pre- and post-regulation comparisons of crappie population and fishery data. We compared changes in the Sam Rayburn Reservoir crappie population and fishery to those observed at nearby Toledo Bend Reservoir, regulated with a crappie bag limit only, in an attempt to distinguish any environmental or angler-behavior differences that may have confounded effects of the regulations at Sam Rayburn Reservoir.

Study Sites

Sam Rayburn Reservoir, located in East Texas, was impounded on the Angelina River in 1965 and covers 46,356 ha at conservation pool (50.1 m above msl). It is the largest reservoir completely within the state of Texas and is mesotrophic and relatively clear (Secchi range 1–2 m), with mean and maximum depths of 4 and 30 m, respectively. The annual mean water level fluctuation during the study period was 3.73 m. Structural habitat is primarily flooded timber. Aquatic vegetation coverage at this reservoir was considered moderate during the study period (range 5%–15%) and primarily hydrilla *(Hydrilla verticillata).* Both white and black crappie populations exist in the reservoir.

Toledo Bend Reservoir, located in Texas and Louisiana, was impounded in 1968 on the Sabine River and covers 74,899 ha at conservation pool (52.4 m above msl). It is mesotrophic and clear (Secchi range 1–3 m) with mean and maximum depths of 8 and 36 m, respectively. The annual mean water level fluctuation during the study period was 1.97 m. Immense stands of flooded timber are found throughout the reservoir. Aquatic vegetation coverage was higher (range 13%–24%) than at Sam Rayburn Reservoir and primarily hydrilla. A 50-fish bag limit was in place during the study period, but no MLL was imposed. Both white and black crappie are present in the reservoir.

Methods

Trap Netting

White and black crappie populations at Sam Rayburn Reservoir were sampled during standardized fall trap netting surveys. Trap nets were made of two 0.9- × 1.8-m rectangular frames, four 0.7-m diameter hoops, and a 0.9 deep, 19.8-m long leader with 12.7-mm square knotless nylon webbing. Trap nets were set perpendicular to the shore at fixed sites containing habitat suitable for crappies and fished overnight. Standard unit of effort was a net night (approximately sunset to sunrise). Sampling was conducted in October, November, or December when surface water temperature ranged from 10 to 18 C. Sampling effort ranged from 20 to 40 net nights per survey year (1986–1989, 1991–1997). Crappies collected from trap nets were sorted by species, measured (total length, TL) to the nearest mm, and weighed to the nearest g. Sagittal otoliths were removed from a stratified sub-sample (5 fish per 25.4-mm length group) of crappies taken during fall trap netting each year for age and growth analysis. Ages were estimated using procedures described by Schramm and Doerzbacher (1985). Mean length at age estimates were compared to averages from the Pineywoods Ecological Region (Prentice 1987) in which Sam Rayburn Reservoir is located.

Catch-per-effort (CPE, fish/net-night) was used to index population abundance of crappies in 127–203-mm ($CPE_{127–203}$), 204–253-mm ($CPE_{204–253}$), and ≥ 254-mm ($CPE_{\geq 254}$) length groups. These three length groups were selected to assess possible changes in size structure of the crappie population following implementation of the

254-mm MLL at Sam Rayburn Reservoir. Pre- and post-regulation period data were collected in 1986–1989 and 1991–1997, respectively. Data from 1990 were excluded from analyses, as part of the year was included in both the pre- and post-regulation time periods.

Because trap netting was conducted at fixed sites, we used a repeated-measures analysis of variance (ANOVA) design using mixed model procedures (SAS 1999) to test for significant differences among pre- and post-regulation CPE estimates of each length group. An autoregressive covariance structure (e.g., ar[1]) was used to account for autocorrelation of consecutive annual estimates of CPE, year was nested within regulation period (pre- or post-regulation) (SAS 1999). Due to the non-normal distributions of trap net CPE, analyses were conducted using the ranks of each individual trap net station by year. White and black crappie data were combined for all analyses. Individual trap net stations were nested within (subsamples of) years and our yearly estimates served as replicates for our test of regulation differences. The significance level for these analyses was set at $\alpha = 0.10$. Estimates of mean length at age of capture for crappies were not tested statistically, due to relatively small sample sizes during both the pre- and post-regulation periods.

