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North American Journal of Fisheries Management
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/ujfm20

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Published online: 15 Apr 2015.

To cite this article: Andrew L. Rypel (2015) Effects of a Reduced Daily Bag Limit on Bluegill Size Structure in Wisconsin Lakes, North American Journal of Fisheries Management, 35:2, 388-397, DOI: 10.1080/02755947.2014.1001929

To link to this article: http://dx.doi.org/10.1080/02755947.2014.1001929

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North American Journal of Fisheries Management 35:388–397, 2015
© American Fisheries Society 2015
ISSN: 0275-5947 print / 1548-8675 online
DOI: 10.1080/02755947.2014.1001929

MANAGEMENT BRIEF

Effects of a Reduced Daily Bag Limit on Bluegill Size Structure in Wisconsin Lakes

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Abstract

This study evaluated the effect of reduced aggregate panfish bag limits (from 25 to 10) on the size structure of Bluegill *Lepomis macrochirus* populations in seven natural lakes in Wisconsin. For assessing the overall significance of treatments, each treatment lake was paired with a control lake in which the regulation was not implemented. Across all lakes, mean total length (TL) of sampled Bluegills was significantly greater in treatment lakes than in control lakes after the regulation was implemented: on average, mean TL increased by 20.3 mm. However, efficacy of reduced bag limits varied substantially across lakes as mean TL improvements ranged from −5.1 to 63.5 mm in individual lakes. This variation could be strongly explained ($R^2 = 0.81$) by lake Secchi depth (lakes with reduced water clarity showed larger improvements in mean TL, $R = -0.62$) and regulation duration (size structure improved continuously with time after the reduced daily bag limit was implemented, $R = 0.75$). Reduced bag limits are a useful tool for providing improvements to Bluegill size structure in Wisconsin lakes, but would be most effective in more productive waterbodies and will require substantial time investments after implementation.

The Bluegill *Lepomis macrochirus* is a widespread fish species in North America with major recreational, ecological, and cultural significance (Coble 1988; Drake et al. 1997; Spotte 2007; Rypel 2011). However, angler harvest of many Bluegill populations can be intense and represents a major driver of undesirable size structure (Coble 1988; Beard and Kampa 1999; Crawford and Allen 2006). For example, Bluegill size structure can rapidly deteriorate in individual lakes because of angler exploitation (Goedde and Coble 1981; Coble 1988); however, size structure can also decline over macrogeographic scales if harvest is intense and widespread (Olson and Cunningham 1989; Beard and Kampa 1999). In Wisconsin, the mean and maximum lengths of Bluegills have been declining statewide since the 1940s, and overexploitation by anglers is generally considered to be a leading cause of this change (Beard and Kampa 1999, A.L.R., unpublished data). Similar declines in size structure have been observed in other regions (Olson and Cunningham 1989; Paukert et al. 2002; Wolf-Christian et al. 2006), and a review of regulations in U.S. states suggests a prevalence of relatively high daily bag limits for Bluegills (Sammons et al. 2006).

Complex life histories and behaviors render Bluegills particularly vulnerable to degradations in size structure due to angling pressures and therefore present unique challenges for sustainable fisheries management (Jennings 1997; Aday et al. 2003; Cooke et al. 2009; Quinn and Paukert 2009; Rypel et al. 2012). Reproductively mature male Bluegills can take the form of either large-bodied parental males or small-bodied “sneakers,” which include female mimics (Dominey 1980; Gross and Charnov 1980; Gross 1982). Parental males grow quickly, and if they survive, achieve large body sizes that allow them to attract female mates, improve colony position, and defend their nests from predators and conspecific sneaker males (Gross 1982; Neff 2003). Alternatively, sneaker males mature rapidly (sometimes by age 1) but divert energies away from body growth in favor of robust testes development (Booth and Keast 1986). Thus sneakers are ultimately dwarfed and slow-growing and demonstrate cuckoldry, including a lack of nest guarding (Philipp and Gross 1994; Drake et al. 1997; Aday et al. 2003, 2008). Divergent life history strategies for male Bluegills are pertinent to fisheries management because anglers prefer large parental males over sneakers for their large size (Jennings et al. 1997; Beard and Essington 2000; Quinn and Paukert 2009). Furthermore, parental males

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Received September 18, 2014; accepted December 18, 2014

are often visually and intensely targeted by anglers in conspicuous shallow water colonies during the spawning season (Becker 1983).

