Evaluation of Creel and Length Limits for Crappies and Yellow Perch in Wisconsin

by

Kyle J. Mosel

A Thesis

Submitted in partial fulfillment of the

Requirements of the degree

MASTER OF SCIENCE

IN

NATURAL RESOURCES (FISHERIES)

College of Natural Resources

UNIVERSITY OF WISCONSIN

Stevens Point, Wisconsin

March 16, 2012

APPROVED BY THE GRADUATE COMMITTEE OF:

Dr. Daniel A. Isermann, Committee Chairman

Associate Professor of Fisheries

College of Natural Resources

Dr. Michael J. Hansen

Professor of Fisheries

College of Natural Resources

Dr. Paul F. Doruska

Associate Professor of Forestry

College of Natural Resources

Dr. Nancy A. Nate

Post Doctorate Research Associate

College of Natural Resources

Jonathan Hansen

Fisheries Biologist

Wisconsin Department of Natural Resources

ABSTRACT

Black crappie *Pomoxis nigromaculatus* and yellow perch *Perca flavescens* support popular, harvest-oriented fisheries across most of their range, including Wisconsin. Harvest in these fisheries is typically regulated using daily creel limits and, in some cases, minimum length limits. Several previous evaluations have suggested that the effectiveness of these harvest regulations in meeting management objectives varies among fisheries.

Harvest regulations for black crappies and yellow perch in Wisconsin have not been thoroughly evaluated and the Wisconsin Department of Natural Resources (WDNR) wants to know whether potential changes in harvest regulations will be effective in reducing harvest and improving fisheries. My objectives were to determine if: 1) species-specific reductions in daily creel limits or statewide minimum length limits could reduce harvest of yellow perch and black crappie in Wisconsin and 2) reductions in daily creel limits or implementation of minimum length limits might improve yield, harvest, and size structure of black crappie and yellow perch fisheries within the state.

I simulated the effects of daily creel limit reductions (i.e., reduced from 25 fish per angler to 20, 15, 10, and 5 fish per angler) and statewide minimum length limits (i.e., 178-, 203-, 229-, 254-, 279-mm) on statewide angler harvest using information on black crappie and yellow perch harvest obtained during 263 creel surveys conducted on Wisconsin lakes during 1998-2008. I also simulated the effects of daily creel limit reductions and minimum length limits (203- (i.e., no MLL), 229-, 254-, and 279-mm) on yield, harvest, and size structure for black crappies and yellow perch using Beverton-Holt equilibrium yield models. A no length limit scenario was simulated for each species using

203-mm as the length at which black crappies and yellow perch recruited to the fishery. For each species, yield models were run for three growth trajectories (i.e., slow, average, and fast) that were estimated from length and age data obtained during annual spring fyke net surveys from 1990-2010. Simulations were conducted using the average instantaneous natural mortality (*M*) rates for each growth trajectory across a range of instantaneous fishing mortality (*F*) rates.

Creel survey interviews indicated that most anglers did not harvest a black crappie (95.45%; 223,426 of 234,076) or yellow perch (94.83%; 221,955 of 234,076), and only a few anglers harvested a daily creel limit of 25 yellow perch (0.12%; 280 of 234,076) or black crappie (0.04%; 95 of 234,076). Harvest reductions of less than 10% were predicted if the current daily creel limit of 25 fish was reduced to 20 or 15 fish per day for both black crappies and yellow perch. Daily creel limits would need to be < 7 black crappies and < 8 yellow perch per day to reduce harvest by 25% or more. In order to affect harvest, daily creel limits would need to be 5 fish per day or less for both black crappies and yellow perch. Black crappie harvest reductions were less than 10% at statewide minimum length limits of 178-mm (1.21% reduction) 203-mm (7.13% reduction) and greater than 10% at statewide minimum length limits of 229-mm (34.53% reduction), 254-mm (69.07% reduction), and 279-mm (88.55% reduction). For yellow perch, harvest reductions were less than 10% at a statewide minimum length limit of 178-mm (5.67% reduction) and greater than 10% at statewide minimum length limits of 203-mm (25.17% reduction), 229-mm (74.73% reduction), 254-mm (90.34% reduction), and 279-mm (96.83% reduction).

For slow-, average-, and fast-growing black crappie populations, yield was maximized under a no length limit scenario (i.e., 203--mm minimum length limit) unless u was high (u > 35%), and larger minimum length limits decreased harvest on average by 27-76%. For slow- and average-growing yellow perch populations, a 229-mm minimum length limit could increase yield if exploitation was > 31% and 55%. However, when u < 30%, a 203-mm minimum length limit maximized yield. When growth was fast, a 203-mm minimum length limit maximized yield and provided the smallest reduction in harvest for yellow perch. Larger minimum length limits decreased harvest on average by 31-63%.

