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Effect and Acceptance of Bluegill Length Limits in Nebraska Natural Lakes

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Abstract.—Bluegill *Lepomis macrochirus* populations in 18 Nebraska Sandhill lakes were evaluated to determine if a 200-mm minimum length limit would increase population size structure. Bluegills were trap-netted in May and June 1998 and 1999, and a creel survey was conducted during winter 1998–2001 on one or two lakes where bluegills had been tagged to determine angler exploitation. Thirty-three percent of anglers on one creeled lake were trophy anglers (i.e., fishing for large [$\geq$250 mm] bluegills), whereas 67% were there to harvest fish to eat. Exploitation was always less than 10% and the total annual mortality averaged 40% across all 18 lakes. The time to reach 200 mm ranged from 4.3 to 8.3 years. The relative stock density of preferred-length fish increased an average of 2.2 units in all 18 lakes with a 10% exploitation rate. However, yield declined 39% and the number harvested declined 62%. Bluegills would need to reach 200 mm in 4.2 years to ensure no reduction in yield at 10% exploitation. Both yield and size structure were higher with a 200-mm minimum length limit (relative to having no length limit) only in populations with the lowest natural mortality and at exploitation of 30% or more. Although 100% (N = 39) of anglers surveyed said they would favor a 200-mm minimum length limit to improve bluegill size structure, anglers would have to sacrifice harvest to achieve this goal. While a 200-mm minimum length limit did minimally increase size structure at current levels of exploitation across all 18 bluegill populations, the populations with the lowest natural mortality and fastest growth provided the highest increase in size structure with the lowest reduction in yield and number harvested.

Bluegill *Lepomis macrochirus* populations are often managed for harvest with little attention being given to the quality of the fish harvested. However, recent concern over the reduced size structure of bluegill populations has led to increased efforts to create or maintain bluegill populations with a higher proportion of larger individuals. The average size of harvested bluegills decreased over a 58-year period in Minnesota (Olson and Cunningham 1989), while the proportion of larger bluegills harvested by anglers in Wisconsin declined over an 11-year period (Beard and Kampa 1999). The authors attributed these changes, in part, to increased harvest by anglers.

Increased bluegill harvest may reduce size structure and increase bluegill mortality (Goedde and Coble 1981; Coble 1988). Coble (1988) reviewed bluegill literature and found an average exploitation rate of 27% across 46 estimates, whereas Kruse (1997) found bluegill exploitation of 10–36% in small Missouri impoundments, and Parsons and Reed (1998) found bluegill exploitation ranging from 8% to 32% in four Minnesota natural lakes. Goedde and Coble (1981) estimated that 13% of bluegills greater than 150 mm were harvested within the first 3 d of Mid Lake, Wisconsin, being opened to angling; exploitation from the first month after opening was 35%.

Although exploitation may influence bluegill populations, other factors (such as recruitment, growth, and predation) may also exert a substantial influence (Novinger and Legler 1978; Coble 1988; Parsons and Reed 1998; Paukert et al. 2002). In these Sandhill lakes, largemouth bass *Micropterus salmoides* predation was important in creating high-quality bluegill populations (Paukert et al. 2002), which is similar to Midwestern impoundments (Novinger and Legler 1978). In Minnesota, the study lake with the highest bluegill exploitation also had the highest size structure, which was attributed to fast growth (Parsons and Reed 1998). Coble (1988) suggested that high exploitation, coupled with relatively high recruitment, may keep

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bluegill size structure low. Although bluegill reproductive strategies may influence population size structure (e.g., Jennings et al. 1997), angling mortality is typically considered the most important factor in structuring bluegill populations (Beard and Essington 2000).