Attempts to improve Bluegill size structure in Wisconsin lakes, frequently limited to a single manager working on a single lake, have usually focused on reducing Bluegill abundances so as to improve growth rates (e.g., Otis et al. 1998). Although such efforts can be effective, they are ultimately too laborious and cost-prohibitive to implement at larger scales. Direct attempts to curb exploitation have been rarer. From 1965 to 1997, Wisconsin had an aggregate daily bag limit of 50 panfish (i.e., Bluegills, Pumpkinseed *Lepomis gibbosus*, Black and White Crappie *Pomoxis* spp., Yellow Perch *Perca flavescens*). In an effort to improve statewide size structure of panfish, the statewide daily limit was reduced in 1998 to an aggregate of 25 fish. However, recent modeling studies suggest that daily limits may need to be reduced to even lower levels to promote desirable improvements to panfish size (Mosel 2012; D. Isermann, U.S. Geological Survey and N. Nate, University of Wisconsin–Stevens Point, unpublished data). Results from evaluations of other forms of regulations (e.g., minimum length limits) have been somewhat equivocal in their effect on size structure (Paukert et al. 2002; Ott et al. 2003; Crawford and Allen 2006; Sammons et al. 2006). One experimental study of reduced daily limits for Bluegills in Minnesota (decreased from 30 to 10 fish) showed promise for improving size structure in natural lakes (Jacobson 2005). Yet there has been little research from other regions and from lakes with a wider range of environmental characteristics. A better understanding of lake-specific factors that drive regulation efficacy might help managers make better predictions on where special angling regulations might be most appropriate for implementation.

Aggregate daily limits for panfish were reduced from 25 to 10 fish on a series of Wisconsin lakes over the past 15 years to address concerns about undesirable size structures in Bluegill populations. Consequently, reductions in harvest associated with reduced daily limits were hypothesized to be sufficient to improve Bluegill size structure in these lakes. The goals of this study were to (1) retroactively evaluate the effectiveness of a reduced daily limit on Bluegill size structure in seven Wisconsin lakes and (2) test whether the efficacy of the regulation changes was related to the characteristics of the lakes and populations studied.

METHODS

Eight lakes located throughout Wisconsin were studied that varied in their physical, chemical, and ecological properties (Table 1). The daily aggregate limit for panfish in seven of these lakes was reduced from 25 to 10 fish, whereas in the eighth lake (Twin Valley Lake), the daily limit was increased from 25 to unlimited (i.e., a reverse treatment). Bluegill populations were sampled over time by fisheries biologists as part of their annual fisheries assessments, which operate on an annual rotation (i.e., individual lakes are sampled every 3–8 years, depending on lake size, usage, and number of surrounding lakes). Consequently, populations were sampled at different times relative to when the regulation change occurred, given the timing of the lakes' sampling rotation. For example, Altoona Lake was sampled only 3 years following the regulation change, whereas Long Lake and Cox Hollow Lake were sampled 8 years after the regulation change. For lakes that were sampled multiple times following the regulation change, only data for the most recent postregulation sampling event were analyzed. For the preregulation period, however, multiple sampling events (if they existed) were grouped so long as data did not predate the regulation change by more than 10 years. Fish populations were sampled with boat-mounted boom or mini-boom electrofishing equipment and pulsed direct current (DC). In some lakes, additional sampling gear, Wisconsin Department of Natural Resources (WDNR) standard fyke nets (25.4-mm-mesh size), were used (Table 1); in no case, however, did sampling gear differ between time periods for an individual lake. A minimum sampling of 50 individual Bluegills was required for each time period (pre/post) in each lake for the data to be included in the analysis. Reduced daily limits for Bluegills were also imposed on several other lakes, but those lakes were not included in this analysis because they did not conform to the data standards as outlined above. Ultimately, the eight study lakes provide a fairly typical representation of the lakes and panfish angling opportunities common to Wisconsin.

A before–after control impact design was used for this study as replication occurred over time (before versus after) and space (treatment versus control). Thus, each treatment lake was paired with a similar control lake that did not receive the reduced daily limit. Control lakes were selected after regulation implementation by locating lakes of similar area, maximum depth, and trophic state index within the same or neighboring county as each of the treatment lakes (Table 1). Control lakes also needed to have before-and-after fisheries assessment data that were collected ±1 year of the collection period in treatment lakes. In a few cases, the same control lake was used for multiple treatment lakes when data for another suitable control lake were not available (Table 1).

Two-way analyses of variance (ANOVAs) were used to test for differences in mean TL and mean maximum TL (the mean TL of the 10 largest fish) before and after the reduced daily limit changes in treatment and control lake pairs. In each model, the length of all captured Bluegills was the dependent variable and treatment type (treatment or control) and period (before or after) were categorical variables. The significance of the reduced daily limit was therefore assessed by way of the significance of the treatment type × period interaction term. Finally, omnibus two-way ANOVAs incorporating data from all lakes (one for mean TL and another for mean maximum TL) were performed. Here, two-way ANOVAs were

TABLE 1. Characteristics of 14 Wisconsin lakes used to evaluate the effect of a reduced daily bag limit on size structure of Bluegill populations; n/a = not applicable.