Creel Surveys

Standardized, stratified, access point creel surveys were conducted annually from 1987 through 1998. For each quarterly period (December–February, March–May, June–August, September–November), five weekend days and four weekdays were sampled. Creel clerks interviewed anglers at boat ramps to derive estimates of crappie catch rates (fish/angler-hour), release rates (fish/angler-hour), mean length (mm) and weight (kg) of harvested fish, harvest rates (fish/angler-hour and kg/angler-hour), and the distribution of angler bag sizes. In addition, anglers were asked "How would you rate today's fishing success compared with fishing at other lakes that you have fished: very good, good, average, poor, or very poor?" Responses were coded 1–5, with 5 assigned to "very good" and 1 to "very poor." Estimates of total directed effort (hours/ha) were obtained from roving angler counts. From January 1987 through August 1988, counts were conducted on approximately one-fifth of the reservoir each creel day, then expanded to derive total directed effort for the reservoir. From September 1988 throughout the rest of the study period, complete reservoir counts were derived each creel day by way of aerial flights. Information from both angler interviews and counts were used to calculate total yield (*N*/ha and kg/ha).

We used an ANOVA design (Proc GLM) to test whether pre- (1987–1989) and post-regulation (1991–1998) crappie catch rates, release rates, mean length and weight of harvested fish, harvest rates, directed fishing effort, yield, and fishing success ratings were significantly different. Due to the non-normal distributions of our metrics, analyses were conducted using the ranks of each individual metric across all years. Again, data from 1990 were excluded from analyses. When estimating mean directed effort and yield, years served as replicates. For all other creel variables, individual interviews were nested within (subsamples of) years and our yearly estimates served as replicates for our test of regulation differences. White and black crappie were combined for all analyses. The significance level was set at $\alpha = 0.10$.

Comparison of Reservoirs

During the evaluation period at Sam Rayburn Reservoir, similar trap netting and creel survey data were available from Toledo Bend Reservoir. Due to the close proximity of the reservoirs (approximately 64 km), their similar size, habitat, and fishery characteristics, and the unregulated nature of the crappie fishery at Toledo Bend Reservoir, data were compared between the two reservoirs to better assess possible effects of the crappie regulations implemented at Sam Rayburn Reservoir. More specifically, these comparisons provided a means to assess possible environmental factors that may have confounded results at Sam Rayburn Reservoir. Due to their similarities, we assumed that any major environmental factors affecting crappie populations would similarly affect both reservoirs. In addition, incorporating Toledo Bend Reservoir into this study provided a means to examine potential regional changes in crappie angler characteristics and behavior over the evaluation period.

Trap netting methods at Toledo Bend Reservoir were identical to those at Sam Rayburn Reservoir. Trap net sampling effort at Toledo Bend Reservoir ranged from 20 to 40 net nights per survey year (1986–1996). Trap netting data were pooled into similar periods (1986–1989 and 1991–1996) as those at Sam Rayburn Reservoir and results were statistically compared between periods. Mean length at age of capture estimates were compared to averages from the Pineywoods Ecological Region (Prentice 1987) in which Toledo Bend Reservoir is located. Creel data comparable to that for Sam Rayburn Reservoir were available during 1989–1996. Creel survey methods were identical to those at Sam Rayburn with the following exceptions: 1) Sampling effort for creel surveys was 9 days per quarter (2 weekend days and 1 weekday per month) and 2) Estimates of total directed effort were obtained from aerial flights. Methods for all statistical analyses were identical to that for Sam Rayburn Reservoir.

Results

Trap Netting

At Sam Rayburn Reservoir, catch rates of all three length groups examined increased significantly from the pre- to the post-regulation period (Table 1). A greater percentage increase was noted for length groups protected by the MLL (127–253 mm, $P = 0.06$ and 0.03) than crappies recruited to the fishery (≥254 mm, $P = 0.01$). Trends in the yearly estimates of mean catch rates indicate that 2–5 years after implementation of the MLL (1992–1995), numbers of crappies increased substantially (Table 1). During 1996–1997, catch rates declined and were similar to pre-regulation estimates.

Trap netting results from Toledo Bend Reservoir were similar to those from Sam Rayburn Reservoir and were significantly higher for two of the three length groups during the 1991–1996 period (Table 1, $P = 0.14$, 0.02, and 0.06 for $CPE_{127–203}$, $CPE_{204–253}$, and $CPE_{\geq 254}$, respectively). Again, similar to trends observed at Sam Rayburn Reservoir, catch rates typically increased or peaked during 1992–1995, then declined in 1996.

Table 1. Crappie (white and black combined) catch rates (fish/net-night) from fall trap netting at Sam Rayburn Reservoir, Texas, 1986–1997, and Toledo Bend Reservoir, Texas, 1986–1996. *N* = number of trap net sets per year or period. MCPE = mean crappie catch per year or period (coefficient of variation estimates in parentheses). MCPE length group values were pooled for two periods (Sam Rayburn - pre-regulation 1986–1989 and post-regulation 1991–1997, Toledo Bend 1986–1989 and 1991–1996). Period means followed by the same letter were not significantly different (repeated-measures ANOVA, $P < 0.10$).

