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EVALUATION OF AN 11-IN MAXIMUM LENGTH LIMIT FOR SMALLMOUTH BASS POPULATIONS IN NORTHEASTERN MINNESOTA[1]

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Abstract.— We evaluated the effects of an 11-in maximum length limit (total length; TL) on the size structure of smallmouth bass *Micropterus dolomieu* caught by anglers in four northeast Minnesota lakes. Using angler catch data collected during creel surveys, we compared size structure and catch rate of smallmouth bass prior to and after the implementation of the maximum length limit on four lakes. For comparative purposes, we examined angler catch data from four lakes regulated with only the prevailing statewide restriction on black bass harvest (i.e., 6 bass daily). The total assessment period was 10 years or more for all lakes. Based on available data it appeared that the size structure of smallmouth bass captured by anglers improved following implementation of the maximum length limit; however, angler catch rates of bass greater than or equal to 11 in TL did not increase significantly.

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Introduction

Length-based harvest regulations, typically in the form of minimum length limits and protected slot-length limits, have been used to manage smallmouth bass fisheries with varied success (Paragamian 1984; Austen and Orth 1988; Slipke et al. 1998; Newman and Hoff 2000; Buynak and Mitchell 2002). Studies evaluating the effects of these length-based regulations have typically compared smallmouth bass size structure before and after the regulations were enacted, or simultaneously compared smallmouth bass populations between regulated and unregulated fisheries. Studies have rarely integrated long-term analyses with reference fisheries when evaluating harvest regulations. The use of reference lakes (Lyons et al. 1996; Shroyer et al. 2003; Isermann 2007) and relatively long evaluation periods (Wilde 1997; Allen and Pine 2000; Isermann 2007) have been advocated to account for biological and environmental variance that may impact the fisheries being evaluated. Reference lakes serve to help account for changes in population size structures related to regional biological or environmental influences. Allen and Pine (2000) suggested that length limit evaluation periods of greater than five years may be necessary to identify actual changes in largemouth bass *Micropterus salmoides* populations. The responses of smallmouth bass populations to length limits have been typically evaluated over relatively short time intervals (e.g., 2-3 years). Furthermore, the population dynamics of smallmouth bass in northern waters suggest that longer evaluation periods may be necessary to observe changes in size structure that might result from more stringent harvest regulation (Beamesderfer and North 1995).

We evaluated the effects of an 11-in maximum length limit (total length; TL) on the size structure of smallmouth bass populations in four northeast Minnesota lakes. These regulations require that anglers release all smallmouth bass that are greater than or equal to 11 in TL. The effects of this form of length limit have not been previously evaluated. Using data collected from creel surveys we documented changes in the size structure and angler catch-per-unit-effort (CPUE; bass/angler h) of smallmouth bass in lakes where 11-in maximum length limits were enacted and compared these trends to trends in lakes where maximum length limits were not enacted. The evaluation was conducted over a 10- to 15- year period that encompassed both pre-and post-regulation time periods.

Methods

Maximum length limits (11-in) were implemented in 1996 and 1997 on four lakes located in northeastern Minnesota (Figure 1; Table 1) in an effort to improve smallmouth size structure based on predefined criteria (Table 2). Four additional lakes were designated as reference lakes (Figure 1; Table 1) where only the prevailing statewide harvest regulation for smallmouth bass was in place (i.e., 6 bass daily bag limit). The size structure of smallmouth bass caught by anglers on each lake was evaluated periodically between 1988 and 2004 using standard roving creel surveys. For regulated lakes, at least two surveys were performed before and after implementation of maximum length limits. Total evaluation periods, measured as the time from the initial creel survey conducted on each lake to the most recent creel survey conducted, ranged from 10 to 15 years.

Length frequencies and angler catch-per-unit effort (CPUE; smallmouth bass / angler h) of smallmouth bass were estimated using data collected during creel surveys. Smallmouth bass harvested by anglers were directly measured (TL) to the nearest millimeter; TL measurements were subsequently converted to inches. Total lengths of smallmouth bass caught and released by anglers were based on angler recollection and were expressed directly in inches. Smallmouth bass were assigned to 1-in TL intervals for analysis. The length frequency of stock-size ($\geq$ 7 in) smallmouth bass caught by anglers was assumed to be