Lake	Latitude	Longitude	Area (ha)	Years post-regulation	Max. depth (m)	Secchi depth (m)	Treatment type	Experimental lake pair	Sampling gear used in before and after surveys
Cox Hollow Lake	43.01	−90.11	33.0	8	9.1	2.8	Treatment	Blackhawk Lake	Boat electrofishing
Blackhawk Lake	43.02	−90.28	86.0	n/a	12.2	5.8	Control	Cox Hollow and Twin Valley lakes	Boat electrofishing
Twin Valley Lake	43.02	−90.09	55.0	8	9.8	1.4	Treatment	Blackhawk Lake	Boat electrofishing
Eau Claire Lake	44.76	−91.11	550.3	n/a	7.6	1.6	Control	Altoona Lake	Boat electrofishing
Altoona Lake	44.81	−91.42	291.3	3	7.6	1.2	Treatment	Eau Claire Lake	Boat electrofishing
Lake Menomin	44.89	−91.91	408.2	5	10.4	0.6	Treatment	Popple Lake	Boat electrofishing
Tainter Lake	44.98	−91.86	649.4	6	11.3	0.9	Treatment	Popple Lake	Boat electrofishing and fyke net
Popple Lake	45.06	−91.30	38.2	n/a	7.6	1.5	Control	Tainter and Menomin lakes	Boat electrofishing
Long Lake	45.25	−91.40	378.7	8	30.8	2.5	Treatment	Axhandle Lake	Boat electrofishing and fyke net
Axhandle Lake	45.28	−91.48	34.8	n/a	22.3	3.9	Control	Long Lake	Boat electrofishing and fyke net
Diamond Lake	46.26	−91.15	130.5	n/a	25.3	3.8	Control	Middle Eau Claire Lake	Boat electrofishing and fyke net
Middle Eau Claire Lake	46.30	−91.52	356.0	2	20.1	5.8	Treatment	Diamond Lake	Boat electrofishing and fyke net
Bony Lake	46.32	−91.51	77.0	2	16.8	6.2	Treatment	Eagle Lake	Boat electrofishing and fyke net
Eagle Lake	46.50	−91.36	66.1	n/a	15.8	4.2	Control	Bony Lake	Boat electrofishing and fyke net

conducted where mean or mean maximum Bluegill TL for each lake were the dependent variables and treatment type (treatment or control) and time period (before or after) were categorical variables. Again, the significance of the regulation change was assessed through the treatment type × period interaction term.

To evaluate whether the efficacy of each regulation change was related to the environmental characteristics of each study lake and fish population, a metaanalysis metric (the $\log_{10}$ [response ratio]) was used in combination with multiple linear regression. Log_{10}(response ratios) were calculated following Borenstein et al. (2011) for each treatment lake as

$$\text{Log}_{10}(\text{response ratio}) = \log\left(\frac{\Delta\,\text{ST}}{\Delta\,\text{SC}}\right),$$

where ΔST is the change in mean TL of Bluegills between time periods in the treatment lake, and ΔSC is the change in mean TL of Bluegills between time periods in the control lake. Jacobson (2005) presented data for eight Minnesota lakes analogous to those collected in this study (i.e., mean Bluegill lengths); in four treatment lakes the daily limits for Bluegills were reduced from 30 to 10 and in four control lakes the Bluegills daily limit was maintained at 30. Here, using the above equation, response ratios were calculated for the before-and-after mean Bluegill length data presented in Jacobson (2005) and those ratios were incorporated into this analysis to bolster statistical power. Because the treatment and control lakes were not paired in the Jacobson (2005) study, response ratios were calculated for each Minnesota lake by using an average of the data for the four control lakes presented in their study. Furthermore, data on mean maximum TL were not available in Jacobson (2005); thus, only patterns in mean TL were evaluated for this specific analysis. To identify potential collinearity and reduce the number of predictors, a Pearson correlation matrix was constructed relating $\log_{10}$(response ratio), $\log_{10}$(lake size), $\log_{10}$(lake maximum depth), $\log_{10}$(mean lake Secchi depth)—a frequently used proxy for lake fertility—mean Bluegill TL before regulation change, and duration of regulation. Finally, a multiple linear regression was performed to predict $\log_{10}$(response ratio) by using the variables identified as potential predictors from the correlation matrix above (i.e., $\log_{10}$(Secchi depth) and regulatory duration). All statistics were evaluated using $\alpha < 0.05$ to indicate significance.

RESULTS

Mean and mean maximum TL of Bluegills increased in five of the seven treatment lakes with daily limits of 10 fish (Figures 1 and 2). Mean and mean maximum TL over the same period also increased in four of six control lakes (Figure 2). In every case where mean Bluegill TL in treatment lakes was below the state average, size increased to above the state average following treatment (Figure 2). Bluegills in the eighth (unlimited limit) treatment lake decreased substantially in both mean TL (from 206 to 146 mm) and mean maximum TL (from 329 to 179 mm) following regulation liberalization. After accounting for temporal changes in Bluegill size in the control lakes, four of the seven treatment lakes showed a significant increase in mean Bluegill TL in the 10-fish-limit treatment lakes (Table 2; all treatment type × period interaction

