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CAN MINIMUM LENGTH LIMITS IMPROVE SIZE STRUCTURE IN MINNESOTA BLACK CRAPPIE POPULATIONS?[1]

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Abstract—During 1993 to 2008 we monitored black crappie populations in four Minnesota lakes before and after implementation of minimum total length limits (MLLs; 9-, 10- and 11-in minimums) to determine whether these harvest regulations were effective in improving crappie size structure. Length frequencies of harvested black crappies observed in creel surveys conducted before MLLs were implemented suggested that in most instances MLLs would have reduced harvest by 40% or more had they been in place prior to 1997. However, no size structure improvements were apparent in three of the four lakes where MLLs were implemented. In Green Lake it appeared that the 9-in MLL had a positive impact on black crappie size structure in trap nets but size structure remained relatively poor when compared with other study lakes, and size structure of harvested crappies did not improve. Illegal harvest varied widely among fisheries, but in three of six creel surveys conducted after MLLs were implemented more than 20% of the crappies measured by creel clerks were smaller than the specified MLL.

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Minimum length limits (MLLs) have been widely used in an effort to reduce angler harvest within crappie fisheries *Pomoxis* spp. (Hale et al. 1999; Isermann et al. 2002; Hurley and Jackson 2002). Often one of the primary goals of these regulations is to improve crappie size structure (Hale et al. 1999; Bister et al. 2002; Hurley and Jackson 2002); however, MLLs are not always effective in achieving this goal (Bister et al. 2002; Hurley and Jackson 2002) or improvements in size structure have been outweighed by corresponding declines in harvest or yield (Hale et al. 1999; Boxrucker 2002).

Most of the previous evaluations of crappie MLLs have been conducted in the southern portion of the USA. Minimum length limits have seen relatively limited use for crappies in Minnesota and other portions of the Upper Midwest. One of the primary factors that can limit the success of crappie MLLs is the relatively high rate of natural mortality observed within many southern crappie populations (Larson et al. 1991; Reed and Davies 1991; Allen and Miranda 1995). Minimum length limits may prove more effective in improving crappie size structure in the Upper Midwest if crappie longevity increases with latitude, a trend noted among largemouth and smallmouth bass (Beamesderfer and North 1995), two species closely related to crappies. Conversely, growth rates of centrarchids generally decline with increasing latitude (Modde and Scalet 1985; Beamesderfer and North 1995). Slow growth could negate the potential effectiveness of MLLs as a management tool for crappie populations (Allen and Miranda 1995).

To evaluate whether MLLs could improve size structure in Minnesota black crappie *P. nigromaculatus* populations, we monitored four populations before and after the implementation of MLLs (9-, 10-, and 11-in minimums). During the same time period, trends in size structure were also monitored in three black crappie populations where MLLs were not implemented. Our primary objectives were to: 1) assess whether MLLs had potential for success based on creel information available before MLL implementation; 2) describe trends in size structure within these crappie populations, and 3) evaluate angler noncompliance with the MLLs.

Methods

Initially five lakes where selected for implementation of black crappie MLLs and four lakes were selected as reference populations, where crappie harvest was regulated only by the prevailing statewide daily creel limit of 10 crappies per angler. Black crappie populations used in this evaluation were not selected at random. From 1992 to 1993, candidate lakes for the project were selected using available biological data on fish populations (e.g., length frequency and catch-per-unit-effort data from electrofishing) and through recommendations provided by area fishery managers and the public. Final selection of lakes and associated regulations (Table 1) were determined through consultations between fisheries managers and the public during 1995 and 1996. Minimum length limits were implemented in the spring of 1997.

Beginning in 1993 standard roving creel surveys were occasionally conducted on South Lida, Spider, and Green lakes to assess angler harvest of black crappies; however, no more than two creel surveys were conducted during a specific sampling period (i.e., pre- or post-MLL) on any individual lake. No creel surveys were conducted on Maple Lake. We assessed the potential of MLLs for reducing harvest using length frequency distributions of harvested crappies observed in creel surveys conducted before MLL implementation. We calculated the percentage of harvested fish that would have been released theoretically had the specified MLL been in place and angler compliance with the regulation was 100%. Only creel periods where at least 25 harvested crappies were measured were used in this portion of the analysis.