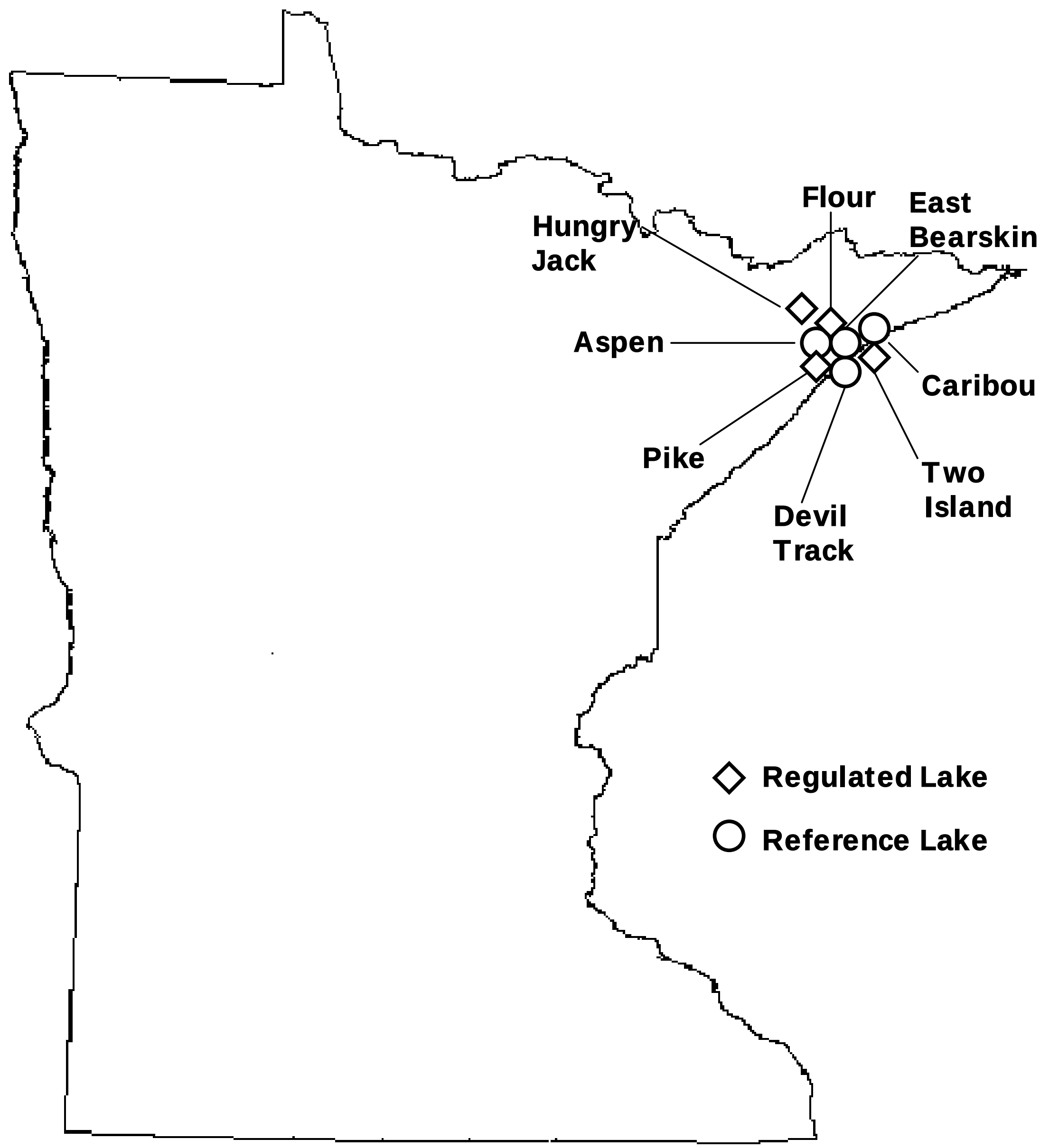


Figure 1. Locations of lakes used to evaluate smallmouth bass *Micropterus dolomieu* regulations in Minnesota.

Table 1. Surface area, percentage of surface area considered as littoral zone (i.e., depth less than or equal to 15 ft), maximum depth, secchi disk readings, and ecological lake class (Schupp 1992) for four lakes in northeastern Minnesota where 11-in maximum length limits were implemented and for four lakes used as reference populations. Only the prevailing statewide harvest regulation of 6 bass daily was in effect on reference lakes.