		MCPE		
Year/Period	*N*	127–203 mm	204–253 mm	≥ 254 mm
		Sam Rayburn Reservoir		
1986	24	0.29 (159)	0.33 (144)	0.04 (490)
1987	40	0.77 (242)	0.17 (340)	0.30 (253)
1988	30	0.76 (183)	0.23 (244)	0.20 (242)
1989	30	0.50 (267)	0.43 (188)	0.80 (172)
1991	24	0.50 (213)	0.50 (221)	0.16 (289)
1992	24	0.54 (188)	1.00 (204)	0.54 (231)
1993	20	1.05 (197)	0.60 (273)	0.25 (220)
1994	20	5.60 (160)	2.60 (155)	1.65 (136)
1995	20	3.20 (132)	2.85 (149)	0.75 (136)
1996	20	0.35 (282)	0.35 (267)	0.50 (165)
1997	20	0.20 (262)	0.20 (262)	0.35 (212)
Pre-regulation	124	0.61 a (235)	0.28 a (224)	0.35 a (252)
Post-regulation	148	1.57 b (263)	1.14 b (229)	0.59 b (207)
		Toledo Bend Reservoir		
1986	34	0.09 (429)	0.00	0.03 (583)
1987	40	0.18 (286)	0.38 (261)	0.40 (203)
1988	30	0.53 (286)	0.67 (202)	0.73 (113)
1989	20	0.40 (338)	0.10 (308)	0.10 (308)
1991	24	0.29 (237)	0.25 (243)	0.83 (189)
1992	24	0.50 (177)	2.42 (224)	0.63 (210)
1993	24	0.17 (289)	1.21 (184)	2.96 (163)
1994	20	1.30 (279)	1.55 (249)	0.60 (205)
1995	20	1.40 (414)	1.95 (323)	0.45 (197)
1996	20	0.00	0.25 (364)	0.45 (274)
1986–1989	124	0.27 a (361)	0.30 a (302)	0.33 a (207)
1991–1996	132	0.59 a (464)	1.27 b (302)	1.03 b (242)

Black crappie mean length at age estimates at Sam Rayburn Reservoir exceeded the averages from the ecological region, both before and after implementation of the regulation (Table 2). White crappie mean length at age estimates were lower than the ecological region averages, with the exception of age-2 fish, before implementation of the regulation and exceeded those averages following implementation of the regulation. Pre- and post-regulation averages indicated that white crappie growth generally exceeded that of black crappie with the exception of age-1 and age-4 fish during the pre-regulation period. On average, white and black crappie recruited to 254 mm during their second and third year, respectively, both before and after the regulation was imposed. Growth rates of white crappie appeared to increase from the pre- to the

Table 2. Mean length at age of capture for white (W) and black (B) crappie (sexes combined) collected by fall trap netting at Sam Rayburn Reservoir, Texas, 1986 and 1989 (pre-regulation), and 1991, 1993, 1994, 1996, and 1997 (post-regulation) and Toledo Bend Reservoir, Texas, 1987, 1991, and 1993–1995. Sample sizes are in parentheses.

	Mean length (mm) at age of capture							
	Age 1		Age 2		Age 3		Age 4	
Year/Period	W	B	W	B	W	B	W	B
Sam Rayburn Reservoir								
Pre-regulation	154 (1)	184 (11)	260 (14)	217 (20)	263 (9)	242 (7)	296 (3)	297 (4)
Post-regulation	209 (23)	180 (30)	274 (24)	213 (42)	314 (7)	266 (15)	367 (2)	298 (1)
Toledo Bend Reservoir								
1987–1995	225 (43)	200 (30)	299 (43)	254 (18)	325 (7)	286 (2)	362 (5)	284 (1)
Averages[a]	185	155	246	198	292	236	325	269

a. Pineywoods ecological region averages from Prentice (1987), lengths derived for November 1.

post-regulation period, growth rates of age-1 and age-2 black crappie were slightly lower and age-3 and age-4 were higher following implementation of the regulation. Mean length at age estimates at Toledo Bend Reservoir generally exceeded, with exception of age-4 fish, those from Sam Rayburn Reservoir (Table 2). Although white crappie growth exceeded that of black crappie at Toledo Bend Reservoir, both typically reached 254 mm during their second year.