Beginning in 1993, black crappie populations were sampled intermittently from most lakes using spring (late April to first week of June) sets of standard trap nets (six of seven lakes). Crappies on Maple Lake were sampled with fall (i.e., late September to mid-October) trap nets. North Lida and Little Mantrap lakes were initially included in the

Table 1. Minnesota lakes used to evaluate minimum length limits (MLLs) for black crappies including reference lakes where no MLLs were implemented. Length limits were implemented in May of 1997. Lake location (county), class, area, and the MLL applied to each lake are reported.

Lake	County	Class	Area (ha)	Length Limit (in)
South Lida	Otter Tail	25	355	11
Green	Chisago	27	711	9
Maple	Douglas	25	338	10
Spider	Hubbard	25	226	10
Big Moose	Beltrami	25	236	None
West Silent	Otter Tail	25	136	None
Mound	Todd	25	113	None

evaluation but these lakes were dropped due to insufficient sampling effort. During each trap net survey all or a subsample of black crappies were measured to the nearest mm (total length; TL) to describe black crappie size structure.

Based on length frequency distributions, black crappies were not fully recruited to spring trap nets until they had reached at least 7 in (possibly longer). Similarly, data for crappies less than 7 in TL were not available for all years in Maple Lake, where fall trap nets were used as a sampling gear. Consequently, only crappies greater than or equal to 7 in TL were included in the analyses. Proportional size distribution (PSD; formerly relative stock density, Guy et al. 2007) of black crappies greater than or equal to 9 in (PSD-9) and 10 in (PSD-10) were used to describe size structure, recognizing that all black crappies used in the analyses were longer than recommended stock length (5 in; Gabelhouse 1984). Trends in PSD values were plotted for the time series available for each lake and ranked values of PSD were compared between pre- (1993-1998) and post-regulation periods (1998-2008) using Wilcoxon two-sample tests. For reference populations, trends in PSD were plotted for comparison with size structure trends in lakes that were regulated by MLLs; median PSD-9 and PSD-10 were calculated for the entire sampling period in each reference lake.

The lack of consistent creel information prevented comparisons of the size structure of harvested crappies during pre- and post-regulation periods for all but one lake. Two creels were conducted on Green Lake both before and after MLL implementation, which allowed a limited comparison of the size structure of harvested crappies during pre- and post-regulation periods. Lengths of harvested crappies were pooled across creel surveys within each regulatory period (pre- or post- MLL) and chi-square analysis was used to determine whether PSD-10 of harvested crappies differed significantly between regulatory periods on Green Lake.

The extent of illegal harvest occurring on MLL lakes was assessed using length frequencies of harvested crappies obtained during creel surveys conducted after 1997. Only creel surveys in which a minimum of 25 crappies was measured were included in this portion of the analysis. Illegal harvest was described using the percentage of harvested crappies that were smaller than the MLL on each lake.

Results

Eight of the creel surveys conducted before implementation of MLLs had a minimum of 25 crappies measured during the course of the survey (Table 2). Based on size structure of harvested black crappies, most of the MLLs had high potential to reduce harvest, as in all but one case greater than 40% of black crappies harvested prior to length limit implementation were under the proposed minimum size limit and would have been released theoretically if angler compliance with the MLLs was 100% (Table 2).

In most of the study lakes there was no apparent trend in PSD-9 or PSD-10 of black crappies collected in trap nets (Figures 1 and 2). Mean ranked PSD values did not significantly differ between pre-and post-regulation periods in three of four lakes where MLLs were implemented (Tables 3 and 4). It appeared that a 9-in MLL had a positive impact on black crappie size structure in Green Lake (Figures 1 and 2) where mean ranked PSD-9 and PSD-10 differed significantly between pre- and post-regulation periods; however, size structure remained relatively poor (median PSD-10 = 3) when compared with other study lakes (Tables 3 and 4). Comparisons with reference lakes were relatively uninformative because PSD in reference lakes was generally higher than in MLL lakes.

In Green Lake, PSD-10 of black crappies harvested by anglers in the two creel surveys conducted prior to implementation of the 9-in MLL was significantly higher ($\chi^2 = 26.7$, df = 1, $P < 0.0001$) than PSD-10 observed in the two surveys conducted after the MLL was implemented (Figure 3). This did not reflect the trend in PSD-10 observed in trap nets and was likely a product of angler noncompliance with the 9-in MLL (Table 5).