Harvest regulations are unlikely to be universally effective for improving black crappie and yellow perch fisheries in Wisconsin lakes. Minimum length limits are most likely to be effective if natural mortality is low for black crappie and yellow perch populations in Wisconsin. However, most Wisconsin black crappie populations had M estimates greater than 0.30. At high exploitation rates, minimum length limits should improve both yield and size structure, unless too many fish are lost to natural mortality. Current harvest data suggests that to effectively reduce harvest, daily creel limits would need to be 5 fish a day or less for both black crappies and yellow perch. However, drastically reducing the daily creel limit from 25 to 5 fish per day may be socially unacceptable. To effectively reduce harvest using statewide minimum length limits, minimum length limits would need to be 229-mm or greater for black crappies and 203-mm or greater for yellow perch. However, statewide length limits larger than those previously suggested may not be reasonable on the statewide scale due to the large variation in growth for both species.

ACKNOWLEDGMENTS

I would like to thank everyone who made this thesis possible. My advisor, Dr. Daniel Isermann, gave me the opportunity to work and learn under his fin by teaching me the fundamentals of fisheries science. I would also like to give Dr. Nancy Nate a special thanks for all of the work she did on extracting and helping me organize the data. I also appreciate the constructive criticism provided by the other members of my graduate committee: Dr. Michael Hansen and Dr. Paul Doruska of the University of Wisconsin-Stevens Point, and Jonathan Hansen of the Wisconsin Department of Natural Resources. I would also like to thank all the Wisconsin Department of Natural Resources biologists and creel clerks that collected the data used in my analyses. Lastly, I would like to thank my family, friends, and fellow graduate students for their support over the last two years.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Yellow perch *Perca flavescens* are common in all major river systems and many lakes in Wisconsin, except in unglaciated areas of Wisconsin (Becker 1983). Yellow perch are tolerant of nutrient-rich, turbid waters across a wide range of temperature (Becker 1983) and can be prolific in small lakes (Brown 2009). Yellow perch typically spawn from mid-April to May at water temperatures of 6.7°-12.2°C (Scott and Crossman 1973). Spawning usually takes place at night near rooted vegetation, brush, or fallen trees, and also over sand or gravel (Scott and Crossman 1973). Yellow perch eggs are held together by long, gelatinous strands reaching up to seven feet in length. Females may carry up to 210,000 eggs, but fecundity varies with female age and length (Scott and Crossman 1973). Eggs usually hatch after 8-10 days depending on water temperature (Becker 1983). Yellow perch do not provide parental care for their young and recruitment in perch populations is highly variable (Forney 1971; Henderson 1985; Isermann et al. 2005). Variation in recruitment has been related to lake hydrology (Henderson 1985), water temperature (Craig et al. 1979), and food availability (Mills et al. 1989). In most Wisconsin lakes, yellow perch rarely exceed 254-mm in total length (TL) and typically weigh less than 0.45 kg. The Wisconsin state record yellow perch caught from Lake Winnebago in 1954 weighed 1.47 kg (WDNR 2010).

Black *Pomoxis nigromaculatus* and white crappies *P. annularis* occur in Wisconsin, with black crappies being more prevalent in northern waters and white crappies being more prevalent in southern waters (Becker 1983). Crappies can become sexually mature at 150-mm, but most do not become mature until they reach 195-mm

(Scott and Crossman 1973). Crappie spawning usually peaks in May and June when water temperatures reach 14-23° C (Scott and Crossman 1973; Becker 1983). Like other centrachids, crappies are nest builders, but crappies often build nests deeper (0.46-1.83 m) than other centrachids (Scott and Crossman 1973). Male crappies construct and aggressively defend nests (Scott and Crossman 1973). Each female crappie may produce several thousand to several hundred thousand eggs depending on length and age (Becker 1983). Males continue to guard nests until eggs hatch (Becker 1983). Crappies grow rapidly in their first year up to 76 mm (Becker 1983; Trautman 1957). Crappie recruitment varies (Mitzner 1981; Allen and Miranda 2001; Sammons et al. 2001) in relation to predator density (Powell 1973; Gabelhouse 1984), lake type (Guy and Willis 1995) hydrology (Siefert 1968; Mitzner 1981; Beam 1983), temperature (Pine and Allen 2001), turbidity (Pope 1996), and habitat (Ming 1971). The state record white crappie caught from Cranberry Marsh in Monroe County weighed 1.73 kg (WDNR 2010). The state record black crappie caught in 1967 from Gile Flowage in Iron County weighed 2.04 kg (WDNR 2010).

