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Largemouth Bass Management in Wisconsin: Intraspecific and Interspecific Implications of Abundance Increases

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Abstract.—Largemouth Bass (LMB) *Micropterus salmoides* is one of the most popular sport fish in the United States and is intensively managed across much of its range. Beginning in 1989, Wisconsin implemented more restrictive harvest regulations for LMB, including greater minimum length limits, reduced bag limits, and a catch-and-release-only season during the spawning period across much of northern Wisconsin. We tested for trends in LMB relative abundance, growth, and angler catch and harvest in relation to LMB management policies from 1990 to 2011. We also tested for potential sport fish community responses to changes in LMB abundances using Walleye (WAE) *Sander vitreus* as an example. Angler catch rates and electrofishing catch per unit effort of LMB greater than 8 and 14 in increased significantly statewide. Mean length of age-6 LMB decreased significantly statewide. Release rates of LMB increased from about 80% in 1991 and then plateaued at more than 96% from 2005 to 2011. Concurrent with increases in LMB, adult WAE densities declined in lakes containing LMB. Ongoing research is being conducted to test for interactions between LMB and WAE and to test for additional environmental drivers, such as climate warming, that may be associated with increased LMB abundances. Largemouth Bass abundances have increased in Wisconsin, possibly in response to changes in harvest regulations, angler behavior, and potentially other

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environmental drivers. These increases in LMB abundances have had negative intraspecific effects on growth and may be negatively affecting WAE stocks. We recommend that management goals for LMB consider intra- and interspecific consequences, particularly in water bodies where multispecies fisheries are desired.

Introduction

Largemouth Bass (LMB) *Micropterus salmoides* is one the most popular sport fish in the United States (USFWS 2011) and has been intensively managed and researched across its entire range. A substantial body of LMB-related management literature derives from research conducted in the southern half of the United States, where LMB is often the priority species for fisheries managers. In Wisconsin, near the northern limit of the LMB range (Becker 1983), this species is often less popular among anglers and of lower management priority compared to other species (e.g., Walleye [WAE] *Sander vitreus*; panfish species *Lepomis* spp., *Pomoxis* spp., Yellow Perch *Perca flavescens*, and Muskellunge *Esox masquinongy*). Nevertheless, LMB comprises a large proportion of the fish caught by Wisconsin anglers (Gaeta et al. 2013) and has been managed as an economically and recreationally valuable sport fish.

Management of LMB populations in Wisconsin has largely focused upon regulating angler harvest using a combination of length and bag limits and seasonal closures or restrictions (e.g., catch-and-release-only seasons during the spawning period). The history of LMB management in Wisconsin can be characterized by three time periods during the 1880s to 2010s, which have generally alternated between protective harvest regulations and more harvest-oriented goals (Table 1). Formal fisheries management in Wisconsin began in the 1880s, and LMB was one of the first sport fish protected with regulations. These protective regulations remained until the 1950s, when a shift to a maximum sustainable yield paradigm occurred for most fish species. This period of liberalized LMB regulation lasted until the late 1980s and early 1990s, when Wisconsin implemented a statewide minimum length limit, bag limits, and a protective catch-and-release-only season during the spawning period in northern Wisconsin. The most recent protective harvest regulations were intended to increase the abundance of all sizes of LMB and reduce quality overfishing, which was reported to be widespread (Simonson 2001).

The implementation of more restrictive LMB regulations throughout the 1990s was ushered in with broad public support. Wisconsin's more restrictive LMB harvest regulations were not unique and coincided with a national trend towards efforts to reduce LMB fishing mortality (Allen et al. 2008), which has been declining since about 1980. In addition to broad LMB harvest regulations, rates of voluntary release have also increased since the 1980s to high levels (80–90%) in popular Texas and Florida waters (Myers et al. 2008) and in Minnesota lakes (Isermann et al. 2013). Voluntary release trends in northern Wisconsin may be following a similar trajectory (Gaeta et al. 2013).

Currently, LMB harvest regulations in Wisconsin are undergoing another transition. Since the mid-2000s, anglers and managers have proposed removing LMB minimum length limits to promote harvest on many LMB populations. These proposed regulation changes have primarily arisen from anecdotal accounts of increased LMB abundances, particularly in northern Wisconsin. These accounts

Table. History of Largemouth Bass regulations in Wisconsin.

Time period	Regulations
1880s–1950s	Closed season (3 months)
	Bag limit (15/d)
	Minimum length limit (10 inches)
1950s–1980s	Length limits and many bag limits eliminated
1980s–2008	Statewide minimum length limit (12 inches, then 14 inches statewide)
	Aggregate bag limit of 5, including Smallmouth Bass *Micropterus dolomieu*
	Catch-and-release-only during spawning season in the northern zone
	Increased lake-specific protective regulations
2008–present	Increased removal of minimum-length limits and protective slots
	Numerous proposals to allow harvest during spawning

suggest that LMB abundance increases have resulted in intraspecific declines in growth and negative effects on WAE. Therefore, an experimental suite of management actions were implemented on 26 lakes in 2011 in an effort to reduce LMB abundances and increase WAE densities. These regulations included removing black bass (LMB, Smallmouth Bass) minimum length limits, reducing WAE bag limits, increasing WAE length limits, and stocking extended growth WAE fingerling (152–203 mm) in the fall. This approach used the most readily available and socially acceptable tools and will form the basis of an adaptive management experiment to be evaluated iteratively against a set of reference lakes over the next 15 years. Black bass (LMB, Smallmouth Bass) minimum length limits were also removed in two counties in northwestern Wisconsin to improve bass growth rates.