Illegal harvest of crappies varied widely across lakes, ranging from 0 to 87% (Table 5). Illegal harvest was not observed on North and South Lida lakes, as no crappies under the minimum size limit were observed in angler creels. Conversely, black crappie smaller than the specified MLL comprised 25% or more of angler harvest in the three post-MLL creel surveys conducted on Green and Spider lakes. Highest illegal harvest (87%) was observed during the open water creel survey on Green Lake during 2000,

Table 2. The percentage of harvested black crappies that would have been released theoretically if minimum length limits (MLLs) had been in place on selected study lakes prior to 1997 (% released) based on creel surveys conducted before MLLs were implemented. All data are from creel surveys conducted during open water periods (May–August). Lake name, year of creel survey, MLLs, total number of crappies measured by creel clerks, and the total number of crappies smaller than the MLL are reported.

Lake	Year	MLL (in)	Measured (N)	Total < MLL (N)	% released
N. Lida	1995	11	71	60	85
	1996		33	26	79
S. Lida	1995	11	32	14	44
	1996		44	30	68
Spider	1995	10	131	116	89
Spider	1996		55	38	69
Green	1995	9	32	7	22
	1996		118	74	62

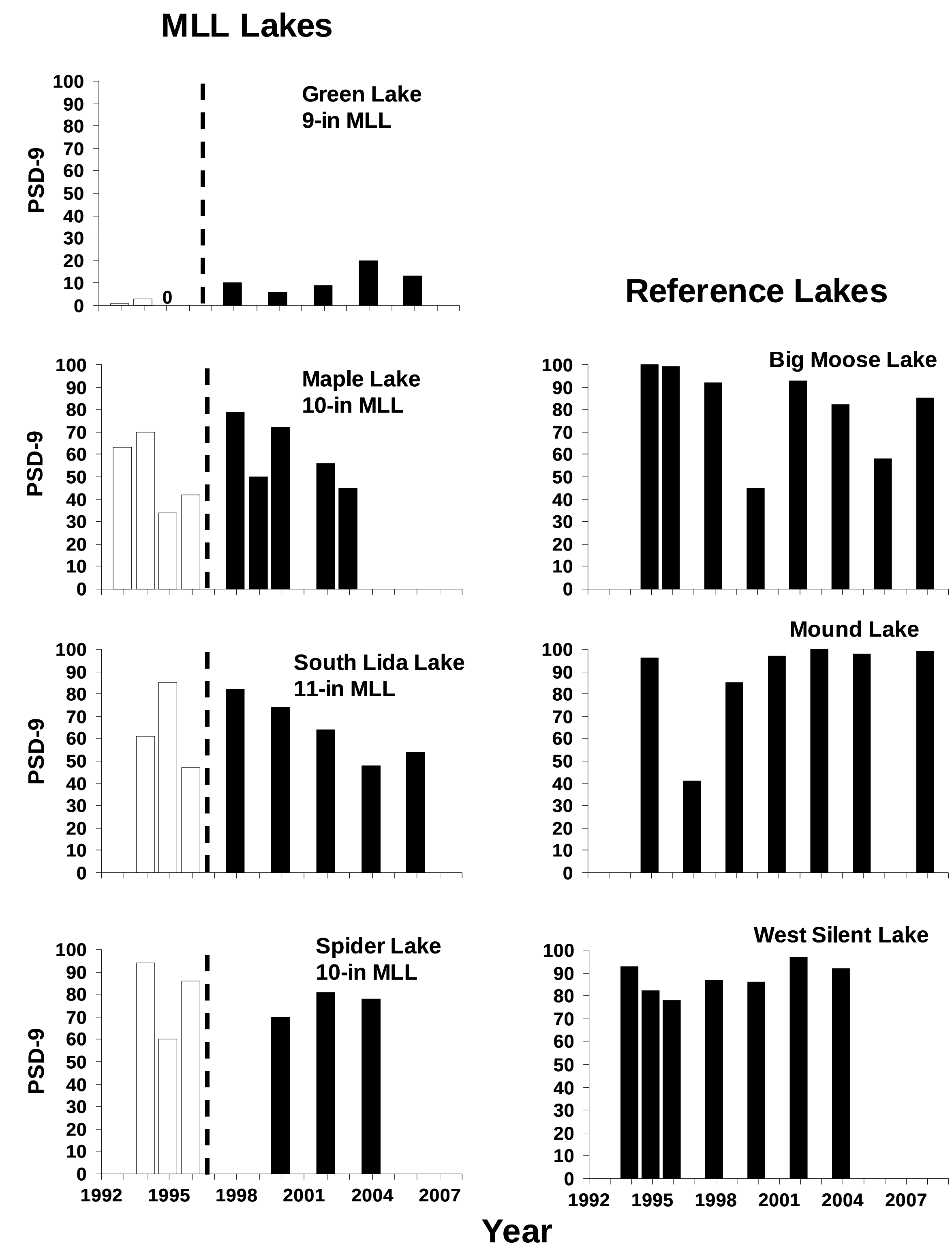

Figure 1. Proportional size distribution of black crappies greater than or equal to 9 in total length (PSD-9) in four Minnesota lakes where minimum length limits (MLLs) were implemented in 1997 and in three reference lakes where only the statewide daily bag limit of 10 crappies per angler was in place. Black crappies were collected in trap nets set during spring or fall. Dashed lines represent 1997, the year MLLs were implemented. For MLL lakes white bars represent observations of PSD-9 before MLL implementation, black bars represent observations of PSD-9 after MLL implementation.