Crappies and yellow perch support popular, harvest-oriented recreational fisheries across much of their range, including Wisconsin. Angler exploitation can reduce both abundance and size structure in crappie and yellow perch fisheries (Goedde and Coble 1981; Web and Ott 1991; Isermann et al. 2005). Specifically, anglers selectively remove relatively large individuals from panfish populations, which can reduce the number of fish that are of a desirable length (i.e., quality overfishing; Kempinger et al. 1975; Goedde and Coble 1981; Colvin 1991; Beard and Kampa 1999; Boxrucker 2002). In most states and provinces, harvest of black crappies and yellow perch is regulated by daily creel limits and minimum length limits (Boxrucker and Irwin 2002; Isermann et al. 2005). Daily creel limits restrict the number of fish that can be harvested by an individual angler in a single day. Minimum length limits prohibit harvest of fish less than a specified length. Both harvest regulations are implemented under the assumption that individual anglers will release some of the fish they may have harvested if the regulations were not in place. Consequently, daily creel limits and minimum length limits are typically implemented to reduce harvest (Colvin 1991; Hale 1999; Isermann et al. 2007), improve catch rates and size structure (Hale et al. 1999; Bister et al. 2002; Boxrucker 2002), or to distribute harvest among anglers over longer periods (Carlton 1975; Fox 1975; Cook et al. 2001; Hurley 2002).

Previous evaluations have suggested that creel limits for crappies and yellow perch affect only a small percentage of anglers, because few anglers harvest a limit and most anglers catch few or no fish (Snow 1982; Webb and Ott 1991; Baccante 1995; Cook et al. 2001). However, reduced creel limits could improve size structure of crappies and yellow perch if angler harvest represents a significant source of mortality (Colvin 1991; Isermann et al. 2007; Allen and Miranda 1995) and if anglers are compliant (Isermann and Carlson 2009). However, previous evaluations suggest that in crappie and yellow perch fisheries, reducing harvest by 25% or more would generally require daily creel limits of less than 10 fish per angler per day (Radomski 2003; Isermann et al. 2007), which may not be socially acceptable to anglers because these fisheries are usually harvest-oriented (Weigel unpublished; Hale et al. 1999; Reed and Parsons 1999; Boxrucker 2002).

Previous evaluations of minimum length limits for crappies have yielded mixed results. Minimum length limits sometimes reduced crappie harvest and increased abundance and size structure (Webb and Ott 1991; Colvin 1991; Boxrucker 2002), but sometimes did not affect these metrics (Reed and Davies 1991; Larson et al. 1991; Noble and Jones 1999; Hale et al. 1999; Bister et al. 2002; Hurley and Jackson 2002; Isermann and Carlson 2009). Minimum length limits can improve crappie size structure, but decreased harvest may not be popular among harvest-oriented anglers (Boxrucker 2002). Abundance of quality- and preferred- length crappies and angler catch rates increased under a 254-mm length limit in Ft. Supply Reservoir, Oklahoma, but angler dissatisfaction regarding reductions in harvest led to removal of the length limit (Boxrucker 2002). Size structure of black crappies did not increase in four Minnesota lakes under minimum length limits of 229-, 254-, and 279-mm, even though these regulations were predicted to reduce harvest by 40% or more (Isermann and Carlson 2009). Minimum length limits can alleviate growth overfishing in crappie fisheries and can maintain yield during times of increased fishing pressure (Webb and Ott 1991). Conversely, if harvest has little effect on total mortality, minimum length limits may not be effective (Noble and Jones 1999). Restrictive harvest regulations for crappies have been ineffective when natural mortality is high (Reed and Davies 1991; Larson et al. 1991). Additionally, crappie growth rates decreased after length limits were implemented for Lake Alvin, South Dakota and two southeast Nebraska reservoirs (Bister et al. 2002 and Hurley and Jackson 2002). To increase growth rates of black crappies, a 229-mm minimum length limit was removed from Lake Alvin, South Dakota, because of low prey availability (Bister et al. 2002). Growth was slower and natural mortality increased under a 254-mm minimum length limit in Delaware Reservoir, Ohio, so the minimum length limit was reduced to 229 mm to allow anglers to harvest more crappies (Hale et al. 1999).

Modeling has also suggested that minimum length limits can increase abundance or size structure in crappie and yellow perch populations (Allen and Miranda 1995; Maceina et al. 1998; Isermann et al. 2002; Isermann et al. 2007). Minimum length limits can improve yield and average weight in crappie fisheries, but only if growth is relatively fast and natural mortality is relatively low (Allen and Miranda 1995). A 254-mm minimum length limit for crappies in Weiss Lake, Alabama, was predicted to increase yield because conditional natural mortality was low (less than 35%), but harvest would be reduced by 23% (Maceina et al. 1998). When crappie growth was fast (reaching 254-mm or 229-mm in less than 3 years) and conditional natural mortality was low (30%), length limits were most effective for balancing increased yield and size structure against harvest for crappies in some Tennessee reservoirs (Isermann et al. 2002). Minimum length limits (i.e., 229-mm and 254-mm) for yellow perch in South Dakota were predicted to increase age and size structure (Isermann et al. 2007).