In an effort to evaluate the statewide relevance of these anecdotal accounts, we tested for trends in LMB population metrics and angler behavior during 1990–2011. We also tested for trends in adult WAE density in lakes containing LMB in northern Wisconsin. Our goal was to provide managers with an empirical analysis of LMB trends in response to regulation changes and angler behavior. Additionally, we tested whether trends in LMB and WAE metrics demonstrated the potential for interspecific interactions. Describing these trends in LMB and WAE in Wisconsin may help inform future LMB management decisions, especially within the context of a complex, multispecies sport fishery.

Methods

We used data collected throughout Wisconsin during 1990–2011 to test for trends in LMB population metrics, LMB angler behavior, and adult WAE densities in lakes containing LMB. The majority of the data were collected from lakes in the northern third of Wisconsin (Ceded Territory), where the greatest density of lakes is found (Figure 1). In the Ceded

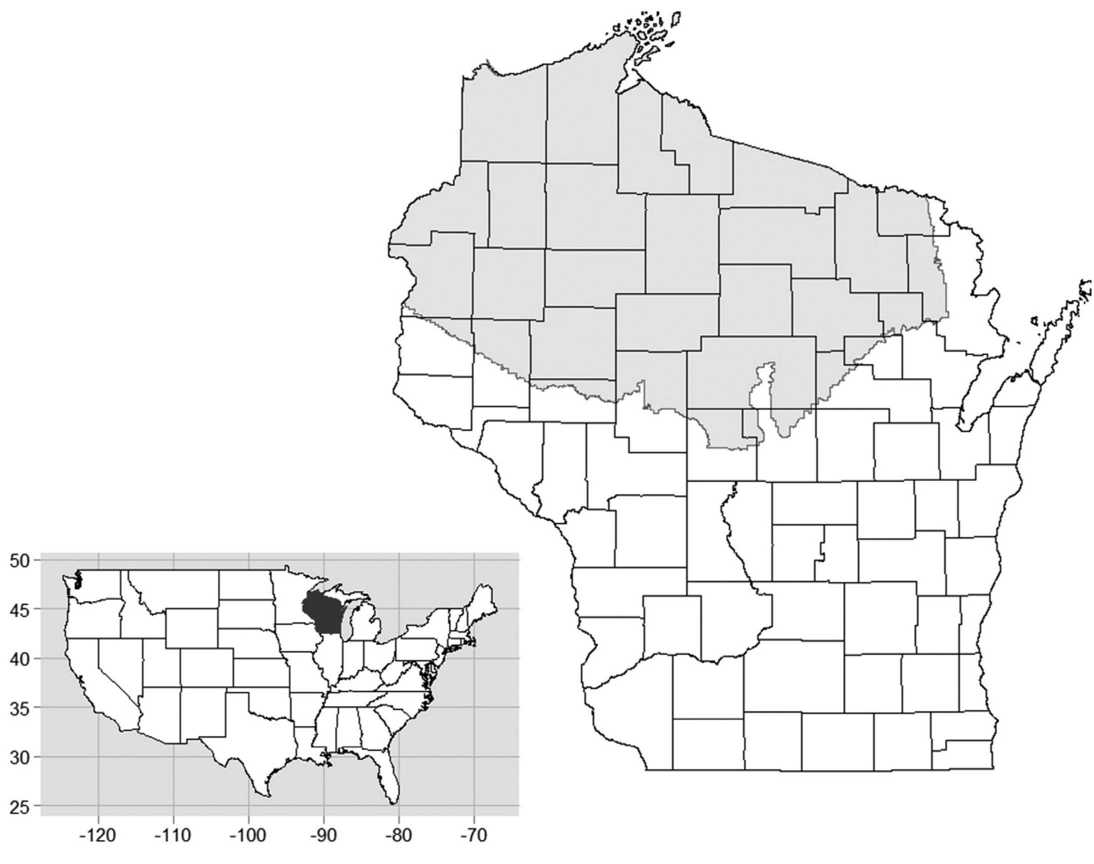

Figure 1. Map of Wisconsin with the Ceded Territory of Wisconsin shaded in gray.

Territory, a standardized fisheries sampling program has been in place since 1990 as part of a larger monitoring effort focused on the mixed recreational and tribal spearing WAE fishery (Hansen et al. 1991). Northern Wisconsin lakes range substantially in surface area, depth, and productivity. On average, these lakes tend to be of moderate surface area (461 acres), depth (4.8 m), and productivity (2.6 m Secchi depth and 35.2 mg/L $CaCO_3$ alkalinity) (Table 2). According to Carlson (1977), the majority of lakes we examined would be considered mesotrophic. An examination of four lakes representative of the Ceded Territory also suggest that trophic status (chlorophyll-*a* concentrations) has not changed during 1981–2012 (Stanley 2013).