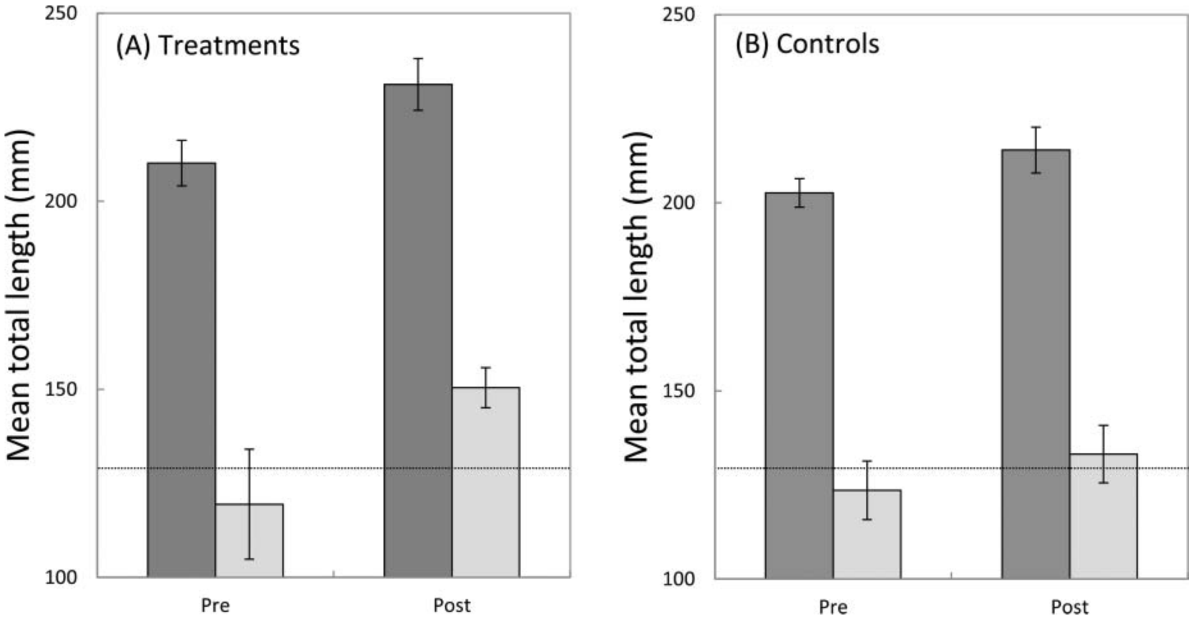

FIGURE 1. Mean TL (light gray bars) and mean maximum TL (dark gray bars) for Bluegills across all (**A**) treatment and (**B**) control lakes before and after implementation of a reduced aggregate daily bag limit for panfish (from 25 to 10 fish per day). Error bars represent the mean ± 1 SE. Horizontal dashed lines represent the statewide average TL for Bluegills in Wisconsin lakes.