Based on previous studies, rates of natural mortality and growth are important factors that regulate whether minimum length limits meet management objectives (Reed and Davies 1991; Allen and Miranda 1995; Isermann et al. 2007). Yellow perch and crappies typically exhibit high natural mortality (Larson 1991; Reed and Davies 1991; Goedde and Coble 1981). High natural mortality might negate benefits from a minimum length limit because few fish may reach the minimum length limit or most of their growth is attained by the time they reach the length limit (Hale et al. 1999; Nobel and Jones 1999; Isermann et al. 2007). Slow growth might negate increases in number and yield expected from a minimum length limit if most fish are lost due to natural mortality by the time they reach the length limit (Larson et al. 1991; Reed and Davies 1991; Hale et al. 1999). Rates of growth and natural mortality likely vary among crappie and yellow perch populations in Wisconsin due to differences in latitude, fish assemblages, lake productivity and morphometry, and fishing mortality.

Harvest regulations for crappies and yellow perch in Wisconsin have varied widely since the first panfish harvest regulation was implemented in 1925 to restrict angler harvest to 20 six-inch crappies, 30 sunfish, and 30 yellow perch per day (Becker 1983). Today, crappies and yellow perch are managed by a statewide aggregate daily creel limit of 25 fish per individual angler. However, since 1998, the number of waterbody-specific harvest regulations for panfish has increased. In 2010, 84 water bodies across 20 counties had special panfish regulations that differed from the statewide regulation. Special regulations included reduced or no daily creel limit, minimum length limits (8 or 10 in), and season closures (Table 1; WDNR 2009). Reasons for implementing special harvest regulations are not well documented.

Crappies and yellow perch represent two of the most harvested and popular fish species in the state of Wisconsin (McClanahan 2003). Based on an angler survey conducted for 2006 (B.Weigel, WDNR, unpublished data), 1.4-million anglers spent 71-million hours fishing in the state of Wisconsin in 2006. Collectively, panfish (e.g., bluegill, yellow perch, and black crappies) were the most sought group of fish and accounted for 45% of all angling trips. Panfish also represented the highest number of fish caught (57.7 million and 65% of all fish caught) and the highest number of fish harvested among Wisconsin anglers (25.7 million and 78% of all fish harvested). Panfish harvest rate (number of fish harvested / number of fish caught) was 45% and was second only to the estimated harvest rate for catfish (69%).

Effectiveness of yellow perch and crappie harvest regulations in Wisconsin has not been thoroughly evaluated and potential effects of reduced daily creel limits and increased minimum length limits on these fisheries are not known. Increasing complexity of harvest regulations is a common complaint among Wisconsin anglers and a concern for fishery managers, and a complex array of different harvest regulations may not be warranted for crappies and yellow perch in Wisconsin. Proliferation of panfish regulations for individual water bodies suggests that fishery managers have developed criteria for implementation, but no rationale has been defined for selecting a specific harvest regulation for crappie and yellow perch fisheries in Wisconsin. Simulations of regulation effects would provide insight as to when and where harvest regulations may improve crappie and yellow perch fisheries.

My objectives were to determine if: 1) species-specific reductions in daily creel limits or statewide minimum length limits could reduce harvest in black crappie and yellow perch fisheries in Wisconsin; 2) reduced daily creel limits or minimum length limits can improve yield, harvest, and size structure in crappie and yellow perch fisheries in Wisconsin.

METHODS

Daily Bag Limit Reductions and Statewide Minimum Length Limits.—Angler harvest data from 263 WDNR creel surveys on 186 water bodies during 1998-2008 was used to quantify the effects of species-specific reductions in daily creel limits and statewide minimum length limits on angler harvest of black crappie and yellow perch (Figure 1). Only creel data from 1998 and more recent was used because the daily creel limit was reduced to 25 panfish in 1998. Creel surveys were conducted during the angling season from the first Saturday in May through March 1 of the following year using a random stratified roving-access design with stratified random sampling (Rasmussen et al. 1998). Some creel surveys (i.e., 17 for crappies and 16 for yellow perch) covered the entire month of March or a full calendar year. Only creel surveys with at least 30 angling parties interviewed and with ≥ 50 harvested black crappies or yellow perch observed by creel clerks were used in analyses.

For each angling party interviewed by creel clerks, I determined how many black crappies or yellow perch each party would have harvested if the daily creel limit for each species had been less than 25 fish per day of if a statewide minimum length limit was imposed. The percent reduction in harvest achieved under each of these lower daily creel limits or statewide minimum length limits was calculated for each creel survey as:

$$\%\ harvest\ reduction = 1 - \frac{fish\ harvested\ under\ reduced\ creel\ or\ minimum\ length\ limit\ X}{fish\ harvested\ under\ 25\ fish\ creel\ limit\ (i.e., no\ MLL)},$$

(Equation 1)

where X = the reduced daily creel limit (i.e., 20, 15, 10, or 5 fish/d) or minimum length limit (i.e., 178-, 203-, 229-, 254-, and 279-mm). As in most creel surveys, harvest rates (fish per hour) of anglers contacted by creel clerks are assumed to represent harvest rates of all anglers on a particular lake. Observed harvest rates are multiplied by estimated angler effort to estimate total harvest. Consequently, estimates provided by the previous equation reflect the extent to which total harvest estimates for crappies and yellow perch would have been reduced under each daily creel limit or statewide minimum length limits. Mean harvest reductions predicted for each reduced daily creel limit and statewide minimum length limit were used in subsequent model simulations to determine if reductions in yield, size structure, and number harvested differed among reduced creel limits.