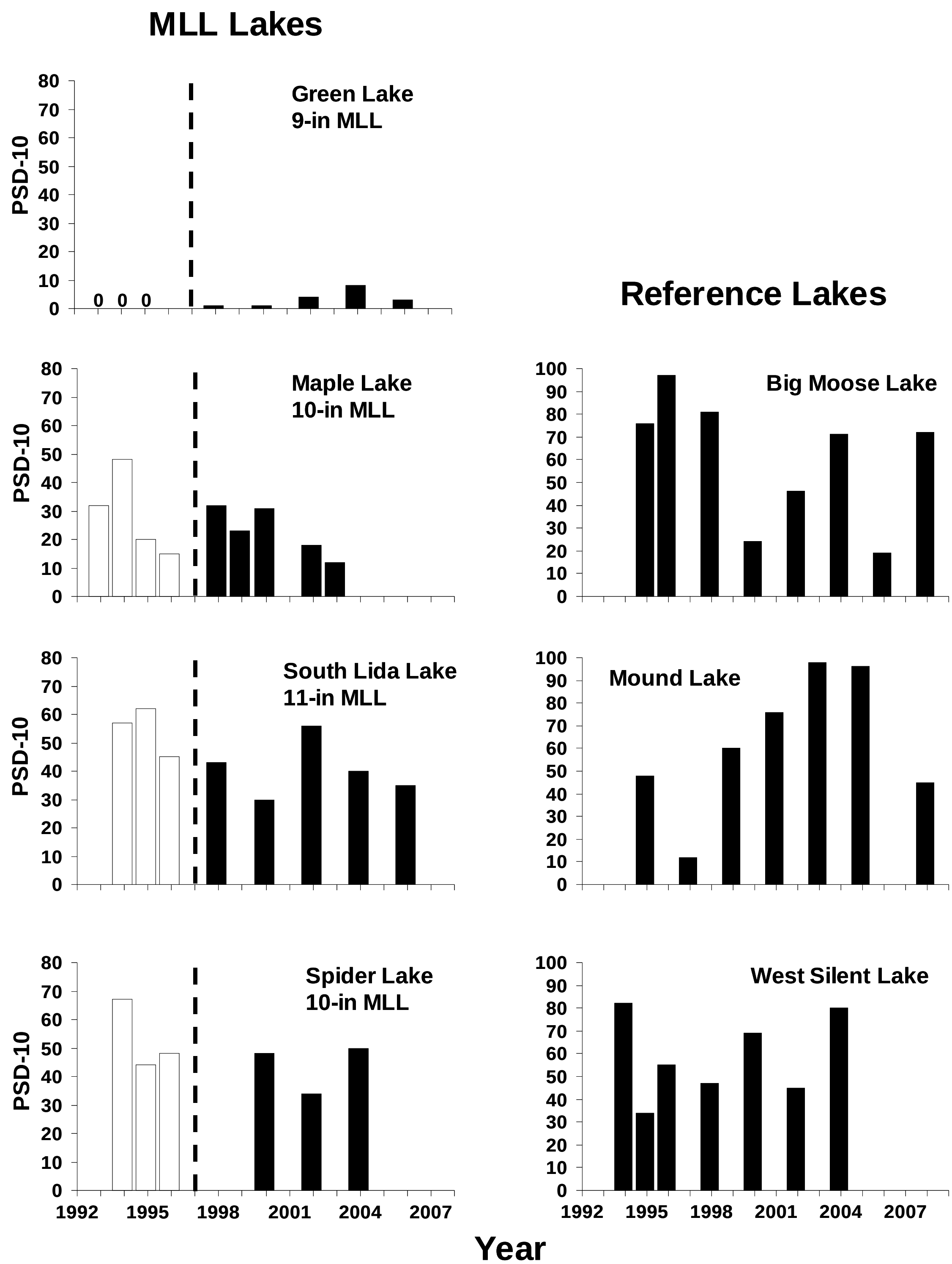

Figure 2. Proportional size distribution of black crappies greater than or equal to 10 in total length (PSD-10) in four Minnesota lakes where minimum length limits (MLLs) were implemented in 1997 and in three reference lakes where only the statewide daily bag limit of 10 crappies per angler was in place. Black crappies were collected in trap nets set during spring or fall. Dashed lines represent 1997, the year MLLs were implemented. For MLL lakes white bars represent observations of PSD-10 before MLL implementation, black bars represent observations of PSD-10 after MLL implementation.

Table 3. Median proportional size distribution of black crappies greater than or equal to 9 in total length (PSD-9) sampled with trap nets during pre- and post-regulation periods and for the entire sampling period in lakes where minimum length limits (MLLs) were implemented and for the entire sampling period in reference lakes. An asterisk denotes the one case where ranked PSD-9 was significantly different between pre-and post-regulation periods in lakes where MLLs were implemented (Wilcoxon two-sample tests, $P < 0.05$).

		Median PSD-9		
Lake	Regulation	Pre-regulation	Post-regulation	Overall
Green	9-in MLL	1	10*	8
Maple	10-in MLL	53	56	56
South Lida	11-in MLL	61	64	63
Spider	10-in MLL	86	78	80
Big Moose	Reference			89
Mound	Reference			97
West Silent	Reference			87

Table 4. Median proportional size distribution of black crappies greater than or equal to 10 in total length (PSD-10) sampled with trap nets during pre- and post-regulation periods and for the entire sampling period in lakes where minimum length limits (MLLs) were implemented and for the entire sampling period in reference lakes. An asterisk denotes the one case where ranked PSD-10 was significantly different between pre-and post-regulation periods in lakes where MLLs were implemented (Wilcoxon two-sample tests, $P < 0.05$).

		Median PSD-10		
Lake	Regulation	Pre-regulation	Post-regulation	Overall
Green	9-in MLL	0	3*	1
Maple	10-in MLL	26	23	23
South Lida	11-in MLL	57	40	44
Spider	10-in MLL	48	48	48
Big Moose	Reference			72
Mound	Reference			60
West Silent	Reference			55