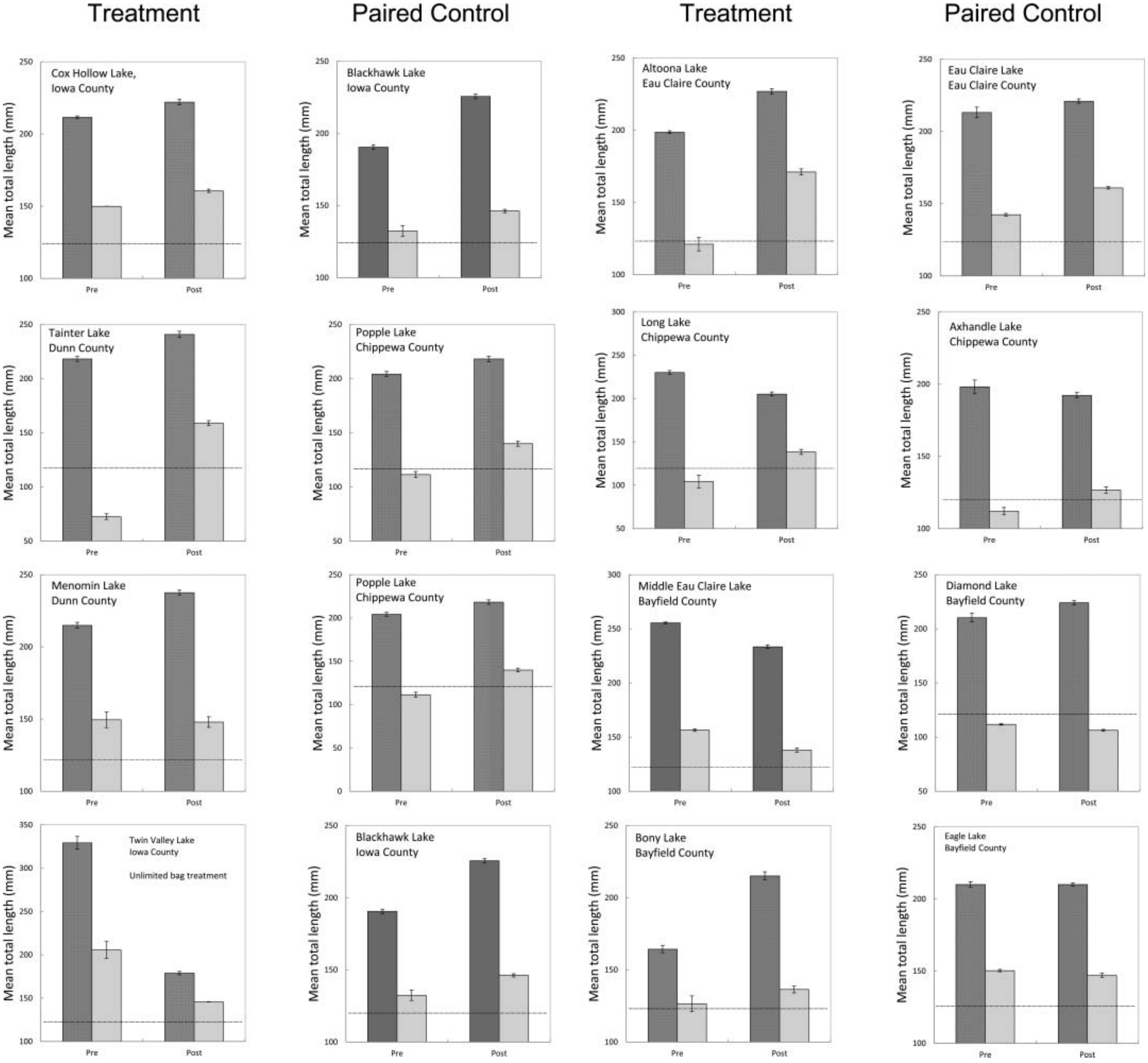

FIGURE 2. Mean TL (light gray bars) and mean maximum TL (dark gray bars) for Bluegills in each treatment and control lake pair before and after implementation of a reduced daily limit. Error bars represent the mean ± 1 SE. Horizontal dashed lines represent the statewide average TL for Bluegills in Wisconsin lakes.

terms, $P < 0.0001$). Furthermore, two-way ANOVA models also showed that mean maximum TL increased significantly in five of the seven 10-fish-limit treatment lakes (Table 2; all treatment type × period interaction terms, $P < 0.0001$). In the unlimited daily limit treatment lake, declines in both mean TL and mean maximum TL were both highly significant (Table 2; all $P < 0.0001$). Across all 10-fish-limit treatment lakes, the significant increase in both mean TL ($P = 0.03$) and mean maximum TL ($P = 0.02$) amounted to an average gain relative to controls of 21 mm in mean TL and 9 mm in mean maximum TL.

Observed changes in Bluegill size structure relative to controls was highly variable for individual treatment lakes. For example, Tainter Lake showed increases in mean and mean maximum TL relative to that in controls of 86 mm and 3 mm, respectively (Figure 2; Table 2). However, Cox Hollow Lake showed an increase of only 4 mm in mean TL but a 30 mm increase in mean maximum TL relative to

TABLE 2. Results of two-way ANOVAs testing for the effect of a reduced daily bag limit on Bluegill size structure in eight Wisconsin lakes. Using a before–after control impact design, the effect of the reduced daily bag limit on Bluegill size was assessed through the significance of the treatment × period interaction term. Graphical depictions of these effects can be viewed in Figures 1 and 2.

	Mean Bluegill TL				Mean maximum Bluegill TL			
	Model		Treatment × period		Model		Treatment × period	
Lake	*F*	*P*	*t*	*P*	*F*	*P*	*t*	*P*
Cox Hollow Lake	21.73	<0.0001	4.45	<0.0001	31.78	<0.0001	5.33	<0.0001
Twin Valley Lake	132.4	<0.0001	–19.1	<0.0001	296.48	<0.0001	–26.77	<0.0001
Altoona Lake	135.9	<0.0001	15.15	0.0001	13.88	<0.0001	6.09	<0.0001
Lake Menomin	35.74	<0.0001	–0.24	0.81	34.86	<0.0001	6.8	<0.0001
Tainter Lake	227.2	<0.0001	24.07	<0.0001	39.07	<0.0001	6.37	<0.0001
Long Lake	32.06	<0.0001	8.36	<0.0001	35.3	<0.0001	–6.19	<0.0001
Middle Eau Claire Lake	648.6	<0.0001	–9.83	<0.0001	59.55	<0.0001	–6.34	<0.0001
Bony Lake	17.77	<0.0001	1.72	0.09	46.05	<0.0001	10.4	<0.0001
All treatment lakes[a]	2.1	0.14	2.31	0.03	4.27	0.02	2.54	0.02

[a] Conducted using the mean length and mean length of the 10 largest fish for each lake.

controls (Figure 2; Table 2). Conversely, mean TL of Bluegills in Long Lake increased by 27 mm relative to that of Bluegills in its control lake, but mean maximum TL actually declined significantly ($P < 0.0001$) by 25 mm relative to the same control (Figure 2; Table 2).

Variability in the efficacy of reduced daily limits was evidenced by variation in response ratios, which ranged by a factor of ~10. Log$_{10}$-transformed response ratios did not correlate significantly with lake area ($R = 0.20$, $P = 0.56$), lake maximum depth ($R = -0.33$, $P = 0.33$), or Bluegill size at the outset of the regulation change ($R = -0.52$, $P = 0.10$). However, log$_{10}$(response ratios) did correlate significantly with regulatory duration ($R = 0.75$, $P = 0.008$) and mean lake Secchi depth ($R = -0.62$, $P = 0.04$). Results of a multiple regression estimating log$_{10}$(response ratios) of reduced daily limit treatment lakes based on regulatory duration and lake Secchi depth were highly significant ($F = 9.88$, $P = 0.007$, df = 7, $R^2 = 0.81$). Efficacy of the reduced daily limits scaled positively with length of time since regulation implementation and negatively with mean Secchi depth (i.e., more productive lakes; Figure 3a and b). Furthermore, the effect of Secchi depth on the response ratio appeared to be independent of the effect of regulatory duration because residuals from a regression of log$_{10}$(response ratio) against regulatory duration could also be significantly regressed against Secchi depth (Figure 3c).