We specifically tested for LMB trends in relative abundance, growth, catch rates, and release rates during 1990–2011. We also tested for trends in WAE release rates and adult densities in lakes containing LMB. Largemouth Bass relative abundance was indexed using spring AC-electrofishing catch/mi (catch per unit effort [CPUE]) intended to target fish prior to spawning. We only used LMB data collected when water temperatures met Wisconsin Department of Natural Resources (WDNR) protocols (55–70°F). We quantified CPUE data for all LMB greater than 8 in (CPUE8) to index the juvenile and adult population and all LMB greater than 14 in (CPUE14) to index the adult population generally vulnerable to angler harvest.

We used mean total length (TL) at age 6 to assess LMB growth. This age-class offered the greatest sample size and is used for WDNR growth standards (Simonson 2001). Scales were collected from five LMB within each 0.5 in length bin during index surveys. The use of fin spines, instead of scales, to estimate LMB age is currently the suggested protocol in Wisconsin; however, this is a recent change. Therefore, only ages estimated from scales were included in our analysis in an effort to maximize sample sizes and consistency across years.

Recreational LMB angler behavior was evaluated from standard creel surveys (Rasmussen et al. 1998; Beard et al. 2003). We calculated LMB specific catch rates by estimating the number of fish caught and dividing by the total estimated LMB-specific fishing effort for each lake, resulting in catch/h. We calculated mean annual angler release rate as the percent of LMB released relative to the number caught (R_i, release rate, in year *i*) with

$$R_i = \left(1 - \frac{H_{ij}}{C_{ij}}\right) \times 100,$$

where H_{ij} is the estimated number of LMB harvested from lake *j* in year *i* and C_{ij} is the estimated number of LMB caught from lake *j* in year *i*. To test for differences in angling behavior over time between the LMB and WAE recreational fisheries, we also calculated WAE release rates in the same manner. We were unable to differentiate voluntary release from release due to harvest restrictions. Although the northern Wisconsin LMB minimum length limit was increased from 12 to 14 in in 1998 to standardize the statewide minimum length limit, we assumed that any significant relationships detected would largely be attributed to voluntary release because minimal changes in the statewide regulations occurred during all years analyzed.

To test for changes in Ceded Territory adult WAE densities in lakes containing LMB, we used adult WAE population estimates collected during 1990–2011. Adult WAE density (number/acre) was estimated using the Chapman modification of the Peterson mark–recapture method (Hansen et al. 1991). Spring fyke netting was used to establish the marked adult WAE population and AC-electrofishing was used as the recapture gear. Only data from WAE populations with at least an historic record of natural reproduction in lakes containing LMB were used.

For each metric, we calculated the means and standard errors for each year. We used simple lin-

Table 2. Descriptive statistics of selected limnological variables associated with 245 Ceded Territory of Wisconsin lakes creeled from 1991 to 2011.

Variable	Minimum	Median	Maximum
Lake size (acres)	19.5	460.9	14,593.0
Mean depth (m)	0.9	4.8	14.7
Maximum depth (m)	1.5	10.5	35.1
Alkalinity (mg/L $CaCO_3$)	1.9	35.2	121.0
Secchi depth (m)	0.7	2.6	7.2

ear regression to test for changes in mean CPUE8, CPUE14, length of age-6 fish, and catch rates for LMB over time (1990–2011). The percent of LMB released from 1991 to 2011 showed an asymptotic relationship over time. We used a nonlinear least squares approach to identify the asymptote using a self-starting asymptotic regression model given by

$$y = \text{Asym} + (R_0 - \text{Asym}) \times e^{\left(-e^{\text{lrc}} \times x\right)}$$

where Asym is the horizontal asymptote, R_0 is y when x is zero, and lrc is the natural logarithm of the rate constant. Year was centered prior to analysis to allow for model convergence. The analysis was performed in R Cran statistical package (version 2.15.1; R Development Core Team 2012). For all analyses, we only included years for which data were available from more than one lake. Tests for trends in LMB release rates and adult WAE densities used Ceded Territory data only (Figure 1). Adult WAE density was $\log_e$ transformed to satisfy the assumption of normality. Statistical significance was determined at the $\alpha = 0.05$ level.

Results

Relative abundances of LMB greater than 8 and 14 in TL increased significantly statewide during 1992–2011 (Figure 2). On average, CPUE8 increased by 0.76/year statewide. More modest increases in CPUE14 were observed statewide (0.17/year) over the same time period. Year explained 41% and 48% of the variability in CPUE8 and CPUE14, respectively (CPUE8 = 0.755 × year – 1,488.89, $p = 0.002$, $r^2 = 0.41$; CPUE14 = 0.169 × year – 334.39, $p < 0.001$, $r^2 = 0.48$).