	Aspen	Caribou	Devil Track	East Bearskin	Flour	Hungry Jack	Pike	Two Island
Regulation	Ref	Ref	Ref	Ref	11-in max	11-in max	11-in max	11-in max
Surface Area (Acres)	131	728	1838	441	441	459	810	793
Percent Littoral	69.0	60.3	34.1	33.0	33.0	42.0	35.0	64.9
Maximum Depth (ft)	29	27	50	60	80	70	45	20
Secchi Disk (ft)	9.0	10.0	8.5	10.0	19.0	12.0	20.5	10.5
Lake Class	6	6	1	3	3	3	1	16

Table 2. Predetermined goals for four smallmouth bass populations in northeastern Minnesota where 11-in maximum length limits were implemented.

Lake	Regulation	Goal
Flour	11-in maximum	**Creel:** 40% of angled fish ≥ 1 1 in (PSD)[1].
Hungry Jack	11-in maximum	**Creel:** 40% of angled fish ≥ 1 1 in (PSD).
Pike	11-in maximum	**Creel:** Double number of fish ≥ 1 1 in captured by anglers. 40% of angled fish ≥ 1 1 in (PSD).
Two Island	11-in maximum	**Creel:** 40% of angled fish ≥ 1 1 in (PSD).

[1] Original goal for lakes regulated by an 11-in maximum length limit called for 40% of all fish caught by anglers to be ≥ 1 1 in. However, we modified goal to require 40% of stock-size fish (≥ 7 in) captured by anglers to be ≥ 1 1 in (i.e., proportional-stock-density, PSD).

representative of the length frequency of these fish within each population (Ebbers 1987). For each smallmouth bass population, proportional size distribution (PSD [formerly proportional stock density; Guy et al. 2007]), overall CPUE, CPUE of individual length groups, and CPUE of fish ≥11 in ($CPUE_{11}$) were estimated for each evaluation year. To test for the effects of period and treatment on PSD and $CPUE_{11}$, we fit a linear mixed effects model (R package: nlme: lme) that incorporated period, treatment, and period x treatment as fixed effects and treated lake as a random effect.

$$metric = u + \alpha_{period} + \beta_{treatment} + \delta_{periodxtreatment} + A_{lake} + \varepsilon_{period,treament,lake}$$

Here, the metric is either PSD or $CPUE_{11}$, u is the intercept, α_{period} is the period effect, $\beta_{treatment}$ is the treatment effect, $\delta_{period\ x\ treatment}$ is the period x treatment interaction, A_{lake} is the random lake effect (assumed to come from a normal distribution with a mean 0 and variance σ_{lake}^2), and $\varepsilon_{period,treatment,lake}$ is the measurement error applying to an individual PSD or $CPUE_{11}$ in period p under treatment t in lake i (assumed to come from a normal distribution with mean 0 and variance σ_{ε}^2). A significant interaction between period and treatment indicates that treatment effect differed between periods.

Results

Visual inspection of length frequency and CPUE data suggested that there was a general increase in PSD and $CPUE_{11}$ among lakes regulated with an 11-in maximum length limit (Figure 2). Size structure of smallmouth bass among reference lakes appeared to be more consistent over time and generalized trends in PSD and $CPUE_{11}$ were not apparent (Figure 3). A PSD of 40% (i.e., a predetermined goal; Table 2) was achieved during the post-regulation period for Hungry Jack, Pike, and Two Island lakes (Figure 2), but PSD in both Pike and Two Island lakes fell below 40% during the last year a creel survey was conducted. Two Island Lake was the only lake where average PSD for the post-regulation exceeded 40%.

Linear mixed effects models indicated that a significant interaction existed between period and treatment in explaining variation in PSD (Table 3), meaning that the treatment effect (i.e., 11-in maximum length limit or reference lake) differed between periods (pre- and post-regulation). Boxplots showed that PSD in regulated lakes was greater during the post-regulation period than the pre-regulation period (Figure 4). Period and treatment were not significant in explaining variation in $CPUE_{11}$ and there was no significant interaction between period and treatment (Table 3), although a boxplot suggested that the regulation improved $CPUE_{11}$ (Figure 5). Notably, angler effort declined during the evaluation period for both regulated and unregulated lakes (Figures 2 and 3).