DISCUSSION

Reduced daily limits generally had a positive effect on Bluegill size structure in Wisconsin lakes. Reduced daily limits were accompanied by increases in both mean TL and mean maximum TL relative to sizes in control lakes. Furthermore, liberalizing regulations in one lake (i.e., no daily bag limit) had severe deleterious effects on both mean and maximum TL. However, the gains in size produced by reduced daily limits were variable and in many cases could be considered relatively modest. Variation in the efficacy of the reduced limits was correlated with the duration of the regulation change and mean lake Secchi depth.

Daily bag limits are one of the simplest forms of regulations for anglers to understand and are therefore of high interest to many fisheries management agencies. The fact that mean Bluegill TL improved in lakes subjected to reduced daily limits was not surprising as the intent of these regulation changes was to reduce Bluegill harvest sufficiently to increase survival of adult fish from angling. These results therefore support those from an array of other studies that have shown positive effects of reduced daily limits on the size structure of a large variety of sport fishes (Eder 1984; Allen and Miranda 1995; Simonson and Hewett 1999; Van Poorten et al. 2013). Observed changes in Bluegill size structure in Wisconsin lakes also correspond closely with those observed in Minnesota lakes (Jacobson 2005) similarly subjected to a reduced limit of Bluegill (from 30 to 10 fish per day). Across all four Minnesota treatment lakes, mean Bluegill TL increased by 22.8 mm (range, 10–38 mm), and mean TL of age-7 parental males from Minnesota lakes increased by an average of 19.5 mm (range, 6–36 mm). These numbers are extremely similar to the 20.3-mm increase (range, –5.1 to 64 mm) in mean TL observed in this study. Furthermore, even though lakes in both studies showed substantial increases in mean and mean maximum Bluegill TL due to the reduced limit (Tainter Lake in this study, Sanburn Lake in Jacobson [2005]), many lakes

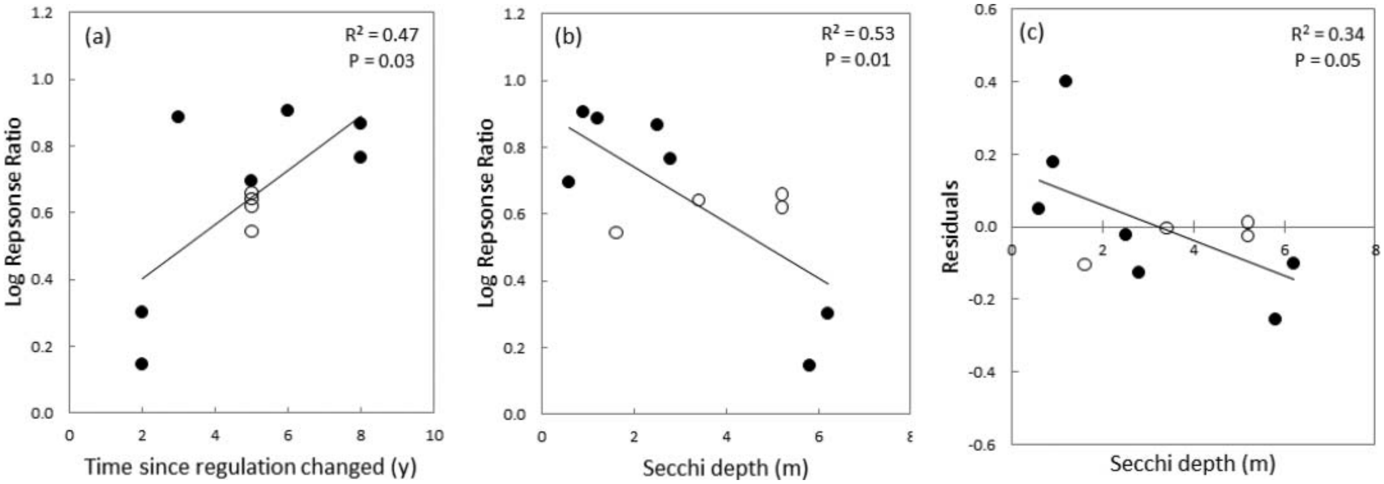

FIGURE 3. Log_{10}(response ratio) for each treatment and control lake pair plotted as a function of **(a)** time since regulation changed; **(b)** lake Secchi depth; and **(c)** lake Secchi depth after accounting for the effect of time since regulation changed. Solid circles represent data from Wisconsin lakes collected as part of this study; open circles represent data extracted and analyzed from Jacobson (2005) for Minnesota lakes.

showed only modest improvements in size. The term "modest" is used here because it remains unclear from the author's conversations with anglers and managers alike whether a 20.3-mm gain in mean Bluegill size is significant in the context of on-the-ground fisheries management.