Length limits have been used to restructure centrarchid populations (e.g., Hickman and Congdon 1974; Novinger 1990; Colvin 1991; Newman and Hoff 2000), but have only recently been utilized for bluegill management. An assessment of 49 largemouth bass minimum length limits, however, revealed that they did not necessarily increase the population size structure (Wilde 1997). Harvest regulations (such as a minimum length limit) should only be used when harvest is considered excessive and natural mortality is relatively low. If exploitation is very low, a harvest regulation would be ineffective. If natural mortality is high, older fish may die before being susceptible to angler harvest, thus the length limit would be ineffective (e.g., Hale et al. 1999). In addition, creel data need to be an integral part of a length limit evaluation (Wilde 1997), as angler attitudes and compliance with the regulation may dictate effectiveness (Gigliotti and Taylor 1990; Pierce and Tomcko 1998).

Our objective was to assess the potential effectiveness of a 200-mm minimum length limit on bluegill populations in Nebraska Sandhill lakes through population modeling. The goal of a length limit was to improve size structure to create high-quality fisheries. In light of this objective, we were more concerned with the effects of the length limit on size structure and not yield (e.g., Allen and Miranda 1995). To achieve this objective, we first needed to determine if anglers were willing to comply with a minimum length limit and if exploitation was sufficiently high to make a length limit effective.

Methods

Study area.—Eighteen lakes in north-central Nebraska were sampled for bluegills. These lakes varied in surface area from 19 to 332 ha, were shallow (mean depth from 1.2 to 2.9 m), and had alkalinity values from 85 to 447 mg/L. Summer angling was limited for bluegills in these lakes because of limited access, restrictions (e.g., no outboard motors allowed on 8 lakes), and high submergent vegetation coverage during midsummer (mean = 48%; range = 4–97%).

The fish communities in these lakes were relatively simple. Largemouth bass were found in all 18 lakes and appeared to be the primary predator on bluegill (Paukert et al. 2002). Northern pike *Esox lucius* were present in 10 lakes, yellow perch *Perca flavescens* in 17 lakes, and black bullhead *Ameiurus melas* in 12 lakes. Black crappies *Pomoxis nigromaculatus* were present in only 8 lakes, whereas common carp *Cyprinus carpio* were present in 5 lakes. The current angling regulations for bluegills in all lakes was no length limit and a daily bag limit of 30 panfish (e.g., black crappie, yellow perch, and bluegill) in aggregate.

Fish population assessments.—Eighteen bluegill populations were sampled in May and June of 1998 and 1999 at randomly selected locations with overnight sets of double-throated trap (i.e., modified fyke) nets with 16-mm-bar measure mesh, 1.1- × 1.5-m frames, and 22-m leads. The total sampling effort was 10 trap-net nights in lakes less than 50 ha and 20 trap-net nights in lakes of 50 ha or more. Bluegill catch per unit effort (CPUE) was expressed as the number of fish greater than or equal to 80 mm collected per trap-net night. Ten bluegill per cm length-group were measured for total length (mm) and weighed (nearest g), and scales were taken for age estimation. All additional fish were tallied by cm group. Growth was assessed using the time (in years) to reach 200 mm derived from the von Bertalanffy growth function (Ricker 1975). Bluegill size structure was quantified using the relative stock density of preferred-length (i.e., 200 mm) fish (RSD-P; Anderson and Neumann 1996) for population samples containing at least 20 stock length fish (Paukert et al. 2002).

Bluegill exploitation and angler attitudes.—Bluegill exploitation was estimated using tag returns by anglers on two Sandhill lakes during 1998–2001. In September of each of the 3 years, bluegills were collected using trap nets set overnight, measured to the nearest mm, and tagged with an individually numbered T-bar anchor tag (model FD-94; Floy Tag Inc., Seattle, Washington). All fish were immediately released after tagging. Bluegills were tagged in Pelican Lake in each of the 3 years and also in Hackberry Lake in 1998. Each Floy tag had an individual number and the address of the Nebraska Game and Parks Commission. Reward signs (a drawing for a power ice auger was held at the end of each season) and tag return boxes were placed around the lakes to promote tag returns by anglers. Creel surveys were conducted during the winter months of 1998–2001. To account for tag loss, 299 fish tagged in 2000 were also tagged with a 3-cm-thin diameter nylon T-bar tag. To adjust for nonreporting, all tagged fish the creel clerk saw were recorded on the data sheet; however, the clerk did not offer any encouragement to return the tag. Nonreporting was estimated by the proportion of tags the creel clerk saw in the field that were not subsequently returned.