Mean TL of age-6 LMB decreased significantly statewide during 1992–2011 (Figure 3). On average, mean TL of age-6 LMB declined from 14.6 to 13.4 in. Year explained 44% of the variability in the mean TL of age-6 LMB statewide (mean TL of age-6 LMB = –0.06 × year + 135.33, $p = 0.004$, $r^2 = 0.44$).

Mean angler catch rates of LMB increased significantly (Figure 4). On average, catch rate increased from 0.09 to 0.61 LMB/h. Year explained 72% of the variability in LMB catch rates statewide (catch rate [LMB/h] = 0.026 × year – 51.9, $p < 0.001$,

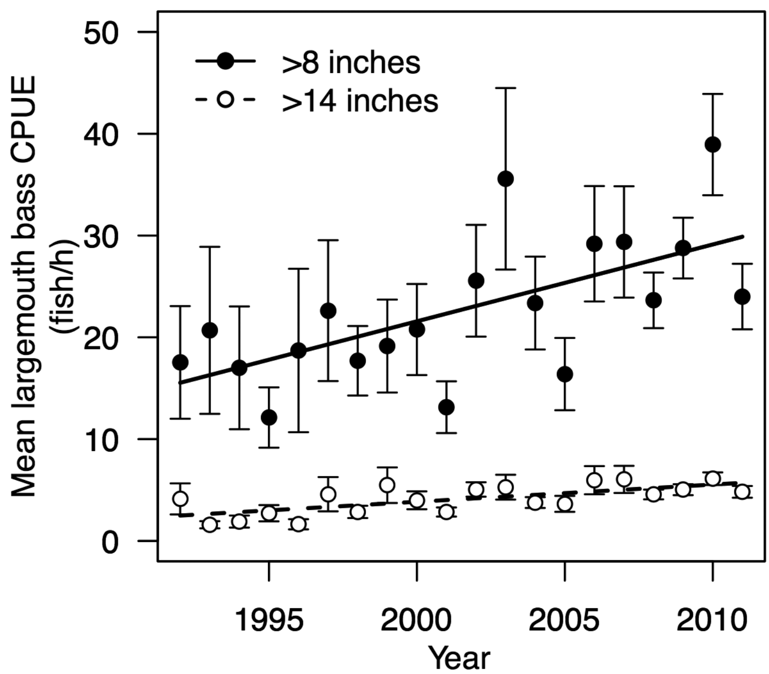

Figure 2. Wisconsin statewide trends in mean catch per unit effort (CPUE; fish/h) for Largemouth Bass greater than 8 (filled circles) and 14 in (open circles) during 1992–2011. Lines represent regression on the means (CPUE8 = 0.755 × year – 1,488.89, $p = 0.002$, $r^2 = 0.41$; CPUE14 = 0.169 × year – 334.39, $p < 0.001$, $r^2 = 0.48$). Error bars represent the standard error about the mean.

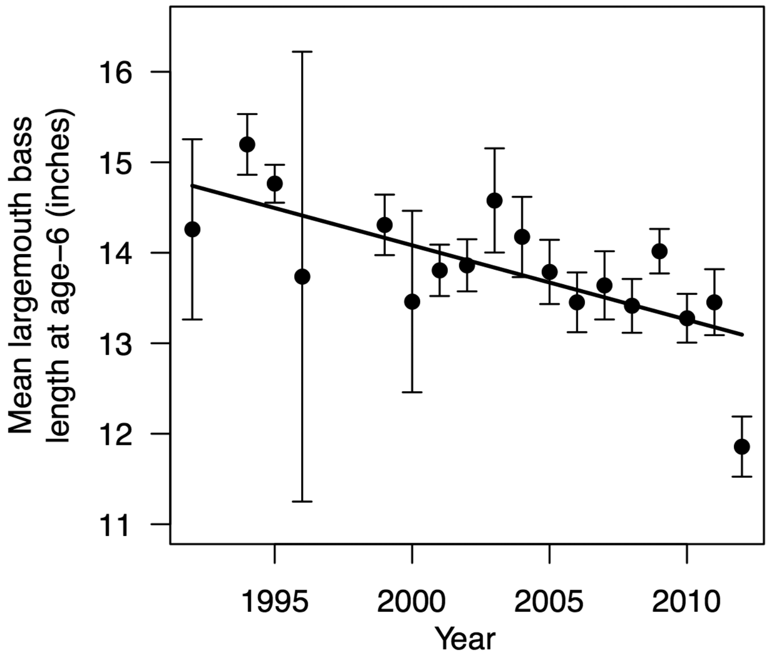

Figure 3. Wisconsin statewide trend in the mean total length of age-6 Largemouth Bass during 1992–2011. Line represents regression on the mean (mean total length of age-6 LMB = –0.06 × year + 135.33, $p = 0.004$, $r^2 = 0.44$). Error bars represent the standard error about the mean.