Discussion

Based on available data it appeared that the 11-in maximum length limit was effective in improving the size structure of smallmouth bass populations in northeast Minnesota lakes. Length-frequency distributions indicated a general shift in PSD during the period following implementation of the maximum length limit (1998-2004), while there were no general trends in PSD observed within reference lakes. Three of the four regulated lakes (Hungry Jack Lake, Pike Lake, and Two Island Lake) met the management goal of a PSD of 40% during the regulated period; however, management goals were somewhat arbitrary and do not necessarily reflect the biological potential of specific smallmouth bass populations. The linear mixed effect model supported the assertion that increases in the PSD of angler-captured smallmouth bass were significantly greater within regulated lakes compared to unregulated lakes.

It should be noted that increases in PSD estimates among regulated lakes might in part be a function of the "recycling" of smallmouth bass within these fisheries. That is, the number of smallmouth bass greater

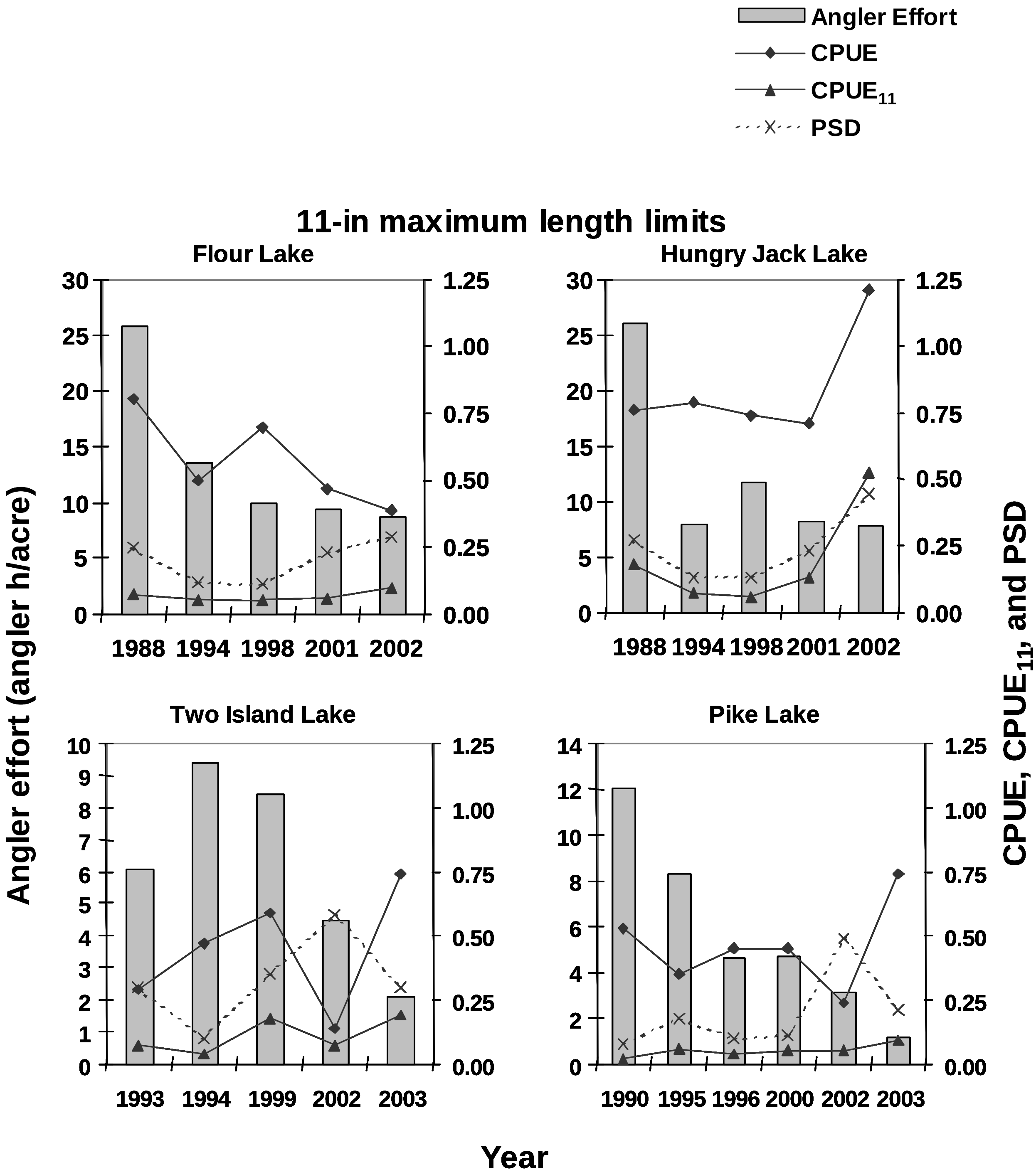


Figure 2. Angler effort (angler h/acre), angler catch-per-unit effort (fish per h; CPUE), and electrofishing catch-per-unit effort ($CPUE_{11}$) and proportional size distribution (PSD/100) of smallmouth bass greater than or equal to 11 in for four northeast Minnesota lakes where 11-in maximum length limits were implemented.