The creel clerk also asked a series of questions to bluegill anglers on Pelican Lake during the winter of 2000–2001. Bluegill anglers were asked (1) if they were on the lake to harvest fish to eat, to catch and release fish, or to catch a master angler (i.e., $\geq$250 mm) bluegill; (2) if they were willing to release all bluegill less than 200 mm if it increased the number of bluegill 250 mm and longer, thus simulating a minimum length limit; and (3) their residency. The questions did not address the extent of the possible reduction in the number of fish harvested with a minimum length limit. Angler residency was separated into local (residents of the county in which the lake was located), nonlocal (Nebraska residents in other counties), and non-Nebraska residents. A likelihood ratio (G) chi-square test was used to determine if angler opinions (i.e., why anglers were fishing that day) were similar across residency.

Population modeling.—We used the Fishery Analysis and Simulation Tools (FAST) model (Slipke and Maceina 2000) to model the likely response of Sandhill lakes bluegill populations to a 200-mm minimum length limit compared to no length limit. We used the dynamic pool model in FAST that allows the input of variable recruitment (Slipke and Maceina 2000) because recruitment variability may override length limit effects (Allen and Pine 2000). This model uses the Jones modification of the Beverton and Holt equilibrium yield model and assumes a type-II fishery (Ricker 1975).

Growth and mortality parameters were estimated from fish in our trap-net samples. Weight-length parameters (i.e., a and b) were estimated for each population from our sampled fish using linear regression from the relationship between $\log_{10}$ length and $\log_{10}$ weight. The theoretical maximum length (L_∞), the growth constant (k), and age at length zero (t_0) were estimated from the von Bertalanffy growth functions (Ricker 1975). Nonlinear regression was used to estimate the von Bertalanffy model parameters. Total instantaneous mortality (Z) was estimated from the descending limb of catch curves for each population. When erratic recruitment prevented the estimation of total mortality from the catch curve, we used the mean total annual mortality from other Sandhill populations where mortality estimates could be computed. We estimated conditional fishing (m) and natural mortality (n) from exploitation rates from the creel data and mortality estimates from the catch curve data. We calculated n (assuming $m = 0.00$) and then held this value fixed for each population, adjusting m to approximate exploitation rates of 10–50% at 10% intervals. Variable recruitment was accounted for using catch at age 3 in trap nets in one Sandhill lake (Hackberry Lake; W. Stancill, U.S. Fish and Wildlife Service, unpublished data) that we adjusted to have a mean of 1,000 recruits. We used catch at age 3 because we considered age-3 fish to be recruited to the trap nets in all lakes sampled and we had no index of age-1 recruitment. Although sampling for younger fish would provide a better estimate of recruitment variability, our data nonetheless still provided us with an index of recruitment.

The model was run for a 20-year simulation, but analysis was conducted for years from the oldest age fish in each population up to the 20 years. The mean yield (kg), the annual number harvested, and the size structure (RSD-P) were calculated. To standardize changes in these parameters across lakes, we calculated the percent change in yield and number harvested, but not RSD-P as it is already a percentage. Linear regression was used to determine the relationship between growth and the change in yield, the change in the number harvested, and size structure.

Results

Bluegill population characteristics varied among water bodies (Table 1). Bluegill mean CPUE ranged from 3 to 233 fish per trap net, while RSD-P ranged from 0 to 74. We collected at least 100 80-mm and longer bluegills in all but two lakes sampled. Growth also was variable, with the time to reach 200 mm ranging from 4.3 to 8.3 years. However, only 7 of the 18 populations attained 200 mm in less than 5 years. The theoretical maximum length (L_∞) was greater than 250 mm for eight populations, with one population attaining 300 mm and none attaining less than 200 mm.