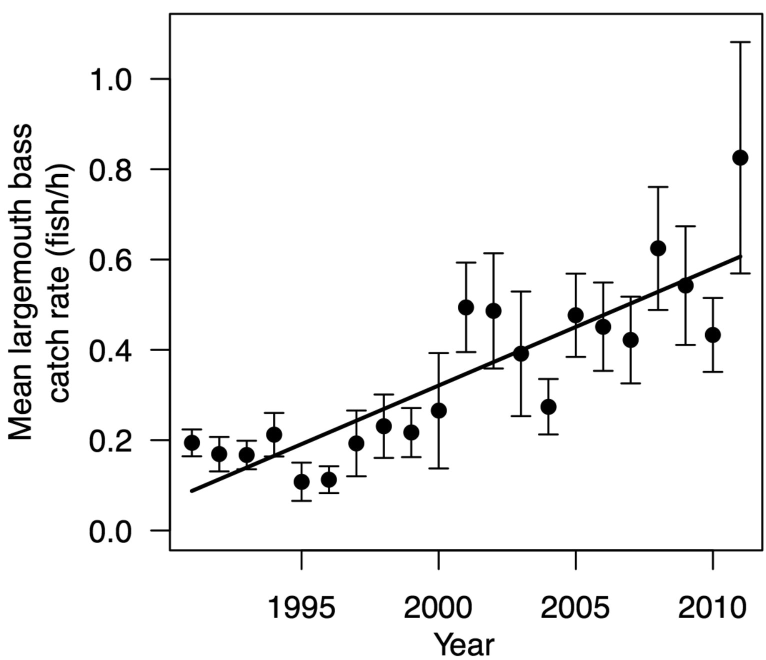

Figure 4. Wisconsin statewide trend in mean angler catch rates of Largemouth Bass during 1991–2011. Line represents regression on the mean (catch rate [Largemouth Bass/h] = 0.026 × year – 51.9, $p < 0.001$, $r^2 = 0.72$). Error bars represent the standard error about the mean.

$r^2 = 0.72$). Angling release rates of LMB increased and then plateaued in the Ceded Territory over time (Figure 5). The nonlinear least-squares asymptotic regression analysis with year centered yielded the following model:

$$y = 96.4 + (95.3 - 96.4) \times e^{\left(-e^{-1.3} \times \text{year}\right)}$$

All model parameters were significant at $p < 0.01$ with a residual standard error of 1.98 on 18 degrees of freedom. Mean LMB release rates increased from about 80% in 1991 and then became asymptotic at more than 96% during 2005–2011 (SE = 0.76%). Angling release rates of WAE significantly decreased over the same time period (Figure 6). Mean WAE release rates decreased from about 71% in 1991 to 55% in 2011. Year explained 27% of the variability in WAE release rate ($y = -0.79 \times \text{year} - 1{,}644$, $p = 0.02$, $r^2 = 0.27$).

Mean adult WAE densities in Ceded Territory lakes of Wisconsin containing LMB significantly declined during 1990–2011 (Figure 7). Mean adult WAE densities declined from about 3.16 to 2.72 per acre. Year explained 13% of the variability in mean $\log_e$ adult WAE density over time (ln[number/acre] = $-0.0085 \times \text{year} + 18.2$, $p = 0.05$, $r^2 = 0.13$).

Discussion

Across Wisconsin, LMB CPUE has increased significantly over the past 20 years. Concurrently, LMB growth and adult WAE densities have decreased. Although restrictive LMB harvest policies offer one plausible explanation for these trends, other factors such as increased voluntary release of LMB and potentially favorable environmental conditions are also plausible explanations. Our results illustrate broad trends that suggest an array of potential drivers, so we cannot offer any definitive mechanism(s) explaining these patterns without additional research. Nevertheless, our observations provide a perspective for managers when considering harvest regulations for a single species within a complex fish community.

Largemouth Bass harvest regulations implemented in Wisconsin (reduced bag limits, greater minimum length limits, and catch-and-release-only during the spawning period in northern Wisconsin) may be viewed as successful in that relative

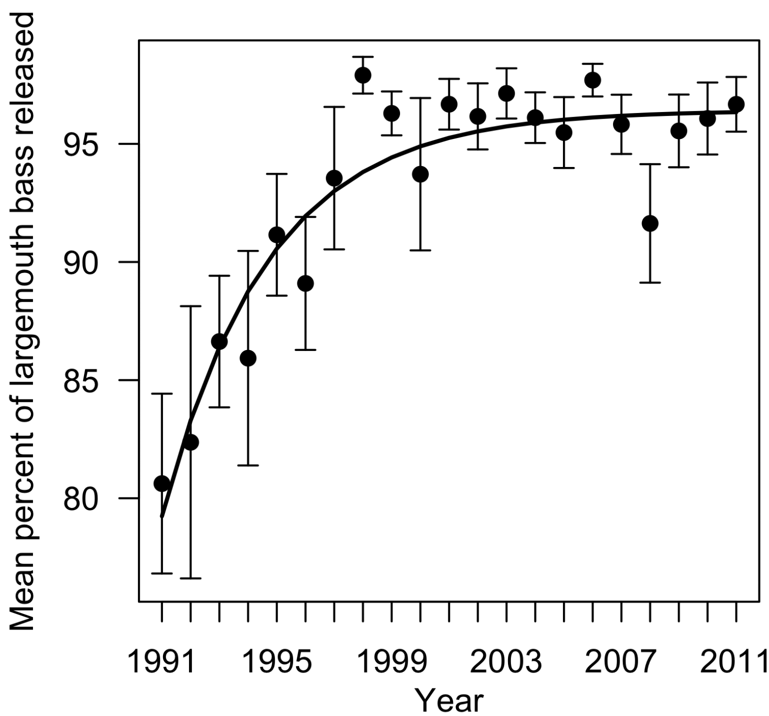

Figure 5. Ceded Territory of Wisconsin nonlinear trend in recreational angler release rates of Largemouth Bass during 1991–2011.