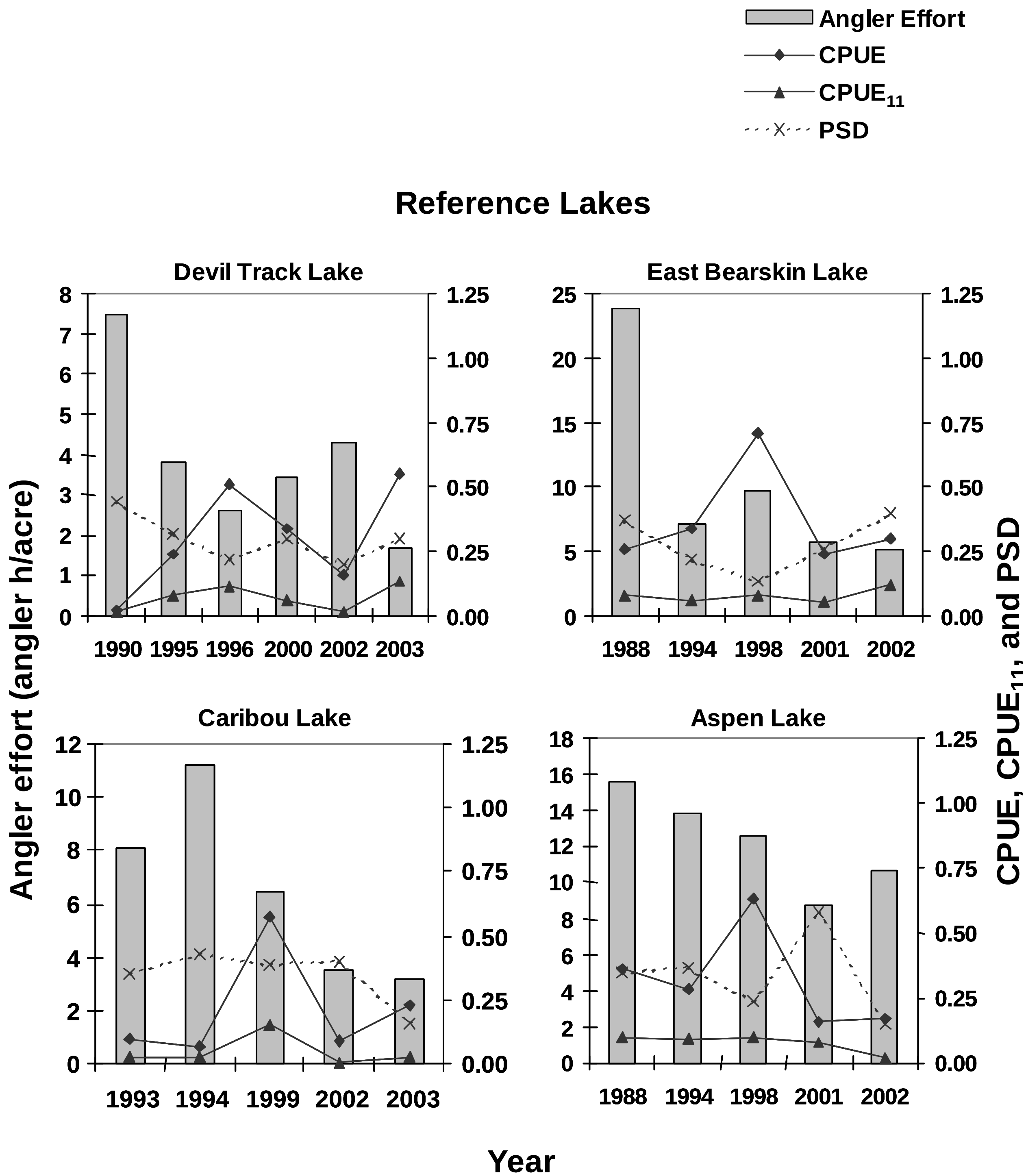


Figure 3. Angler effort (angler h/acre), angler catch-per-unit effort (fish per h; CPUE), and electrofishing CPUE ($CPUE_{11}$) and proportional size distribution (PSD/100) of smallmouth bass greater than or equal to 11 in for four northeast Minnesota lakes selected as reference lakes for comparison with lakes where 11-in maximum length limits were implemented (Figure 2). Only the prevailing statewide harvest regulation of 6 bass per day was in place on reference lakes.