The total annual mortality could not be computed for eight populations because of erratic recruitment; therefore, we used the Sandhills average of the 40% for those populations. Clear Lake bluegill mortality was actually computed at 40% (Table 1). The total annual mortality was typically low, with a maximum value of 53% and an estimated value for four of the populations below 40% (Table 1). Recruitment, based on the 7-year Hack-

Table 1.—Population statistics and von Bertalanffy parameters for 18 bluegill populations in Nebraska Sandhill lakes. Abbreviations are as follows: N = number of 80-mm and longer bluegills sampled; CPUE = mean catch per unit effort of 80-mm and longer fish (per trap-net night), with standard errors in parentheses; RSD-P = the relative stock density of 200-mm and longer fish, with 95% confidence intervals in parentheses; T_{200} = the time in years to reach 200 mm; L_∞ = the theoretical maximum length (mm); t_0 = the intercept for the von Bertalanffy growth function; k = the growth constant; A = total annual mortality. When erratic recruitment prohibited the estimation of A, we used a Sandhill average of 0.40.

Lake	N	CPUE	RSD-P	T_{200}	L_∞	t_0	k	A (%)
Alkali	1,712	86 (23)	22 (2)	4.3	276	0.55	−0.35	0.40
Clear	226	11 (2)	14 (4)	5.2	227	0.57	−0.46	0.40
Clear–NWR[1]	227	11 (3)	22 (5)	6.1	208	0.66	−0.60	0.40
Cozad	2,325	233 (29)	0	6.2	279	0.24	−0.21	0.40
Dewey	397	20 (4)	14 (4)	4.9	268	0.40	−0.30	0.37
Duck	213	21 (11)	2 (2)	5.9	232	0.24	−0.35	0.45
Goose	235	12 (2)	10 (4)	5.1	234	0.34	−0.40	0.44
Hackberry	305	15 (3)	14 (4)	5.3	268	0.48	−0.28	0.39
Island	410	21 (4)	74 (4)	5.1	243	0.48	−0.38	0.40
Medicine	584	58 (15)	10 (2)	4.4	291	0.41	−0.29	0.40
Pelican	3,543	177 (24)	10 (1)	4.7	311	0.48	−0.24	0.25
Schoolhouse	32	3 (2)	9 (11)	5.5	237	0.43	−0.37	0.40
Shell	239	12 (2)	6 (3)	8.3	237	0.25	−0.23	0.47
Shoup	64	6 (1)	39 (12)	4.7	246	0.50	−0.40	0.15
Tower	131	13 (4)	7 (5)	4.9	247	0.45	−0.37	0.50
Twin	146	7 (2)	40 (8)	7.3	213	0.45	−0.41	0.40
Watts	641	32 (4)	12 (2)	4.3	257	0.49	−0.39	0.53
West Long	283	28 (5)	40 (5)	5.1	250	0.46	−0.34	0.40

[1] Valentine National Wildlife Refuge.

berry Lake data, was relatively stable (with a mean of 22 age-3 bluegills collected annually via electrofishing and trap-netting combined, and a coefficient of variation [CV = 100 × SD/mean] equal to 64.5%).

Creel survey data on two lakes indicated that the minimum length of bluegills anglers were willing to harvest was about 150 mm and that exploitation was below 10%. The 1998 Pelican Lake sample indicated that 98% of fish below 150 mm were released, whereas only 51% of the 150- to 180-mm fish were released. The 1998 Hackberry Lake sample indicated that 100% of fish below 150 mm were released and 100% of 150- to 180 mm fish were kept. However, larger fish were also released, as 28% of the 250- to 280-mm bluegill caught in Pelican Lake were released. In 1998, 529 fish were tagged in Pelican Lake and 337 in Hackberry Lake, but only 24 tags in Pelican Lake and 8 in Hackberry Lake were returned by anglers. Only Pelican Lake bluegills were tagged in 1999 and 2000. In 1999, only 4 of 694 tags were returned by anglers and only 16 of 376 tags were reported by anglers in 2000. In 2000, 299 bluegills were double-tagged to estimate tag loss. However, only one of the double-tagged fish was harvested and it had both tags, resulting in a 100% tag retention. Nonreporting was estimated at 25%, as the creel clerk saw four tags in the creel, with three being subsequently returned. After correcting for nonreporting, our exploitation estimates ranged from 0.8% to 6.0% across all years and lakes. In light of these estimates, we assumed a 10% exploitation rate for our modeling exercise and assumed that modeling a minimum length of 150 mm would constitute modeling essentially no length limit.