Creel Surveys

Mean estimates of crappie release rates, harvested lengths, and harvested weights at Sam Rayburn Reservoir increased during the post-regulation period (Table 3, $P \leq 0.001$). During the post-regulation period, documented illegal harvest was relatively low, ranging from 4.2% (1992) to < 1.0% of the harvest (1993, 1996, 1997, and 1998). Yearly trends of mean harvested length and weight were relatively consistent pre- and post-regulation (Fig. 1A). Trends in release rates were variable, rates declined prior to implementation of the regulation, increased, peaked in 1995 (1.50 fish/angler-hour), declined in 1997 (0.29 fish/angler-hour), then increased in 1998 (0.92 fish/angler-hour) (Fig. 1B).

Estimates of release rates at Toledo Bend Reservoir were relatively stable from 1989 to 1996 (Fig. 1F). The 1989–1996 mean release rate (0.29 fish/angler-hour) was similar to the pre- and considerably lower than the post-regulation estimates at Sam Rayburn Reservoir (Table 3). Trends of mean harvested lengths and weights were similar at Toledo Bend Reservoir. Both variables increased through 1992, declined through 1994, and increased up to 1996 (Fig. 1E). Both mean harvested length (262 mm) and weight (0.35 kg) were higher than pre- and lower than post-regulation estimates at Sam Rayburn Reservoir (Table 3).

Angler catch rates of crappie at Sam Rayburn Reservoir did not increase significantly post-regulation (1.18 to 1.60 fish/angler-hour, $P = 0.12$, Table 3). Similar to

Table 3. Mean creel statistics for crappies caught while being sought at Sam Rayburn Reservoir, Texas, pre-regulation period (1987–1989) and post-regulation period (1991–1998) and Toledo Bend Reservoir, Texas-Louisiana, 1989–1996. N = number of creel interviews or years. Coefficient of variation for estimates are enclosed in parentheses. Means followed by the same letter are not significantly different (one-way ANOVA, $P < 0.10$).

	Sam Rayburn				Toledo Bend	
Creel statistic	N	Pre-regulation	N	Post-regulation	N	1989–1996
Catch rate (fish/hr)	473	1.18 a (152)	1,215	1.60 a (193)	1,040	1.65 (142)
Release rate (fish/hr)	473	0.30 a (235)	1,215	0.92 b (270)	1,040	0.29 (301)
Harvested length (mm)	274	248.00 a (13)	708	288.00 b (9)	702	262.00 (13)
Harvested weight (kg)	274	0.30 a (39)	708	0.42 b (26)	702	0.35 (39)
Harvest rate (fish/hr)	473	0.87 a (157)	1,215	0.67 a (178)	1,040	1.36 (143)
Harvest rate (kg/hr)	473	0.24 a (158)	1,215	0.27 a (185)	1,040	0.44 (149)
Directed effort (hours/ha)	3	10.85 a (50)	8	7.38 a (44)	8	5.11 (35)
Yield (fish/ha)	3	9.11 a (63)	8	5.13 a (47)	8	8.41 (57)
Yield (kg/ha)	3	2.48 a (64)	8	2.08 a (44)	8	2.75 (63)
Fishing success rating[a]	473	2.49 a (46)	1,214	2.59 a (47)	1,037	2.71 (42)

a. Angler rating of completed fishing trip success in which codes 1–5 were assigned to very poor, poor, average, good, and very good, respectively.

trends observed with release rates, catch rates were variable among years (Fig. 1B). The 1989–1996 mean catch rate at Toledo Bend Reservoir (1.65 fish/angler-hour) was similar to the Sam Rayburn Reservoir post-regulation period estimate (Table 3). Catch rates also varied at Toledo Bend Reservoir (Fig. 1F). Estimates of harvest rates, expressed as fish/angler-hour, were similar during the pre- (0.87 fish/angler-hour) and post-regulation periods at Sam Rayburn Reservoir (0.67 fish/angler-hour, Table 3, $P = 0.45$). Yearly estimates ranged from 0.40 to 1.06 fish/angler-hour over the study period (Fig. 1C). Likewise, harvest rates by weight were similar between pre- and post-regulation periods (0.24 and 0.27 kg/angler-hour respectively, Table 3, $P = 0.71$) and varied little among years (range 0.14–0.41 kg/angler-hour, Fig. 1C).

Mean harvest rates at Toledo Bend Reservoir (1.36 fish and 0.44 kg/angler-hour) were higher than for either period at Sam Rayburn Reservoir (Table 3). Numbers of fish harvested per angler-hour varied among years, rates declined through 1992, increased up to 1995, then declined in 1996 (Fig. 1G). In terms of weight, harvest fluctuated little among years (range 0.33–0.56 kg/angler-hour).