Growth.—Black crappie and yellow perch age and length data were collected from individual Wisconsin water bodies during March-June fyke-net surveys (Figure 2). Ages were usually estimated using scales, but otoliths were used for age estimation in some populations. Only surveys with at least 50 crappies or yellow perch measured were used to construct age-length keys from subsampled fish with age estimates. Estimates of mean TL at ages 3 through 9 were used to describe black crappie and yellow perch growth because age 3 represented the age at which both species recruit to fyke nets and few fish were observed over age 9. Von Bertalanffy length-age models were fit to mean length at age for each population:

$$L_t = L_\infty\left(1 - e^{-K(t-t_0)}\right) + \varepsilon_i, \text{ (Equation 2)}$$

where L_t = mean TL at age t (t = years), L_∞ = the average asymptotic TL of a fish in the population, and K = the instantaneous rate at which L_t approaches L_∞ (von Bertalanffy 1938). The hypothetical time at which fish total length was equal to zero (t_0) was held at zero because fyke nets did not effectively capture fish less than age-3. Estimates of L_∞ were excluded from further analyses if the estimated average asymptotic total length of a fish in population exceeded the state record length by 10%.

I developed three growth trajectories for both crappies and yellow perch using linear regressions based on the bivariate distribution of L_∞ and K for each species. The bivariate distribution of L_∞ and K was divided perpendicularly to the linear regression at the 33rd percentile of K and the 66th percentile of L_∞ to define slow growth (Figure 3 and 4). Fast growth was defined using the 66th percentile of K and the 33rd percentile of L_∞ (Figure 3 and 4). Average growth was defined using all data points between the 33rd and 66th percentiles (Figure 3 and 4). Growth trajectories were estimated by calculating the mean L_∞ and K for each growth type. The average asymptotic weight of a fish for each growth trajectory (W_∞) was defined using the $\log_{10}$ transformed weight-length model for all black crappies (100-mm and longer) and yellow perch (127-mm and longer) measured and weighed during spring fyke netting (March-June; Figure 5):

$$log_{10}(W_i) = log_{10}(\alpha) + \beta log_{10}(L_i) + \varepsilon_i \text{ , (Equation 3)}$$

where W_i = the mean weight at length L_i, α is a scaling constant (intercept), and β is the allometric shape parameter (slope). Weight-length models were not fit based on growth types because not all growth types had weight data. Average asymptotic weight (W_∞) was estimated for each growth trajectory by substituting L_∞ into the single weight-length model.

Modeling Simulations.—I used a modeling approach similar to that of Allen and Miranda (1995) to evaluate effects of minimum length limits on yield, harvest, and size structure in Wisconsin black crappie and yellow perch fisheries. I used a Beverton-Holt yield per recruit model (Ricker 1975) to simulate how black crappie and yellow perch yield would be affected by reductions in harvest resulting from minimum length limits:

$$\frac{Y}{N_0} = Fe^{-M(t_r - t_0)} W_\infty \left(\frac{1}{Z} - \frac{3e^{-K(t_r - t_0)}}{Z+K} + \frac{3e^{-2K(t_r - t_0)}}{Z+2K} - \frac{e^{-3K(t_r - t_0)}}{Z+3K} \right) \text{, (Equation 4)}$$

where yield per recruit (Y/N_0), is estimated from von Bertalanffy model parameters (K, W_∞, and t_0), instantaneous mortality rates (F, M, and Z), and age at recruitment (t_r). Simulations were run over a 0.20-0.90 range of instantaneous fishing mortality rates (F) across each average instantaneous natural mortality rate (M) for each growth type to simulate a range of exploitation rates reported for black crappies and yellow perch. Estimates of M from the equation proposed by Pauly (1980) were averaged within each growth type to calculate and average rate for each growth type. I added instantaneous fishing mortality (F) to instantaneous natural mortality (M) to calculate instantaneous total mortality (Z). Baranov's equation ($u = F*A/Z$) was used to estimate exploitation (u) from F, A, and Z. Instantaneous natural mortality rate (M) was also estimated for individual populations to determine the range of M exhibited by yellow perch and crappie populations in Wisconsin using the equation proposed by Pauly (1980):

$$Log_{10}M = -0.0066 - 0.279*log_{10}(L_\infty) + 0.6543*log_{10}(K) + 0.4634*log_{10}(T), \quad \text{(Equation 5)}$$

where L_∞ (cm) and K are previously defined parameters from the von Bertalanffy model and T = the mean annual temperature (°C) experienced by the population. Mean annual air temperatures approximately correspond to mean annual water temperatures (Pauly 1980; Shuter et al. 1983) and were used because mean annual water temperatures are not available. Mean annual air temperature data was acquired from the National Climatic Data Center (NOAA) for a 30 year period during 1961-1990 for individual populations (NOAA 2010).