Lake productivity appeared to play an important role in the efficacy of reduced daily limits for improving size structure in Bluegill populations in Wisconsin. Treatment lakes with a lower mean Secchi depth (i.e., presumably more productive lakes) often had some of the highest response ratios and thus Bluegill size increased to a greater extent in these lakes than in others. This is a key finding, which suggests reduced daily limits could be more effective, and thus more appropriate for implementation, in more productive waterbodies. Although not studied because of a lack of data derived from adequate aging structures, the mechanism underlying this pattern is likely somatic growth. Growth rates are one of the key determinants of body size changes in fish populations over space and time (Campana and Thorrold 2001; Rypel 2014a, 2014b). Using a simple example of growth rates from fast-growing and slow-growing Bluegill population in Wisconsin (i.e., statewide 75th and 25th percentiles in length-at-age), one can easily visualize how delayed mortality (in this case attributable to delayed exploitation) could generate higher average Bluegill sizes in some populations than in others (Figure 4). For example, in faster growing populations, delaying mortality due to harvest by only 1 year for a 178-mm fish (i.e., the most commonly harvested size of Bluegills in Wisconsin) would result in an 18-mm increase for each fish. However, the same 1 year delay in mortality would produce only an 11-mm increase in slower growing populations. A strength-of-growth hypothesis is concordant with Paukert et al. (2002), who found that a 200-mm minimum length limit was the most effective limit for improving size structure in faster growing

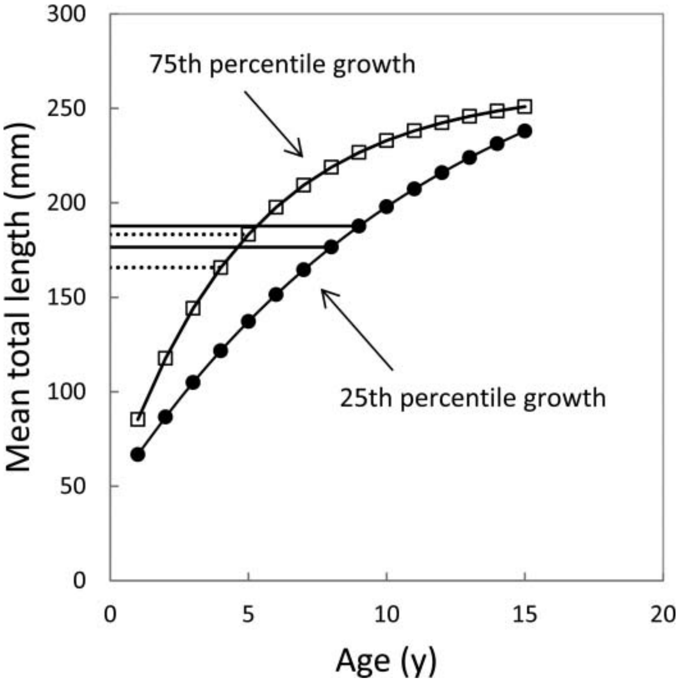

FIGURE 4. Conceptual figure illustrating how differences in growth rates might yield variations in size structure responses to reduced daily bag limits for Bluegills. For example, populations with fast growth (75th percentile for growth in Wisconsin, open squares) attain a harvestable size at ∼4 years of age. However, Bluegill populations with slower growth (25th percentile for growth rates in Wisconsin, closed circles) take ∼9 years to reach harvestable size. If fish survive only 1 year longer due to delayed mortality from angling, Bluegills from faster growing populations will gain considerably more in size (horizontal dashed lines) than those in slower growing populations (horizontal solid lines). Thus regulations that delay angling mortality, such as a reduced daily limit, might be predicted to increase mean TL to a greater extent in populations with greater growth potential.

Nebraska Bluegill populations, especially if they had low natural mortality rates. Numerical simulations have also suggested that for a variety of potential special Bluegill regulation options, the effect of most regulations on size would be greatest if implemented on faster growing populations (Beard et al. 1997). Thus, this analysis provides empirical support for the concept that reduced daily limits have more of a positive effect on mean TL of Bluegills in more productive ecosystems.

The effectiveness of reduced daily limits in Wisconsin lakes also correlated positively with the duration of time since the reduced limit was implemented. This finding makes intuitive sense given what is known concerning the life history of Bluegill in the region. For example, Bluegills in Wisconsin regularly live to >10 years of age (Becker 1983). Thus a reduced daily limit that has been in place for only 3 years (e.g., Altoona Lake) may have covered only 20–30% of the lifespan of individuals in this population. As regulations are retained for longer periods, individual fish would be allowed to matriculate through a larger range of size-and age-classes than previously, thereby improving overall size structure. Undoubtedly, there is a point in time where such an effect will become saturated; however, the plot of $\log_{10}$(response ratios) against regulatory duration suggests that saturation in the response ratio had either not yet occurred or only just begun to occur. Further research on this topic will be important in elucidating the time scale commonly needed to saturate the effect of reduced daily limits.