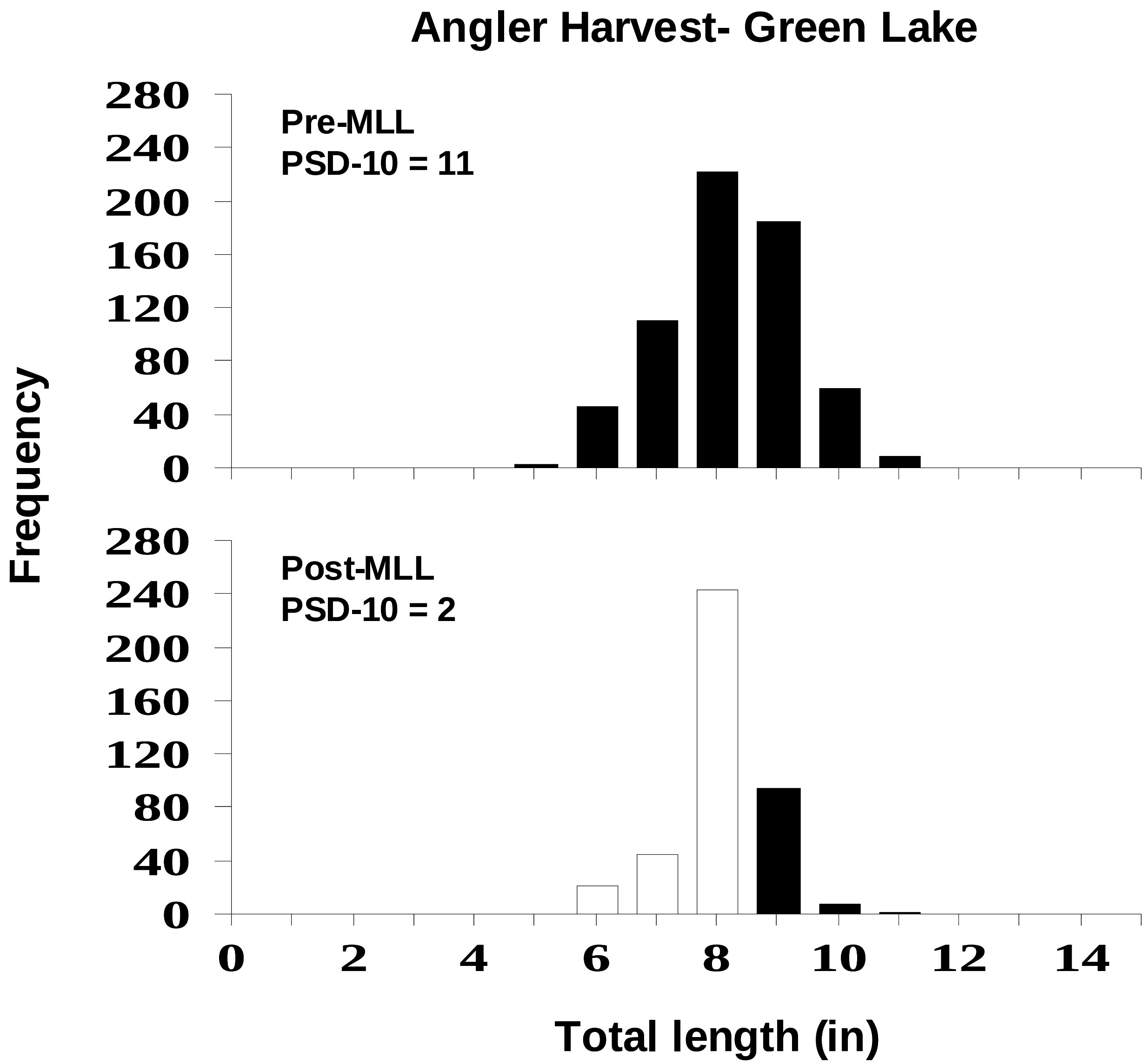

Figure 3. Length frequency and the proportional size distribution of angler-harvested black crappies greater than or equal to 10 inches (PSD-10) on Green Lake, Minnesota. Black crappies were measured during two creel surveys conducted prior to the implementation of a 9-in minimum length limit (MLL) in 1997 (top graph) and during two creel surveys conducted after MLL was in place (bottom graph). White bars in the bottom graph represent black crappies that were illegally harvested (i.e., smaller than 9-in MLL).

Table 5. Percentage of black crappies measured in creel surveys conducted after implementation of minimum length limits (MLLs) that were illegally harvested (i.e., smaller than MLL) on specified study lakes. Lake names, year creel surveys were conducted, creel periods (open water or winter), associated MLL, and total crappies measured (N) are reported for each creel survey.

Lake	Year	Period	MLL (in)	N	Total < MLL (N)	% illegal harvest
S. Lida	2002	Open water	11	48	0	0
	2003	Winter		53	0	0
Spider	2002	Open water	10	47	12	25
Green	2000	Open water	9	326	282	87
	2002	Open water		85	26	31

despite the fact this was 3 years after the 9-inch MLL had gone into effect (Table 5). Illegal harvest on Green Lake decreased in 2002, but remained relatively high (31%; Table 5).

Discussion

Fishery managers contend that angler exploitation is an important factor in regulating size structure in many Minnesota crappie populations. Parsons and Reed (1998) reported that angler harvest influenced black crappie size structure in three of four west-central Minnesota lakes. Similarly, the size structure of harvested fish prior to the implementation of MLLs in this study suggested that length limits would reduce crappie harvest and possibly increase size structure, as a substantial proportion of harvested crappies would have been protected under the proposed limit. However, improvements in crappie size structure were apparent in only one of the four lakes where MLLs were implemented.