A total length of 203 mm was used to represent the length at which black crappies and yellow perch fully recruit to the fishery because this length approximated the 50th

percentile of the cumulative total length frequency distribution of all harvested fish observed in creel surveys (Figure 6 and 7). I used the von Bertalanffy equation to estimate the time in years required to reach each minimum harvestable total length for each growth category. Each simulation was started with N_0 = 100 recruits. Based on previous evaluations (Allen and Miranda 1995; Maceina et al. 1998; Isermann et al. 2002), I simulated the effects of 203- (i.e., no length limit), 229-, 254-, and 279-mm minimum length limits, although an 279-mm length limit may not be reasonable for some Wisconsin perch populations based on L_∞. To simulate the effect of each minimum length limit on yield, I used the von Bertalanffy equation to estimate the time in years required to reach each minimum length limit for each growth scenario. These values were used for t_r in the Beverton-Holt model.

To describe the potential effects of different harvest regulations on size structure, I computed the number of initial 100 recruits that would survive to reach 279-mm under different harvest regulations. For each growth scenario, I used the von Bertalanffy model to calculate the time required to reach each minimum length limit (t_r). The number of recruits surviving to 279-mm was estimated for all combinations of growth, mortality, and length limits:

$$N_{279} = Re^{-Z(t_{279}-t_r)}, \text{ (Equation 6)}$$

where t_{279} - t_r represents the time elapsed between reaching a specific minimum length limit and R = the number of recruits surviving to t_r:

$$R = N_0 e^{-Mr}, \text{ (Equation 7).}$$

For simulations of creel limit reductions and no length limit simulation $t_r = t_{203}$.

To assess the effects of creel limit reductions, I adjusted *Z* in equation 6 based on the expected reduction in exploitation associated with each creel limit reduction or statewide minimum length limit. An average *u* of 0.35 was used based on estimates from previous studies (Larson et al. 1991; Reed and Davies 1991; Allen and Miranda 1995; Parson and Reed 1998; Isermann et al. 2005) to provide an expected *u* for black crappies and yellow perch fisheries in Wisconsin. To simulate the effects of reduced daily creel limits on yield, *u* was reduced from 0.35 based on the mean harvest reduction associated with each creel limit reduction (Objective 1). For example, *u* associated with a 20 fish daily creel limit for black crappies would be equivalent to 0.344 if a 20 fish creel resulted in a 1.56% mean reduction in harvest (i.e., 0.35-0.005).

For both length limit and creel limit simulations, percent increases in the number of fish surviving to 279-mm were used to describe changes in population size structure expected from implementing length or creel limit reductions:

$$\%\ increase = \left(N_R - \frac{N_R}{N_{NR}}\right) * 100, \text{ (Equation 8)}$$

where, N_R represents the number of fish surviving to 279-mm under a specified length limit or reduced daily creel limit and N_{NR} is the number of fish surviving to 279-mm with no minimum length limit or a 25-fish daily bag limit (i.e., no creel limit reduction).

RESULTS

Black Crappies

Daily Creel Reductions and Statewide Minimum Length Limits.—Only 4.55% (10,644 of 234,076) anglers reported harvesting at least one black crappie and only 0.04% (95 of 234,076) anglers harvested a daily creel limit of 25 fish, so the current daily creel limit affected few anglers (Figure 8). Anglers that targeted crappies (i.e., percentage of time fishing for crappies ≥ 50%) harvested 50,310 black crappies, which represented nearly all of black crappies harvested (99.04%; 50,310 of 50,798). Harvest reductions were less than 10% at reduced creel limits of 20 (1.56% reduction) and 15 (4.91% reduction) fish per day and greater than 10% at reduced creel limits of 10 (12.76% reduction) and 5 fish per day (32.88% reduction; Figure 8). Harvest reductions were less than 10% at statewide minimum length limits of 178-mm (1.21% reduction) 203-mm (7.13% reduction) and greater than 10% at statewide minimum length limits of 229-mm (34.53% reduction), 254-mm (69.07% reduction), and 279-mm (88.55% reduction; Figure 6).

Modeling Simulations.—Asymptotic total length of a black crappies (L_∞) ranged from 241-419 mm among the 33 populations used for growth analyses (Table 2). Instantaneous growth rates (K) ranged from 0.16 to 0.55. Based on the relationship between K and L_∞ (Figure 3), three growth trajectories were used for modeling simulations: fast (L_∞= 289-mm and K=0.40), average (L_∞=324-mm, K=0.28), and slow (L_∞=362-mm, K=0.23; Figure 4). Fast-growing black crappie populations reached shorter MLLs quicker than slow- and average- growing populations, while slow-growing crappie populations reached longer MLLs quicker than average- and fast-growing black crappie populations (Table 3). Based on 7,969 black crappies collected in 201 lake surveys (149 water bodies) conducted during April-May from 1990-2010, the shape parameter (β) and the scaling constant (α) for the weight-length relationship of black crappies were 3.23 and -5.36, respectively (Figure 5). The asymptotic average weight (W_∞) for black crappies was defined as 389 grams for fast growth, 563 grams for average growth, and 800 grams for slow growth (Table 3).