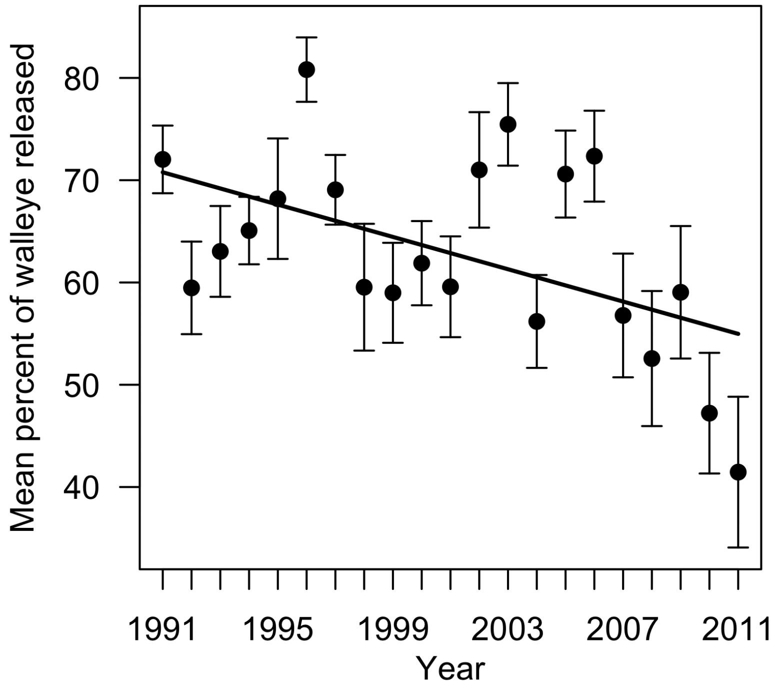

Figure 6. Ceded Territory of Wisconsin trend in recreational angler release rates of Walleye during 1991–2011.

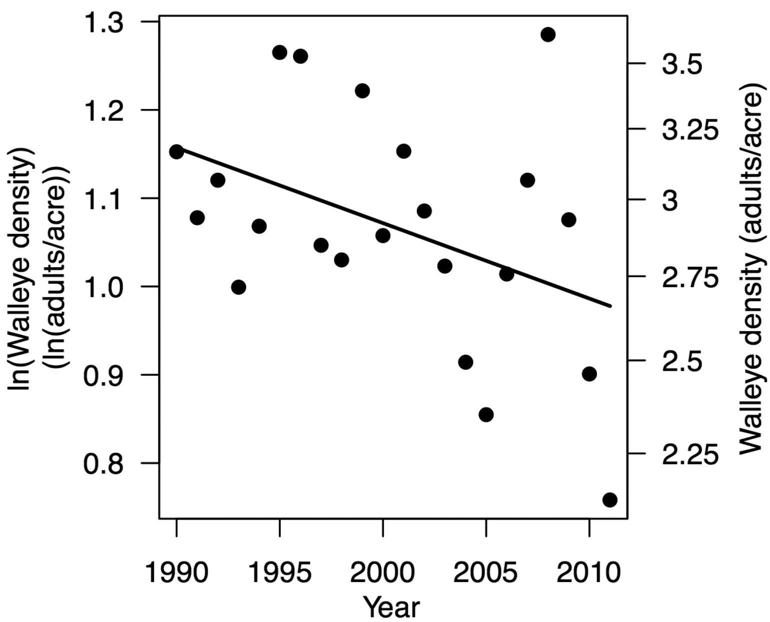

Figure 7. Trend in adult Walleye density (number/acre) in Ceded Territory lakes of Wisconsin containing Largemouth Bass during 1990–2011. Line represents regression on the $\log_e$ mean (ln[number/acre] = –0.0085 × year + 18.2, $p = 0.05$, $r^2 = 0.13$).

abundances and angler catch rates have increased. Evidence from other systems can shed some insight into the relative influence of various regulations in driving these trends. Similar to our findings, Wilde (1997) showed that LMB abundances and angler catch rates increased when minimum length limits were applied. Reduced daily bag limits are often proposed to limit the number of fish harvested, with expectations of increased abundances (Woodward and Griffin 2003). However, achievement of these goals requires angler compliance, a clear understanding of angler effort dynamics as they relate to bag limits, and whether the fishery is primarily harvest oriented or voluntary release (Sullivan 2002; Beard et al. 2003). For example, in a harvest-oriented Wisconsin WAE fishery, angler effort was more directed towards lakes with greater bag limits, despite lower WAE densities and catch rates (Beard et al. 2003). Bag limit restrictions, even if liberalized, may have little effect on fish populations where voluntary release is preferred by the majority of anglers targeting the managed species or where harvesting a daily bag limit is unrealistic (Goeman et al. 1993; Cook et al. 2001). For example, LMB harvest was not distributed equally among anglers and many anglers did not harvest a single fish during an angling trip in Minnesota under a daily bag limit of 6 LMB (Cook et al. 2001). Thus, it is difficult to remove the influence of increased LMB angler voluntary release when evaluating the effectiveness of restrictive harvest regulations such as greater minimum length limits and lower bag limits.