Neither directed effort nor yield was significantly different between the pre- and post-regulation period at Sam Rayburn Reservoir (Table 3, $P \geq 0.31$). Directed effort and yield dramatically declined in 1989 (Fig. 1D). During the post-regulation period, these variables fluctuated within a narrow range, with the exception of declines in 1993 and 1997.

Directed effort at Toledo Bend Reservoir (5.11 hours/ha) was lower than that observed at Sam Rayburn Reservoir (Table 3). Estimates varied among years, values peaked in 1990 and 1994 (Fig. 1H). Yield by number (8.41 fish/ha), was lower than the pre- and higher than the post-regulation estimates at Sam Rayburn Reservoir (Table 3). Yield by weight (2.75 fish/kg), was higher than for either period at Sam

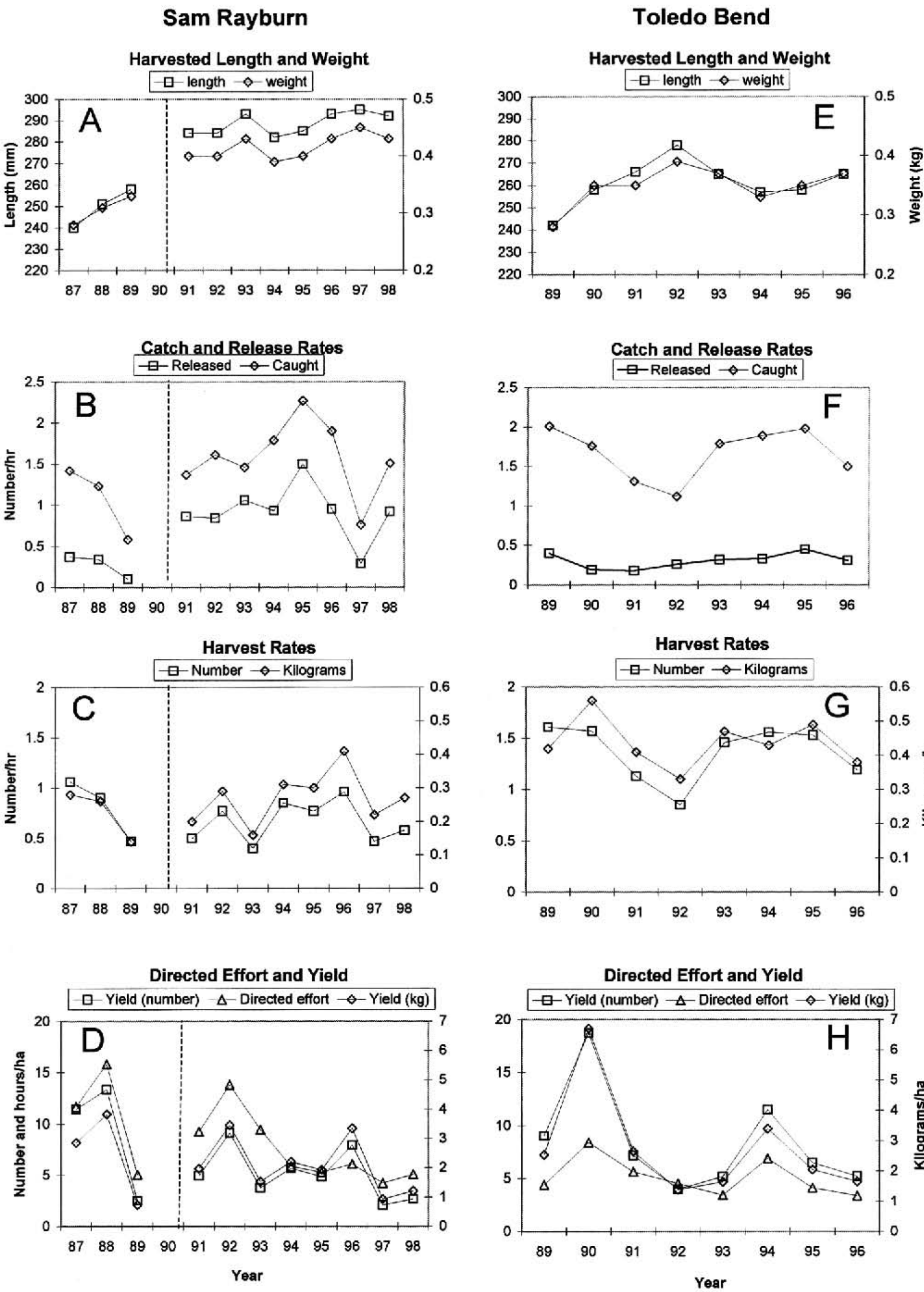

Figure 1. Yearly estimates of creel survey statistics from anglers seeking crappies (black and white combined) at Sam Rayburn (1987–1989, 1991–1998) and Toledo Bend reservoirs, 1989–1996. Dashed line represents September minimum length limit implementation.