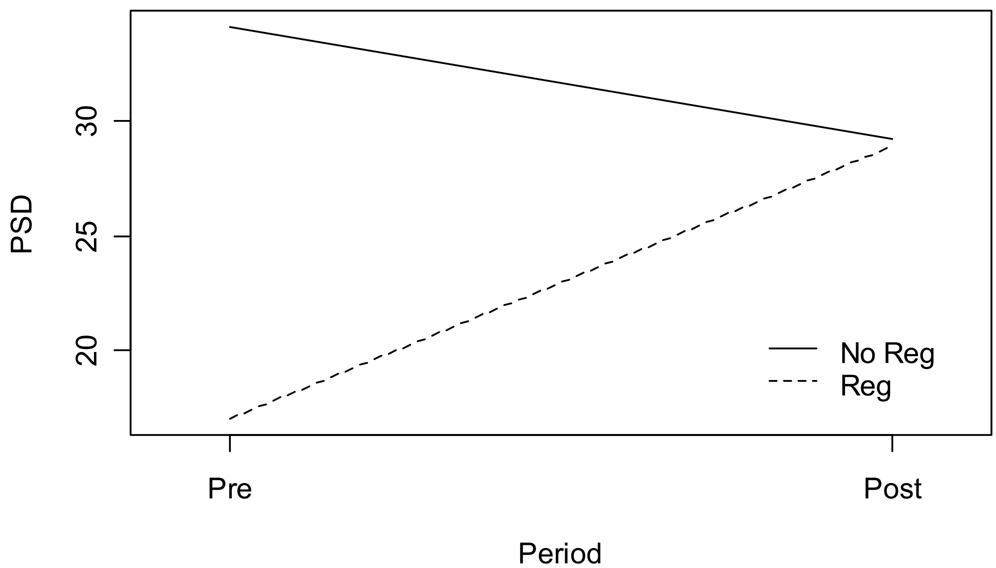
Table 3. Results of linear mixed effects models for proportional size distribution (PSD) and catch-per-unit effort of smallmouth bass greater than or equal to 11 in total length ($CPUE_{11}$) in eight northeast Minnesota lakes used to evaluate the effects of an 11-in maximum length limit. Period refers to years prior to (1984-1996) or following (1998-2004) implementation of the 11-in maximum length limit. Treatment refers to lakes where the 11-in maximum length was implemented or lakes where only the prevailing statewide harvest regulation of 6 black bass per angler per day was in effect for the entire evaluation period (i.e., reference lake).

	DF	F-values	p-values
PSD			
Intercept	1	220.19	<0.0001
Period	1	0.88	0.35
Treatment	1	4.10	0.09
Period x treatment	1	4.99	0.03
$CPUE_{11}$			
Intercept	1	30.03	<0.0001
Period	1	1.85	0.19
Treatment	1	1.29	0.30
Period x treatment	1	1.38	0.25

than or equal to 11 in captured by anglers may merely reflect the repeated capture and release of the same fish multiple times and may not accurately reflect changes in population size structure (Paragamian 1984). The addition of fishery-independent assessments (e.g., electrofishing) to the analysis would help to eliminate potential bias associated with angler catch data. Further, annual assessments of size structure would have benefited the analyses. It is inherently difficult to ascertain whether changes in the size structure of fish populations are related to a length regulation or variable recruitment (i.e., large year class) based on periodic assessment data (Allen and Pine 2000; Isermann 2007).

Given that we found no significant differences in $CPUE_{11}$ between regulated and unregulated lakes, we cannot rule out that trends in $CPUE_{11}$ reflected regional influences. Decreases in angler effort over the evaluation period in both regulated and reference lakes (Figures 2 and 3) may have contributed to similar increases in CPUE estimates among regulated and reference lakes if fishing mortality also declined and more smallmouth bass were available to anglers. Reductions in angler effort also may have contributed to the general improvement in smallmouth bass size structure within the region by reducing overall angler pressure. The reason for the decline in angler effort may be related to a combined effect of poor weather, the closure and deterioration of facilities on some lakes, and the decline in fishing success of other fish species (S. Persons, MNDNR, personal communication).