For slow-growing black crappie populations, instantaneous natural mortality (*M*) averaged 0.33 and ranged from 0.25 to 0.41, for average-growing black crappie populations, natural mortality averaged 0.36 and ranged from 0.32 to 0.44, and for fast-growing crappie populations, natural mortality averaged 0.48 and ranged from 0.38 to 0.71.

For slow-, average-, and fast-growing black crappie populations, a no length limit scenario (i.e., 203-mm MLL) maximized yield and number harvested (Figure 9 and 10), but provided the fewest number of fish reaching 279-mm (Figure 11). Under a 229-, 254-, and 279-mm MLL, the number of black crappies harvested was reduced on average by 27-76% (Figure 10). Creel limit reductions had little effect on yield, harvest, and number of fish reaching 279-mm for black crappies across all growth types because reduced daily creel limits provided only small reductions in exploitation (Figures 12-14).

Yellow Perch

Daily Creel Limit Reductions.—Only 5.17% (12,112 of 234,067) anglers reported harvesting at least one yellow perch and only 0.12% (280 of 234,067) anglers harvested a daily creel limit of 25 yellow perch, so the current daily creel limit affected few anglers (Figure 8). Anglers that targeted yellow perch (i.e., percentage of time fishing for yellow perch ≥ 50%) harvested 62,218 yellow perch, which represented nearly all of yellow perch harvested (99.04%; 50,310 of 50,798). Harvest reductions were less than 10% at reduced creel limits of 20 (3.15% reduction) and 15 (9.00% reduction) fish per day and greater than 10% at reduced creel limits of 10 (19.36% reduction) and 5 (40.12%

reduction) fish per day (Figure 6). Harvest reductions were less than 10% at a statewide minimum length limit of 178-mm (5.67% reduction) and greater than 10% at statewide minimum length limits of 203-mm (25.17% reduction), 229-mm (74.73% reduction), 254-mm (90.34% reduction), and 279-mm (96.83% reduction; Figure 7).

Modeling Simulations.—Asymptotic total length of yellow perch (L_∞) ranged from 189-360 mm among the 28 populations used for growth analyses (Table 4). Instantaneous growth rates (K) ranged from 0.18 to 0.62. Based on the relationship between K and L_∞ (Figure 3), three growth trajectories were used for modeling simulations: fast (L_∞= 253-mm and K=0.36), average (L_∞=300-mm, K=0.24), and slow (L_∞=336-mm, K=0.20; Figure 4). Fast-growing yellow perch populations reached shorter MLLs quicker than slow and average growing populations, while slow-growing yellow perch populations reached longer MLLs quicker than average- and fast-growing yellow perch populations (Table 3). Based on 2,719 yellow perch collected in 81 lake surveys (63 water bodies) conducted during April-May from 1990-2010, the shape parameter (β) and the scaling constant (α) for the weight-length relationship of yellow perch were 3.44 and -5.92, respectively (Figure 5). The asymptotic average weight (W_∞) for yellow perch was defined as 220 grams for fast growth, 397 grams for average growth, and 585 grams for slow growth (Table 3).

For slow growing yellow perch populations, instantaneous natural mortality (M) averaged 0.15 and ranged from 0.13 to 0.17, for average growing yellow perch populations, natural mortality averaged 0.17 and ranged from 0.15 to 0.19, and for fast growing yellow perch populations, natural mortality averaged 0.23 and ranged from 0.17 to 0.36.

For slow-growing yellow perch populations, both 229- and 254-mm MLLs increased yield by >10% when exploitation was > 31% while a 279-mm MLL increased yield by > 10% when *u* was > 37% (Figure 9). A 229-mm MLL increased yield by > 10% for average-growing yellow perch populations when *u* was > 55% (Figure 9). When yellow perch growth was fast, no length limit (i.e., 203-mm MLL) maximized yield (Figure 9). Under 229-, 254-, and 279-mm MLLs, the number of yellow perch harvested decreased on average by 31-63% (Figure 10). Creel limit reductions had little effect on yield, harvest, and number of fish reaching 279-mm for yellow perch across all growth types because reduced daily creel limits provided only small reductions in exploitation (Figures 12-14).