Anglers favored of a minimum length limit on Pelican Lake, although the reasons for angling for bluegills varied. All 39 anglers having an opinion were in favor of a minimum length limit if it increased the number of larger (e.g., ≥250 mm) bluegills. Sixty-seven percent of the anglers preferred to harvest fish to eat, whereas 33% preferred to catch a Master Angler (i.e., >250 mm) bluegill. However, size preferences did not depend on angler residency ($G = 0.99$; df = 2; $P = 0.61$).

The FAST model predicted an average of 38.6% reduction in yield and a 61.7% reduction in the number harvested across all populations at 10% exploitation, whereas RSD-P increased by an average of only 2.2 units (Figure 1). All populations experienced an increase in size structure (range = 0.5–3.4) and a decrease in yield (range = −11.9 to −79.5%) and the number harvested (range = −31.8% to −96.5%). The model indicated that anglers would need to sacrifice yield and number harvested to minimally increase bluegill size struc-

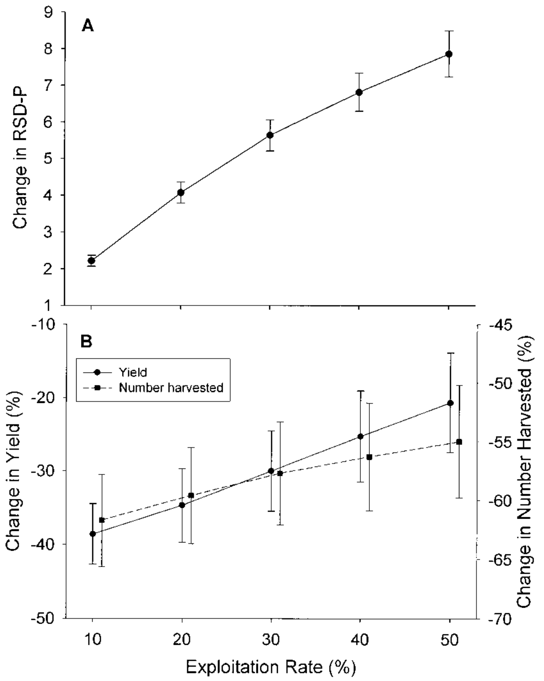

FIGURE 1.—Simulated changes in (**A**) the relative stock density of preferred-length fish (RSD-P) and (**B**) the percent change in yield (left scale) and number harvested (right scale) at five exploitation levels after implementation of a 200-mm minimum length limit on bluegills in Nebraska Sandhill lakes. Values represent the means of 20-year simulations run on 18 bluegill populations; rror bars represent 1 SE. Values are offset on (B) for clarity. We assumed a current exploitation level of 10%.