Rayburn Reservoir. Both yield estimates were highly variable, with peaks in 1990 and 1994 (Fig. 1H).

Crappie angler opinion ratings of fishing success at Sam Rayburn Reservoir were similar between the pre- and post-regulation period (2.49 and 2.59, respectively, Table 3, $P = 0.20$) and varied little among years (range 2.10–2.75). Success ratings were slightly higher and relatively stable at Toledo Bend Reservoir (2.71, Table 3).

The distribution of angler bag sizes at Sam Rayburn Reservoir was similar between the pre- and post-regulation period as well as among years (Fig. 2). Most angler bag sizes consisted of ≤5 fish (73% pre- and 80% post-regulation, range 66%–86% from 1987–1998). In both the pre- and post-regulation periods, only 1.1 % of anglers harvested ≥25 fish. Out of 883 total angling parties encountered during the post-regulation period, only one exceeded their daily bag limit. Average bag sizes at Toledo Bend Reservoir were also similar among years, but the percentage of anglers with ≥10 fish was greater than at Sam Rayburn Reservoir (Fig. 2).

Discussion

As expected, and as other studies have shown, release rates (Hale et al. 1999) and mean length (Colvin 1991, Webb and Ott 1991, Hale et al. 1999) and weight (Webb and Ott 1991) of harvested crappies were significantly higher during the post-regulation period at Sam Rayburn Reservoir. Increases in each of these parameters are the direct result of compliance with the MLL. Voluntary changes in angler behavior were not apparent as release rates and mean total length and weight of harvested crappies during the pre-regulation period at Sam Rayburn Reservoir were similar to those at Toledo Bend Reservoir over the entire study period. The substantial increase in release rates indicates anglers were willing to harvest crappies <254 mm before the limit was imposed. During the pre-regulation period, harvested crappies averaged 248 mm in length and were primarily age 2–3, indicating angler harvest was comprised primarily of young fish. Webb and Ott (1991) studied the effects of crappie harvest at unregulated Texas waters and documented populations of predominantly small, young fish, and attributed this to growth overfishing. Following the change to the 254-mm MLL at Sam Rayburn Reservoir, the mean length of harvested fish increased to 288 mm, or approximately 3–4-year-old fish. Colvin (1991) stated a good management strategy would be, based on equilibrium yield models, to maximize harvest of age 3–4 white crappie while reducing or eliminating harvest of age 1–2 fish. The average size of harvested crappies increased 40% from 0.30 kg during the pre-regulation period to 0.42 kg following the change. Similarly, Webb and Ott (1991) noted a 254-mm MLL significantly increased the mean weight of harvested crappie where growth overfishing had occurred.

The significant increases in trap net catch rates of both protected (<254 mm) and legal size crappies (≥254 mm) coupled with the 36% increase in angler catch rates suggest that the density of stock size crappie increased during the post-regulation period at Sam Rayburn Reservoir. One or more abundant year classes during the post-regulation period likely contributed to these increases. The relatively large in-