Our analysis indicates that release rates of LMB in Wisconsin have significantly increased since 1991, with model predicted release rates surpassing 96% by 2005. The release rates nearly reached the model predicted asymptote of 96.4% (SE = 0.76%) by 2011, when model predicted release rates were at 96.3%. Our findings corroborate a 2011 northern Wisconsin angler diary survey, which estimated release rates of LMB at 96.9% (Gaeta et al., in press), and a broader national trend of increasing LMB release rates over time (Noble 2002; Myers et al. 2008). Isermann et al. (2013) also observed increasing rates of LMB release in Minnesota from 1984 to 2006. They found differing release rates between northern (85% during 2000–2006) and southern (92% during 1995–1999) Minnesota under a no-minimum-length-limit regulation. Given that the northern Minnesota lakes would be more comparable to Wisconsin's Ceded Territory lakes, it is surprising that their most recent release rate was similar to what we documented in 1991. This may suggest some influence of the minimum length limit in Wisconsin since 1991. However, given the increases we observed in LMB available for Wisconsin anglers to harvest (CPUE14), we reasoned that voluntary release was likely the primary driver of these trends. Given the documented increases in release rates observed in Minnesota (Isermann et al. 2013), Texas and Florida (Myers et al. 2008), and Wisconsin (Gaeta et al. 2013; this study), LMB angler release rates appear to be increasing in much of the United States.

Due to the spawning behavior of LMB and their vulnerabilities to angling during the nesting and parental guarding phase, closed and catch-and-release-only seasons during spawning have often been proposed and used in an effort to conserve populations and trophy bass potential (Kubacki et al. 2002; Quinn 2002). Catch-and-release angling policies during the spawning period assume, and have shown in some experimental cases, that delayed hooking mortality (Schramm et al. 1987; Kwak and Henry 1995; Weathers and Newman 1997; Wilde 1998; Wilde and Pope 2008), physiological stress associated with capture and handling (Cooke et al. 2002), and a greater probability for nest abandonment and loss of the brood after capture to negatively influence individual LMB fitness (Suski et al. 2002). Numerous studies have suggested the need for additional research to test for population-level consequences of black bass catch-and-release angling (e.g., Siepker et al. 2007), and we concur. Our observations following the implementation of the catch-and-release-only season during spawning, along with trends in voluntary release, suggest few population-level consequences of this management practice in Wisconsin if increased LMB abundances and catch rates are desired. At the same time, this practice may negatively influence LMB trophy potential and vulnerability to angling (Philipp et al. 2009).

Negative individual and potential population consequences of catch-and-release angling during the spawning period have typically been associated with a reduction in brood size after removal from the nest (Suski et al. 2002; Hanson et al. 2007). Thus, brood reduction as a consequence of bass catch-and-release angling is assumed to negatively influence population-level bass recruitment (Gwinn and Allen 2010). Allen et al. (2011) found no difference in LMB age-0 recruitment across a wide range of adult stock densities in experimental Florida ponds, suggesting that catch-and-release angling during the spawning period would not negatively influence this species at a population level. Our results concur with Allen et al. (2011) in that northern Wisconsin juvenile and adult LMB relative abundances were not negatively influenced by a catch-and-release-only season during the spawning period over time.

Concurrent with significant increases in LMB relative abundances, mean TL of age-6 LMB declined significantly over time. Increases in fish abundances are often associated with a decline in individual growth rates due to density-dependent effects (Diana et al. 1991; Walters and Post 1993; Post et al. 1999; Sass and Kitchell 2005). Although catch-and-release angling effects on bass somatic growth have reached disparate conclusions (Pope and Wilde 2004; Siepker et al. 2006), LMB growth has been observed to be density-dependent in several studies. For example, Paukert and Willis (2004) noted density-dependent LMB growth in small, shallow Nebraska lakes, and Gaeta et al. (2011) suggested density-dependence as a plausible mechanism explaining growth patterns in LMB among northern Wisconsin lakes that varied in coarse woody habitat densities. Given the myriad abiotic and biotic factors influencing fish growth rates (e.g., temperature, structural habitat, and lake productivity; Kitchell et al. 1977; Sass and Kitchell 2005; Sass et al. 2006) and the great environmental variability among lakes in Wisconsin (Sass et al. 2010), our results suggest a density-dependent growth response. We reasoned that density-dependence would be a more plausible regional mechanism influencing LMB growth rates compared to more localized factors that might explain interlake differences in growth. For example, climate warming trends in Wisconsin would suggest elevated LMB growth rates over time (Rypel 2009; Kucharik et al. 2010); however, we observed significant declines further suggesting strong density-dependent effects.