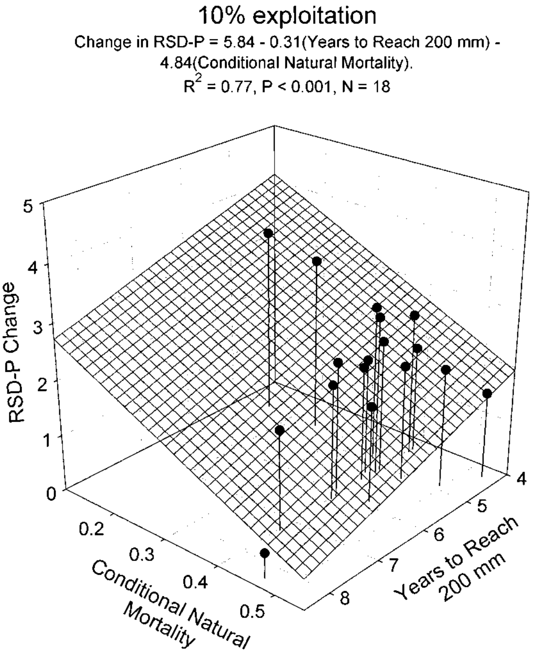

FIGURE 2.—Results of the multiple regression model using conditional natural mortality and years to reach 200 mm to predict the change in the relative stock density of preferred-length and longer bluegills (RSD-P) at an assumed 10% exploitation level. Points represent actual values estimated from 18 populations in our simulation modeling. One observation is hidden because of very similar values for all three parameters.

ture. Increasing exploitation levels from 10% to 50% increased size structure and reduced yield and number harvested. However, yield and number harvested were still reduced with a 200-mm minimum length limit (Figure 1). At 30% exploitation, only two populations (Pelican and Shoup) had an increased yield with the length limit. These two populations exhibited fast growth (time to reach 200 mm = 4.7 years), and the lowest conditional natural mortality (25% for Pelican Lake and 15% for Shoup Lake) of all the lakes sampled.

To have no reduction in yield (i.e., change in yield = 0), bluegills would need to attain 200 mm in 4.2 years or faster. When exploitation was increased to 50%, the time needed to reach 200 mm increased to 4.9 years (i.e., slower growth). However, these estimates were still below the Sandhill mean time to reach 200 mm of 5.4 years.

Change in bluegill RSD-P was strongly associated with bluegill growth and mortality. The change in size structure decreased with time to reach 200 mm and conditional natural mortality at 10% exploitation ($R^2 = 0.77$, $N = 18$, $P < 0.001$; Figure 2). The relationship was similar at all levels of exploitation ($R^2 = 0.77-0.93$). Collinearity diagnostics revealed that conditional natural mortality and the time to reach 200 mm were not collinear at any level of exploitation (condition indices from the collinearity diagnostics were 1.26 for all models). However, partial regression coefficients revealed that conditional natural mortality always had higher r^2 values (0.53–0.61) than time to reach 200 mm ($r^2 = 0.22$–0.34) at all exploitation levels.

Discussion

Our creel survey, population statistics, and modeling simulations suggest that, although anglers were in favor of a 200-mm minimum length limit, they would need to sacrifice yield and number harvested to gain a relatively small increase in size structure for these lightly exploited populations. The Nebraska Sandhills typically have high-quality bluegill populations (Paukert et al. 2002), with growth rates above the Midwest and South Dakota averages (Paukert et al. 2001). Total annual mortality was also relatively low, ranging from 15% to 53%, which was lower than the 59% to 88% estimates for other Midwestern populations (Goedde and Coble 1981; Coble 1988; Parsons and Reed 1998). In addition, our exploitation estimates were assumed to be low. Although our estimates were only for the winter period, we believe exploitation was minimal throughout the rest of the year because (1) no tags were returned from anglers other than in winter, and (2) few anglers were observed on Pelican Lake during April through October (personal observation). Even if exploitation was similar to that in the winter period, our highest estimate would then be 12%, which is still at or below estimates for a newly opened (i.e., 1 month of exploitation) Wisconsin lake (35%; Goedde and Coble 1981), seven Midwestern studies (12–45%; Coble 1988), four small Missouri impoundments (10–36%; Kruse 1997), and four Minnesota lakes (8–32%; Parsons and Reed 1998). Our tag return rate and tag loss information was limited because the creel clerk saw only four tags in the creel. However, our return estimate of 75% and tag retention (100%) was similar to that of Parsons and Reed (1998), who determined a reporting rate of 69% and tag retention of 93%.

Our total annual mortality estimates were based on scales, which may underestimate true age. However, scales may be satisfactory (when compared to otoliths) at northern latitudes (Kruse et al. 1993; Hoxmeier et al. 2001) where there is a distinct growing season. If we overestimated the true age of the bluegills in our study, then the total annual mortality would be lower, and we already found some of the lowest rates reported in the literature.