The reasons why MLLs did not improve black crappie size structure in most study lakes remain unknown. Crappie fisheries have often been characterized as inconsistent or "cyclic" (Miranda and Allen 2000). Much of this inconsistency is likely a direct result of the inherent variation in crappie recruitment (Guy and Willis 1995; Allen 1997; Boxrucker 2002). Recruitment variation can make it difficult to detect actual changes in size structure indices over relatively short periods of time (Allen and Pine 2000). Possibly, the data that were collected during this study were not sufficient to describe the effects of MLLs on black crappie size structure. Inconsistent recruitment also causes variation in the number of harvestable-sized fish available to anglers, which may lead to shifts in angler use of certain fisheries (Webb and Ott 1991; Parkinson et al. 2004). Consequently, when relatively large numbers of crappies attain harvestable size, angler effort may increase to the point that an MLL is not effective in controlling exploitation as a whole despite curtailing harvest by individual anglers (Post et al. 2002). In some Minnesota crappie fisheries, exploitation rates may not be sufficient to significantly alter crappie size structure, or natural mortality may compensate for decreases in fishing mortality such that total mortality rates remain unchanged (Larson et al. 1991; Allen et al. 1998; Boxrucker 2002), negating the expected benefits of an MLL. Furthermore, minimum length limits may not greatly improve size structure if angler harvest merely refocuses on larger fish.

Certainly angler noncompliance can undermine the potential effectiveness of any harvest regulation. Illegal harvest on Spider and Green lakes was high and may have undermined the effectiveness of length limits in improving size structure within these fisheries. Conversely, angler compliance with MLLs did not appear to be an issue on South Lida Lake, yet the 11-in MLL did not appear to improve black crappie size structure. Rates of noncompliance and illegal harvest may be related to angler awareness of regulations. During 2000, when illegal harvest on Green Lake was 87%, only 55% of interviewed anglers on Green Lake reported that they were aware of the 9-in MLL for black crappies (Page and Radomski 2006). Awareness improved to 75% during the 2002 fishery (Page and Radomski 2006) and illegal harvest dropped to 31% (Table 5). Furthermore, on North and South Lida lakes, where angler awareness was high (> 97%, Page and Radomski 2006), no fish under the minimum size limit were encountered in angler creels. Several factors may have contributed to the variability in angler awareness and illegal harvest we observed, including regional differences in publicity efforts, angler attitudes, and enforcement intensity. In the future, increased publicity efforts and enforcement intensity may be needed to promote angler compliance with new regulations.

Management Recommendations

Our results suggest that MLLs will not be universally effective in improving size structure in Minnesota black crappie populations, at least within the first decade following implementation. Longer evaluation of these harvest regulations may yield more meaningful results due to the amount of variation associated with measuring crappie population metrics (Allen and Pine 2000). Furthermore, black crappies in Minnesota waters often live to age 5 and beyond (McInerny et al. *In preparation;* Isermann et al. *In review*); hence, monitoring population trends for 7 to 8 years after MLLs have been implemented may not be sufficient to capture the true effects of these regulations on size structure. Future evaluation of length limits as management strategies for black crappies in Minnesota is warranted, but such an evaluation must be designed to attain meaningful results. This will likely require a significant investment in time (likely > 10 years) and effort (e.g., targeted annual sampling) in order to be informative. This evaluation was also plagued by insufficient replication of individual length limits. A better design would also incorporate a multitude of lakes with crappie populations that exhibited a range of population characteristics.

References

Allen, M. S. 1997. Effects of variable recruitment on catch-curve analysis for crappies. North American Journal of Fisheries Management 17:202-205.

Allen, M. S., and L. E. Miranda. 1995. An evaluation of the value of harvest restrictions in managing crappie fisheries. North American Journal of Fisheries Management 15:766-772.

Allen, M. S., L. E. Miranda, and R. E. Brock. 1998. Implications of compensatory and additive mortality to the management of selected sportfish populations. Lakes and Reservoirs: Research and Management 3:67-98.