We believe our ability to evaluate the effectiveness of the 11-in maximum length limit was enhanced by the incorporation of a relatively long evaluation period and reference lakes. For example, the highest estimates of PSD occurred within 6-7 years after the maximum length limit was implemented. Therefore, if the evaluation period had been five years or less, observed differences in PSD between maximum-length-limit lakes and references lakes may have been less apparent. Other studies that have evaluated regulations over time periods of five years or less typically did not observe positive trends in smallmouth bass size structure. Lyons et al. (1996) evaluated a 14-in minimum length limit during a five-year period and observed significant increases in PSDs and CPUEs of harvestable size fish for two of six smallmouth bass populations



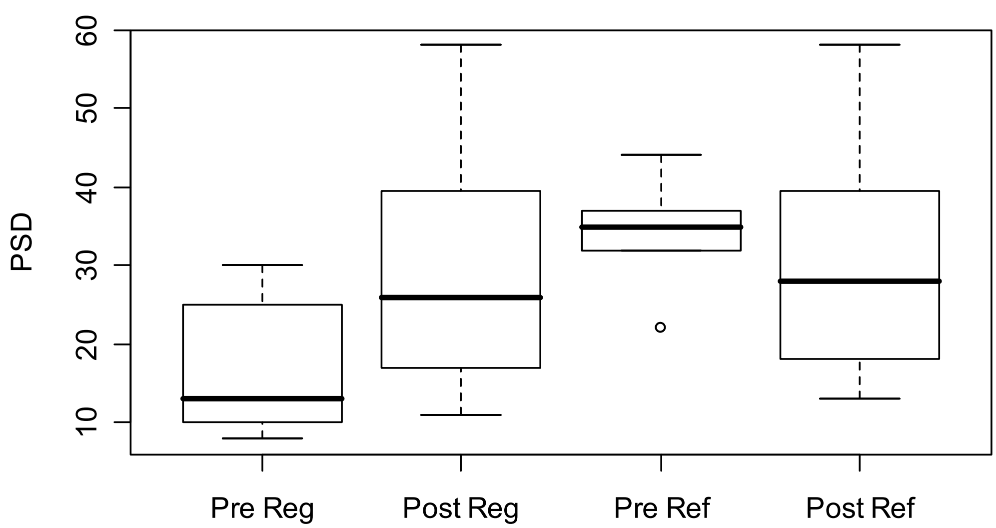
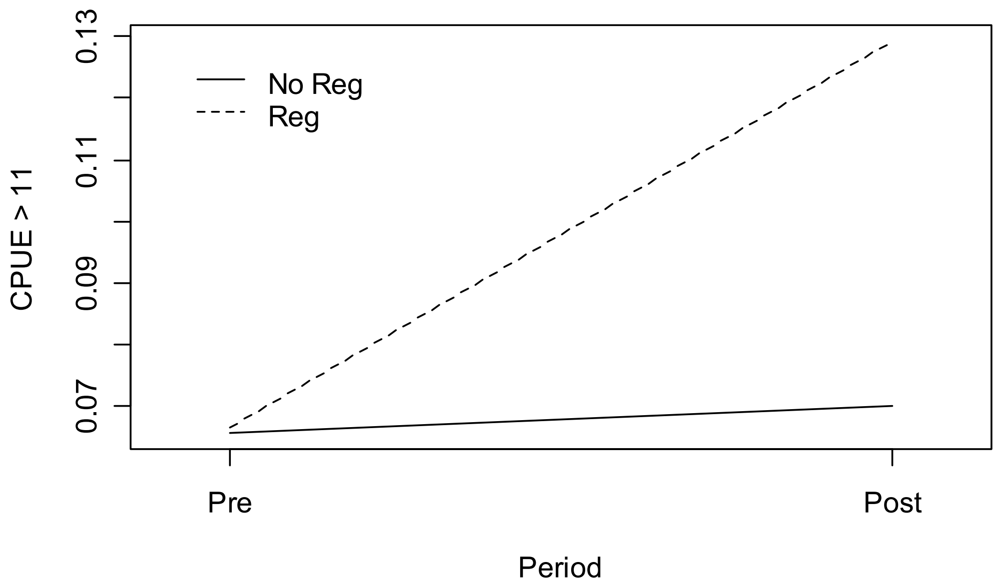


Figure 4. Interaction plot (top) and boxplot (bottom) of the period x treatment interaction for proportional size distribution (PSD) in eight lakes in northeastern Minnesota. Treatments (Reg) represented four lakes where an 11-in maximum length limit was enacted and reference (Ref) represented four lakes where only the prevailing statewide black bass harvest regulation of 6 bass per day was in effect.