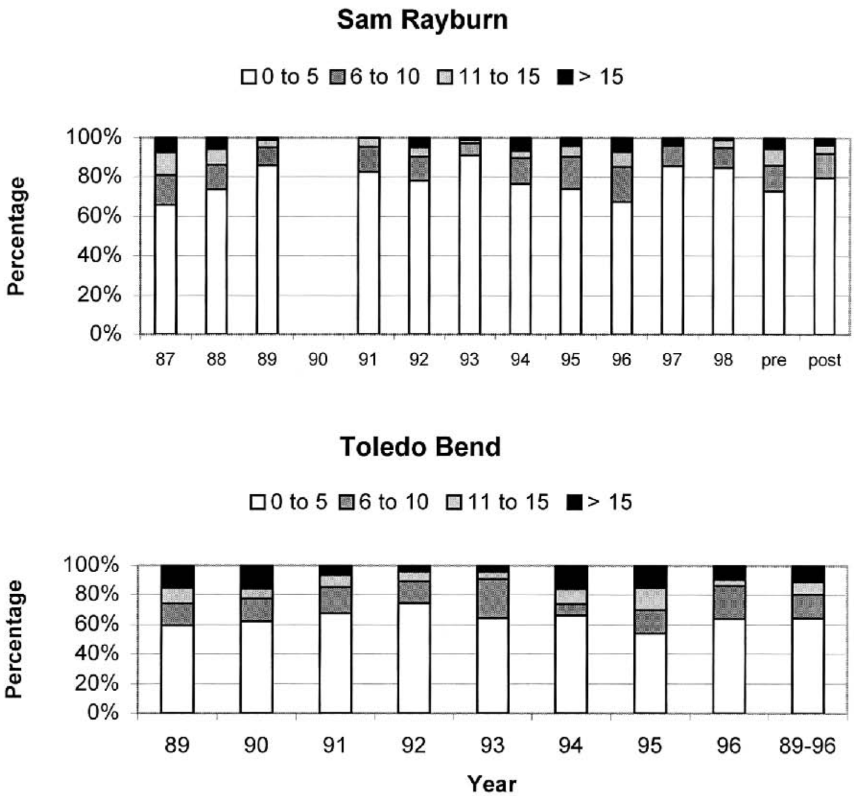

Figure 2. Frequency distributions of crappie angler bag sizes for annual creel surveys at Sam Rayburn (1987–1998) and Toledo Bend reservoirs (1989–1997).

crease in angler catch rates also may have been influenced to some extent by multiple catch and release events of sub-legal fish. The higher trap net CPE for protected length fish was consistent with what Hale et al. (1999) observed following the implementation of a 254-mm MLL on crappie at Delaware Reservoir, Ohio. However, in contrast to their findings, the greatest increases at Sam Rayburn Reservoir occurred in the smaller stock length range (127–203 mm).

The concomitant significant increase in trap net catch rates of two size groups (204–253 and ≥254 mm) of crappies at Toledo Bend Reservoir over compatible time periods suggests factors other than the regulation could have exerted an influence. Both reservoirs experienced water level fluctuations, some severe, over the study period. The impact of these fluctuations and resulting environmental conditions on crappie production at each respective reservoir was not directly assessed in this study. However, the correlation between environmental or hydrological conditions and crappie production in reservoirs has been well established (Beam 1983, Willis 1986, McDonough and Buchanan 1991, Mitzner 1991, Maceina and Stimpert 1998).

Since crappie fisheries tend to be harvest-oriented (Jenkins and Morais 1971, Campbell et al. 1978), harvest rates (fish/hr and kg/hr) and total yield (fish/ha and kg/ha) may be the most important variables relative to restrictive harvest regulations. Reduction in crappie harvest may occur quite commonly as a trade-off for larger fish in the creel (Allen and Miranda 1995, Hale et al. 1999). Hale et al. (1999) considered a 78% decrease in crappie harvest rates following the implementation of a 254-mm MLL at Delaware Reservoir, Ohio, too great to compensate for larger fish. In contrast, at Sam Rayburn Reservoir the number harvested per hour declined only 23% while the weight harvested per hour increased 13% during the post-regulation period. At Sam Rayburn Reservoir, yield was not significantly different between the pre- and post-regulation periods. Although an increase in crappie yield would have been preferred, Allen and Miranda (1995) indicated that is more the exception than the rule at reservoirs due to high natural mortality.

Consistently good growth of crappie throughout the 8-year regulation period at Sam Rayburn Reservoir suggests no reduction in growth from the accumulation of several large year classes in the protected size range, as considered by Reed and Davies (1991). The rapid white crappie growth in Sam Rayburn Reservoir (254 mm at age 2) greatly exceeded what Colvin (1991) considered necessary for minimum length limits to improve white crappie fisheries (229 mm at age 3) as well as what Allen and Miranda (1995) found would be required for adequate yield and average weight of white crappie fisheries (230 mm by age 3). Black crappie growth at Sam Rayburn Reservoir (254 mm by age 2 or age 3) appeared superior to that predicted for high-density black crappie populations to provide viable fisheries in Florida lakes (255-mm by age 3, Allen et al. 1998). Allen et al. (1998) observed that black crappie length at age 3 was related to population densities in Florida lakes and was reduced in high-density populations compared to low-density populations.

Researchers have proposed that MLLs might work to moderate or eliminate variable abundance (Miller et al. 1990, Colvin 1991, Mitzner 1995) and maintain a more stable supply of preferred-size crappies (Webb and Ott 1991). However, these potential effects have not been evaluated (Miranda and Allen 2000). At Toledo Bend Reservoir, yield and directed effort were relatively high during two of the eight study years. The level of directed effort and harvest over annual periods there increased proportional to the number of young, small fish in the creel, suggesting a pattern of overharvest or growth overfishing similar to that described by Webb and Ott (1991). Apparently at this reservoir anglers greatly intensified their effort for crappies during years of plentiful supplies of young fish and would harvest much of that increased supply within one year. During each successive year, young fish comprised an ever-smaller portion of the progressively declining harvest until annual harvest was finally reduced to the predominant, but few, older fish that remained. With the increased supply of young crappies the following year, once again more anglers returned to the fishery and this pattern was repeated.