Allen, M. S., and W. E. Pine III. 2000. Detecting fish population responses to a minimum length limit: effects of variable recruitment and duration of evaluation. North American Journal of Fisheries Management 20:672-682.

Beamesderfer, R. C. P., and J. A. North. 1995. Growth, natural mortality, and predicted response to fishing for largemouth bass and smallmouth bass populations in North America. North American Journal of Fisheries Management 15:688-704.

Bister, T. J., D. W. Willis, A. D. Knapp, and T. R. St. Sauver. 2002. Evaluation of a 23-cm length limit for black and white crappies in a small South Dakota impoundment. North American Journal of Fisheries Management 22:1364-1368.

Boxrucker, J. 2002. Rescinding a 254-mm minimum length limit on white crappies at Ft. Supply Reservoir, Oklahoma: the influence of variable recruitment, compensatory mortality, and angler dissatisfaction. North American Journal of Fisheries Management 22:1340-1348.

Gabelhouse, Jr., D. W. 1984. A length-categorization system to assess fish stocks. North American Journal of Fisheries Management 4:273-285.

Guy, C. S., R. M. Neumann, D. W. Willis, and R. O. Anderson. 2007. Proportional size distribution (PSD): a further refinement of population size structure index terminology. Fisheries 32(7):348.

Guy, C. S., and D. W. Willis. 1995. Population characteristics of black crappies in South Dakota waters: a case for ecosystem specific management. North American Journal of Fisheries Management 15:754-765.

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. North American Journal of Fisheries Management 19:804-814.

Hurley, K. L., and J. J. Jackson. 2002. Evaluation of a 254-mm minimum length limit for crappies in two southeast Nebraska reservoirs. North American Journal of Fisheries Management 22:1369-1375.

Isermann, D. A., S. M. Sammons, P. W. Bettoli, and T. N. Churchill. 2002. Predictive evaluation of size restrictions as management strategies for Tennessee reservoir crappie populations. North American Journal of Fisheries Management 22:1349-1357.

Isermann, D. A., A. L. Thompson, and P. J. Talmage. *In review.* Can sexual dimorphism promote sex-selective harvest within Minnesota black crappie fisheries? North American Journal of Fisheries Management.

Larson, S. C., B. Saul, and S. Schleiger. 1991. Exploitation and survival of black crappies in three Georgia reservoirs. North American Journal of Fisheries Management 11:604-613.

Miranda, L. E., and M. S. Allen. 2000. Use of length limits to reduce variability in crappie fisheries. North American Journal of Fisheries Management 20:752-758.

McInerny, M. C., R. J. H. Hoxmeier, B. D. Koenen, R. Eckstrom, T. Heinrich, and N. Schlesser. *In preparation.* Comparisons of age estimates among calcified structures of crappie in

Minnesota: are scales effective in northern latitudes? North American Journal of Fisheries Management.

Modde, T., and C. G. Scalet. 1985. Latitudinal growth effects on predator-prey interactions between largemouth bass and bluegills in ponds. North American

Journal of Fisheries Management 5:227-232.
Page, K. S., and P. Radomski. 2006. Compliance with sport fishery regulations in Minnesota as related to regulation awareness. Fisheries 31(4):166-178.
Parkinson, E. A., J. R. Post, and S. P. Cox. 2004. Linking the dynamics of harvest effort to recruitment dynamics in a multistock, spatially structured fishery. Canadian Journal of Fisheries and Aquatic Sciences 61:1658-1670.
Parsons, B. G., and J. R. Reed. 1998. Angler exploitation of bluegill and black crappie in four west-central Minnesota lakes. Investigational Report No. 468, Section of Fisheries, Minnesota Department of Natural Resources, St. Paul.
Post, J. R., M. Sullivan, S. Cox, N. P. Lester, C. J. Walters, E. A. Parkinson, A. J. Paul, L. Jackson, and B. J. Shuter. 2002. Canada's recreational fisheries: the invisible collapse? Fisheries 27(1):6-17.
Reed, J. R., and W. D. Davies. 1991. Population dynamics of black and white crappies in Weiss Reservoir, Alabama: implications for the implementation of harvest restrictions. North American Journal of Fisheries Management 11:598-603.
Webb, M. A., and R. A. Ott, Jr. 1991. Effects of length and bag limits on population structure and harvest of white crappies in three Texas reservoirs. North American Journal of Fisheries Management 11:614-622.