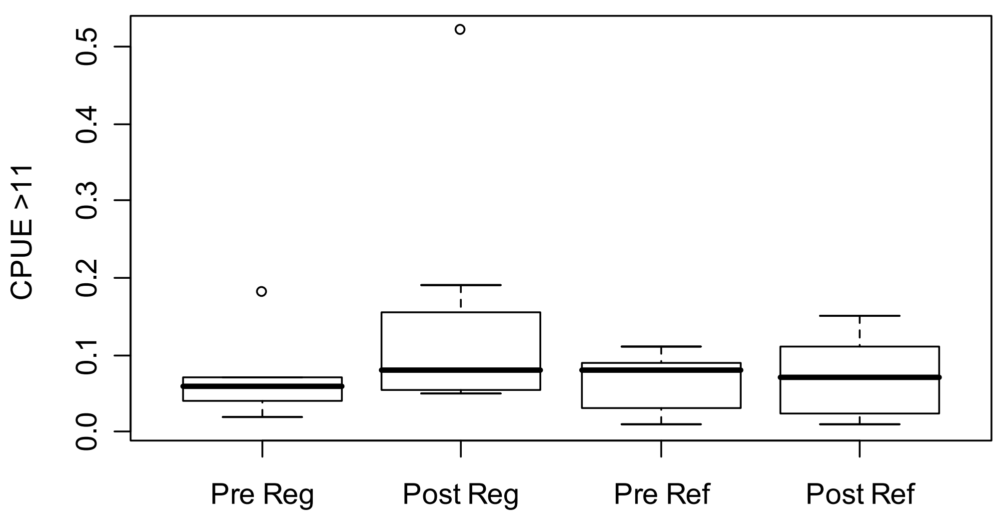


Figure 5. Interaction plot (top) and boxplot (bottom) of the period x treatment interaction for catch-per-unit effort of smallmouth bass greater than or equal to 11 inches total length ($CPUE_{11}$) in eight lakes in northeastern Minnesota. Treatments (Reg) represented four lakes where an 11-in maximum length limit was enacted and reference (Ref) represented four lakes where only the prevailing statewide black bass harvest regulation of 6 bass per day was in effect.

evaluated. All smallmouth bass populations evaluated by Lyons et al. (1996) showed some signs of improvement and it is conceivable that the remaining smallmouth bass populations could have shown significant improvements if a longer evaluation period had been employed. The size structure of a smallmouth bass population within an Iowa river showed no improvement after being regulated for three years by a 12-in minimum length limit (Paragamian 1984), but a model predicted that size structure would improve if the regulation was maintained. In contrast, Austen and Orth (1988) found that a 12-in minimum length limit that had been in effect on a section of stream for nearly 20 years had not improved the size structure of a smallmouth bass population when compared to an unregulated section of stream; however, this evaluation was somewhat limited because a lack of pre-regulation data prevented characterization of the population prior to implementation of the regulation.

Management Implications

We believe that the 11-in maximum length limit was generally effective in improving the size structure of smallmouth bass captured by anglers in Flour, Hungry Jack, Pike, and Two Island Lakes. In 2004 a 12 in-maximum length limit that also allowed anglers to harvest one smallmouth bass greater than 20 in was implemented on Flour, Hungry Jack, and Two Island Lakes. The regulation was enacted to promote consistency in regulations among waters and because some anglers had expressed an interest in harvesting bass between 11 and 12 inches (S. Persons, MNDNR, personal communication). The 11-in maximum was dropped from Pike Lake in 2005 due to concerns that smallmouth bass were having adverse effects on the walleye population.

We suggest that future evaluations of harvest regulations occur on a long-term basis and involve the use of reference lakes. This is not to imply that all regulations will provide benefits given a sufficient amount of time, but longer evaluation periods than what are typically employed may be required to observe actual changes in fish populations. Further, reference lakes are needed for identifying changes in fish size structure that may be independent of regulations. In addition, length limit evaluations would have benefited from independent and annual population assessments to help minimize the effects of sampling biases.

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