Although our study has focused upon harvest restrictions and angler behavior to explain patterns in Wisconsin LMB abundance responses, alternative and interacting factors could also be plausible. One broad category of plausible mechanisms includes changes in abiotic and biotic conditions that have led to elevated LMB recruitment and/or survival at various ages. For example, we observed a greater rate of increase in LMB CPUE8 compared to CPUE14, which could indicate increased juvenile survival. Climate warming and associated increased water temperatures have been shown to lead to stronger Smallmouth Bass year-classes (Casselman et al. 2002). Anecdotal accounts of LMB increasing in response to increased water clarity and plant biomass are common, but standardized time series data are lacking to evaluate this relationship on a broad scale. However, lake trophic status (chlorophyll *a*) did not change in four well-studied Ceded Territory lakes during 1981–2012 (Stanley 2013). Long-term changes in climate and precipitation patterns in Wisconsin offer a host of interacting environmental hypotheses that could facilitate LMB abundance increases at the northern edge of their range (Magnuson et al. 2000; Jensen et al. 2007; Kucharik et al. 2010). For example, Rypel (2009) found strong correlations between LMB growth, precipitation, and temperature. Lyons et al. (2010) also suggested that the distribution of LMB may increase by about 34%, while decreasing by 6–88% for WAE, depending upon the degree of climate warming. Further research into climate associated changes in both WAE and LMB habitat are currently underway.

We observed significant declines in adult WAE densities in lakes containing LMB over time. This pattern could be driven by angler dynamics, as release rates for WAE have decreased over time. Given the concurrent increase in LMB release rates, an already harvest-oriented species such as WAE could be receiving additional harvest pressure from anglers shifting away from LMB. However, other indicators suggest that overall harvest or harvest rates of WAE have not changed over time. Similarly, a number of environmental factors that could potentially explain trends in LMB abundance could also explain trends in WAE abundance. That is, both species could be passengers of environmental change rather than one species driving the abundance of the other. Still, negative correlations between the two species could be a result of antagonistic interspecific interactions. One potential negative interaction between these species is direct predation of naturally reproduced and/or stocked young-of-year WAE by LMB, but previous study conclusions have been variable (Santucci and Wahl 1993; Fayram et al. 2005). Fayram et al. (2005) concluded that LMB could limit survival of stocked WAE, while Freedman et al. (2012) found that LMB predation on stocked WAE had a negligible effect on WAE stocking success. Limited research exists on the interactions of LMB and naturally reproduced WAE.

Management implications

The goals of bass management over the past century have often been related to conservation and enhancement of populations (Quinn 2002). Our results suggest that mechanisms within agency control (e.g., minimum length limits, bag limits, and catch-and-release-only seasons) may interact with less predictable changes in angler behavior and environmental conditions to achieve those goals, but may also lead to imbalances in LMB populations in a fish community context. These imbalances may have implications for other important sport fishes when multiple fish species are being managed.

The purpose of fisheries management is to sustain fish populations; however, commercial fisher and recreational angler perceptions and desires often play a large role in developing fisheries management policies and goals. For example, it may be difficult to achieve a desired balance that appeases the majority of stakeholders (e.g., some desiring fish populations with low catch rates of larger individuals and others preferring high catch rates of smaller individuals), particularly while trying to account for environmental variability. Incorporating diverse stakeholder input throughout the management process, including objective development, discussion of management options, and policy development and implementation can help create buy-in and a supportive public. Moreover, stakeholder involvement and outreach are effective at shaping angler behavior, which likely played an important role in shaping our trends observed in LMB abundances.

A negative trend in adult WAE density in lakes with LMB may suggest negative interactions between these species, but it is correlative, not causative. The mechanism(s) leading to regional WAE declines over time are unknown and warrant further study. Largemouth Bass playing a role in WAE declines is one hypothesis among many. Collaborative (WDNR, University of Wisconsin-Madison, University of Wisconsin-Stevens Point, and Wisconsin Cooperative Fishery Research Unit) and directed research efforts are ongoing to test for LMB-related effects on WAE populations to inform future management of these species in Wisconsin. Research topics currently being addressed include (1) tests for direct negative relationships between LMB and WAE abundances, (2) exploration of lake-specific abiotic and biotic factors that may explain trends in the abundance of both species, (3) field studies to test for LMB predation upon young-of-year WAE, (4) climate change-related bioenergetics modeling exercises to estimate the amount of LMB consumption of young-of-year WAE required to negatively influence WAE recruitment, and (5) climate change-related food web modeling exercises to predict the effects of changing environmental conditions on the sport fish community.

The WDNR is considering another shift in LMB management policies, a shift that will potentially strive to achieve a balance between encouraging LMB harvest while, at the same time, protecting size structure. The lessons learned over the past two decades will be important in shaping the future of LMB management in Wisconsin. Our observations of LMB in Wisconsin suggest that the goals of single species fish management must consider intra- and interspecific effects, potential fish community effects, and angler behavior when sustainable multispecies sport fisheries are desired.

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