Anglers were willing to have a 200-mm minimum length limit on at least one Sandhill lake (Pelican) if the regulation increased the number of larger bluegill, even though about two of three anglers on the lake actually were there to harvest fish to eat. In contrast, Reed and Parsons (1999) found that 56% of Minnesota anglers would oppose a minimum length limit. Strong support for minimum length limits by anglers in our study may be a result of three things: (1) our low sample size ($N = 39$) may not be representative of the true angling population; (2) Pelican Lake typically produces trophy-size bluegills, with over 50% of Nebraska Master Angler bluegills (i.e., ($\geq$ 250 mm) coming from Pelican Lake in some years (D. Bauer, Nebraska Game and Parks Commission, unpublished data); and (3) the lakes surrounding Pelican Lake also produce high-quality bluegills (Paukert and Willis 2000) where anglers have other opportunities to harvest fish. If our sample does represent Sandhill anglers as a whole, our results may suggest that anglers are willing to promote a ‘trophy’ bluegill fishery in an area where other nearby lakes are available to provide fish for harvest.

Although anglers were willing to accept a minimum length limit, they would likely have to sacrifice yield and number harvested to increase the bluegill size structure. The size structure would increase only 2.2 RSD-P units at our assumed 10% exploitation, but the number harvested and yield would decrease by at least one-third in our simulation models. Other studies have suggested that a minimum length limit would increase size structure and yield if growth is fast and natural mortality is low (Allen and Miranda 1995). Our conditional natural mortality estimates were low to moderate, ranging from 15% to 53%, but our growth rates were not fast enough to compensate for the length limit and the yield was reduced. Even at exploitation levels up to 50%, the mean yield across all populations was reduced when compared to no length limit. However, at 30% exploitation and higher, two populations did show increased yield compared to no length limit. Both of these populations had moderate to fast growth, but the lowest conditional natural mortality of all populations sampled, suggesting that natural mortality is more important than growth in determining the effectiveness of bluegill length limits in these lakes (as also indicated by our multiple regression analyses). However, at current exploitation levels, yield would be reduced in all populations with the implementation of a minimum length limit.

Erratic recruitment may override the effects of a length limit (Allen and Pine 2000). However, recruitment variability was relatively low in our study with a $CV = 65\%$. Allen and Pine (2000) suggested that recruitment variability should be less than 90% for white crappie *Pomoxis annularis* populations (for a 254-mm minimum length limit) and less than 40–65% for largemouth bass populations (for 305- and 356-mm minimum length limits). Bluegill recruitment in Sandhill lakes may be sufficiently consistent to sustain higher densities of adult fish (i.e., high size structure) as suggested by Miranda and Allen (2000).

In addition to angling, predators and the environment may exert substantial influences on bluegill populations. Paukert et al. (2002) found that high largemouth bass abundance was important in creating quality bluegill populations in these lakes, which was similar to the results of other studies (e.g., Novinger and Legler 1978; Guy and Willis 1990). Fast bluegill growth has been attributed to increased alkalinity and decreased lake depth in Minnesota lakes (Tomcko and Pierce 2001), whereas increased emergent vegetation appeared to be important in creating quality bluegill populations in these Nebraska lakes (Paukert et al. 2002). Although exploitation may have a pronounced effect on bluegill populations, other factors need to be considered prior to the implementation of harvest restrictions.

In summary, bluegill length limits in these Sandhill lakes may provide a higher proportion of larger fish available to anglers, but the anglers need to be willing to harvest fewer fish. At the current levels of exploitation, length limits may not provide substantial benefits given the moderate growth and mortality of the fish. If exploitation increases (which may be occurring as these lakes have become increasingly popular with nonresident anglers), a minimum length limit may provide higher size structure with lower reductions in yield and number harvested. However, the populations should be monitored to evaluate the effects of the length limit on growth to ensure that bluegill growth will not decline under the length limit and thereby result in a decline in size structure.

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