The social palatability of reduced daily bag limits for Bluegills on a larger scale also remains unknown. For example modest gains in mean TL (about 20 mm across all treatment lakes), such as those observed in this study, may not be worth the cost of a reduced daily limit to some anglers. At least anecdotally, however, this level of size structure increase was sufficient for many anglers to take notice. Indeed, many of the treatment lakes used in this study are now considered by anglers to offer quality Bluegill fishing opportunities (S. Toshner and G. Van Dyke, WDNR, personal communications). However, recent statewide surveys of panfish anglers in Wisconsin have shown equivocal support for reduced daily bag limits (e.g., about 50% of anglers are receptive to statewide reductions in daily limits for panfish). In another study gauging the acceptability of Illinois anglers to an array of potential Bluegill regulations, angler support was greatest for catch and release fishing during the spawning season, lower for reduced daily limits or minimum length limits, and lowest for closed fishing areas (Edison et al. 2006). Statewide regulations for panfish in Wisconsin have historically offered anglers high harvest opportunities. Consequently, it is uncertain at what scale reduced daily limits for Bluegill would become socially acceptable. These questions represent key areas of human dimensions for future research to explore, especially if reduced daily limits or other forms of Bluegill regulations are considered for broader implementation.

One important shortcoming to this study was that direct information on angler harvest was lacking for most of the study lakes. Thus it remains uncertain, albeit plausible, that the reduced daily limits indeed curbed harvest to a level sufficient to improve size structure. Unfortunately, creel surveys remain an exceedingly expensive form of data collection and as such, the deployment and feasibility of conducting these surveys at larger scales have declined in recent years (Smallwood et al. 2012; Greenberg and Godin 2013). However, as is clear from this experiment, size structure increased significantly in treatment lakes relative to controls, and the most plausible reason for this increase remains a reduction in angler harvest. The lack of data on harvest for key evaluation-oriented studies such as these provides yet another example of why investment in creel data is vital for natural resource management agencies, despite the cost. In addition to directly measuring angler effort, creel survey data over a larger spatial scale could be useful for examining the potential for redistribution of angler effort due to implementation of reduced daily limits (Beard et al. 2003). In fact, in modeled scenarios of angler behavior, Cox et al. (2003) suggested that special angling regulations may need to be implemented on a large fraction of surrounding lakes to sufficiently curb any potential for anglers to redistribute effort. Otherwise, positive effects on some lakes could be functionally nullified by intensifying exploitation rates on others. Finally, lower daily limits might increase the propensity for some anglers to reach their limit by creating a more attainable goal, thereby increasing angling pressure and harvest. This sort of pattern may explain why mean maximum TL actually decreased in two treatment lakes (i.e., harvest of quality fish may have increased).

In conclusion, this study indicated that a reduced daily limit of 10 fish per day effectively provided modest improvements to size structure of Bluegills in several Wisconsin lakes. Thus, managers potentially can improve Bluegill size structure in lakes where harvest is viewed to be a problem by using reduced daily limits. Lakes and populations that favor more rapid growth rates would be predicted to perform better with the implementation of reduced daily Bluegill limits. It remains important to recognize that the time investment required for reduced limits to yield positive effects might be long. Theoretically, fish populations could need to undergo several generations to fully benefit from the effects of any fishery regulation change (Hoenig and Gruber 1990; Winemiller 2005). In the case of Bluegills this might range from 20 to 40 years. However, the positive effect could also be starting to saturate in Wisconsin lakes in only 8–10 years. Even though natural resource management agencies may find it difficult to commit to regulatory change for long periods, this study emphasizes the importance of continuity over time for a reduced daily limit regulation. Indeed, well-crafted management plans are needed, including successional plans for personnel change, as well as strong public outreach and support. The lack of life history data on parental and sneaker male Bluegills and how these strategies respond to various fishing regulations also represents a key gap in knowledge that went unaddressed in this study. Finally, although this analysis and several other studies (Paukert et al. 2002; Jacobson 2005; Crawford and Allen 2006; Sammons et al. 2006) have shown positive effects of reduced limits on sunfish size structure, few studies have empirically evaluated the efficacy of even more stringent forms of regulation (e.g., five-fish limits, slot length limits, or potentially season closures). Thus, although this study suggests that managers consider a reduced limit of 10 Bluegills per day, other tools may be more or less effective for different populations or scenarios. Consequently, evaluations of the effectiveness of other types of regulations for Bluegills and other panfish species are also needed.

ACKNOWLEDGEMENTS

I thank a large number of WDNR biologists and technicians who assisted in collection, entry, and management of these data, especially Gene Van Dyke, Scott Toshner, Marty Engel, and Heath Benike. I also thank the members of the panfish team at WDNR who provided helpful feedback throughout this analysis, including Joanna Griffin, Jon Hansen, Max Wolter, Steve Avelallemant, Ron Bruch, Pat Short, Dan Hatleli, Al Niebur, Kurt Welke, Dan Isermann (U.S. Geological Survey), and Wally Trudeau (Wisconsin Conservation Congress). I also thank John Lyons, Greg Sass, and Jon Hansen for reviewing earlier iterations of this manuscript. Financial support for this study was provided by the WDNR, Bureau of Science Services, Federal Aid in Sport Fish Restoration (Project F-95-P, study SSPF).

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