Conversely, at Sam Rayburn Reservoir, the overall range of harvest and directed effort during the post-regulation period seemed to be reduced, possibly indicating more stable recruitment and a more consistent fishery due to the MLL. No exception-al spikes in yield and effort were noted. In contrast to Toledo Bend Reservoir, there seemed to be less of a relationship between directed effort and harvest with size of fish harvested. Annual harvest rates generally trended higher throughout the post-regulation period, apparently due to increased densities of protected-length fish and their recruitment into the fishery, as well as the increased supply of adult fish ≥254 mm.

Another potential concern when imposing a MLL is the impact hooking mortality may have on the population as a result of increased release of small fish. Hooking mortality was not addressed as part of this evaluation, but previous studies have generally shown adequate survival of angler-caught crappies, even for multiple catch and release events (Childress 1987, Colvin 1991). It is unlikely hooking mortality significantly affected results at Sam Rayburn Reservoir, considering the 36% increase in total catch rates and the sustained levels of harvest and yield during the regulation period.

Typically, bag limits are implemented to more evenly distribute harvest among anglers (Noble and Jones 1999). Although the 25-fish bag limit was incorporated as part of the crappie regulations at Sam Rayburn Reservoir, this limit was not effective. The distribution of bag sizes was similar during the pre- and post-regulation periods, the majority were ≤5 fish. Only 1.2% of crappie anglers actually harvested their limit of 25 fish. Seldom are bag limits biologically effective and tend to be used by anglers as more of a gauge of fishing success (Noble and Jones 1999). For example, at Upper Red Lake, Minnesota, Cook et al. (2001) demonstrated a positive relationship between the number of black crappie harvested and how anglers rated fishing.

Summary and Management Implications

Study results showed that following implementation of crappie MLL and bag limits, the size of harvested crappies increased and harvest rates and yield were maintained as desired; however, some evidence indicated catch rates increased, exceeding expectations. In addition, our study indicated that implementing a MLL has the potential to increase the density of crappies. However, environmental and hydrologic conditions probably had a comparable affect on crappie year class strength, specific effects due to the MLL and these factors in this study were impossible to separate. Due to the harvest-related nature of the crappie fishery at Sam Rayburn Reservoir, ideal results would have included increases in total yield.

Although this study demonstrated the ability to alter crappie harvest characteristics, the specific desires of crappie anglers at Sam Rayburn Reservoir are currently unknown. Based on similar fishing success ratings between the pre- and post-regulation periods, it appears that increasing total catch rates and average size of crappies harvested had no effect on Sam Rayburn Reservoir crappie anglers. However, if opinions of Toledo Bend Reservoir anglers are reflective of those at Sam Rayburn Reservoir, a majority of anglers support the 254-mm MLL. In 1997, TPWD imposed the 254-mm MLL at Toledo Bend Reservoir, Texas. A study by Thailing and Ditton (2000) revealed that only 20% of Texas anglers at Toledo Bend Reservoir were opposed to this regulation. By implementing MLLs, fishery managers may have the potential to provide different types of crappie harvest opportunities. Due to the demonstrated and increasing specialization among crappie anglers (Allen and Miranda 1996), future research should address the specific types of opportunities that crappie anglers prefer.

This study demonstrated that the 25-fish bag limit was not biologically effective. Due to a relatively even distribution of harvested crappies among anglers, our results do not necessarily indicate a need for a more effective bag limit. However, limits set too high may provide anglers with unrealistic expectations of their potential harvest (Cook et al. 2001). Therefore, one management option would be to eliminate the bag limit entirely at Sam Rayburn Reservoir. However, due to the demonstrated benchmark role that creel limits serve, fishing success is at least partially related to the creel limit in place (i.e., the percentage of crappie anglers that catch a limit is positively related to fishing satisfaction) (Cook et al. 2001). Although crappie fishing success ratings at Sam Rayburn Reservoir were deemed acceptable during the post-regulation period (between average and good), decreasing the bag limit could enhance fishing satisfaction and provide more realistic harvest expectations. Due to the harvest-oriented nature of the Sam Rayburn Reservoir crappie fishery, we speculate that a reduction in the 25-fish bag limit would be unpopular with a majority of anglers and may cause a decline in directed effort. Even though our study indicated that harvesting a creel limit was a rare event, anglers tend to be optimistic and value the opportunity to harvest a higher limit of fish (Cook et al. 2001).

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