DISCUSSION

Daily Creel Limits

Current daily creel limits for black crappie and yellow perch in Wisconsin affect only a small percentage of anglers who harvest a creel limit of 25 black crappies or yellow perch. Most Wisconsin anglers catch few or no black crappies or yellow perch, similar to previous studies that found most anglers rarely harvest more than 5 fish on a single trip (Snow 1982; Webb and Ott 1991; Baccante 1995; Cook et al. 2001). In Wisconsin, reducing the creel limit from 25 to 20 or 15 fish would likely have little effect on reducing statewide harvest because few anglers harvest 15 or more fish. In crappie and yellow perch fisheries, reducing harvest by 25% or more would generally require daily creel limits of less than 10 fish per angler (Radomski 2003; Isermann et al. 2007). Similarly, daily creel limits would need to be 5 fish per day or less to significantly reduce harvest in Minnesota (Cook et al. 2001) and Iowa (Larscheid 1992). Additionally, under a daily creel limit of 10 fish per angler, exploitation of yellow perch still exceeded 60% on Pelican Lake, South Dakota, despite the fact that only a small percentage (5%) of anglers achieved a daily creel limit (Isermann et al. 2005). Even if daily creel limits of less than 10 fish per angler could reduce harvest and improve size structure, these low creel limits could be socially unacceptable (Larscheid 1992; Reed and Parsons 1999; Cook et al. 2001; Edison et al. 2006). In Minnesota, most anglers (53%) believed that a daily limit of 30 bluegill was just right for proper bluegill management, and they opposed reducing the creel limit to 15 (78% opposition), 10 (96% opposition), or 5 (100% opposition) bluegills per day (Reed and Parsons 1999). Conversely, Illinois anglers favored a 10-fish daily creel limit over a 25-fish daily creel limit (Edison et al. 2006). Alternatively, daily creel limits could be set at a level where 10% of the anglers would be expected to harvest a daily creel limit (Cook et al. 2001). Using this strategy, current creel limits would need to be adjusted to less than 10 fish per day for both black crappies and yellow perch in Wisconsin.

Minimum Length Limits

In general, black crappie populations in Wisconsin had lower rates of M than populations in Alabama, Oklahoma, Missouri, Kansas, Nebraska, and Ohio (M = 0.08-0.94, Ellison 1984; Mosher 1985; Angyal et al. 1987; Colvin 1991; Hammers and Miranda 1991; Miller 1991; Reed and Davies 1991; Brock 1994; Zale and Stubbs 1991) but rates were similar to those reported for some Minnesota populations (M = 0.21-0.43, Parsons and Reed 1998). Lower rates of M for black crappie populations in Wisconsin were a consequence of slower growth than southern populations. Slow- and average-growing black crappie populations had rates of *M* that were low enough to allow MLLs to increase yield and size structure. Fast-growing black crappie populations had rates of *M* that exceeded 0.30, which were high enough to negate any predicted benefit in yield from reduced creel limits or MLLs.

Yellow perch populations in Wisconsin had a lower range of *M* (0.13-0.36) than in two South Dakota lakes (*M* =0.54; Isermann et al. 2005), Chequamegon Bay, Lake Superior (*M* = 0.51; Bronte et al. 1993). Even with the lower natural mortality rates, fast-growing yellow perch populations would not likely benefit from MLLs because of high *M* and low L_∞. Yellow perch populations exhibiting slow to average growth rates could yield more under a 203- and 229-mm length limit, if exploitation is > 55% and *M* < 0.20.

Regardless of natural mortality rates, if exploitation was less than 20%, 203-mm length limits maximized yield for both black crappies and yellow perch in Wisconsin, which is consistent with other studies that showed minimum lengths limits improved yield from crappie fisheries only under moderate to low natural mortality and with relatively fast growth (Colvin 1991; Allen and Miranda 1995; Maceina et al. 1998). For example, minimum length limits were predicted to improve yield and average weight of crappie fisheries in Nebraska, Ohio, Kansas, Missouri, Oklahoma, and Alabama, if growth was fast and natural mortality was low (Allen and Miranda 1995). In Weiss Lake, Alabama, a 254-mm minimum length limit would improve crappie yield if conditional natural mortality was less than 35%, but harvest would be reduced (Maceina et al. 1998). For fast-growing black crappie populations in Wisconsin, *M* actually exceeded that observed for Weiss Lake. For some Tennessee reservoirs, minimum length limits were predicted to be most effective in balancing increased yield and size structure against reduced harvest for fast-growing crappie populations (Isermann et al. 2002), which was also the case for Wisconsin crappie populations under a 203-mm MLL if $M < 0.30$.

Minimum length limits could improve age and size structure for yellow perch in some South Dakota lakes if natural mortality was low and growth was average or fast (Isermann et al. 2007), but for Wisconsin I found that minimum length limits would only improve yield and number of larger fish if natural mortality was less than 0.30. Previous modeling studies of yellow perch populations predicted that yield would increase slightly or decline under minimum length limits (Boe 1984; Lucchesi 1988; Bronte et al. 1993). Yield increased slightly for yellow perch under 178- and 203-mm length limits, but the number of older fish increased substantially in the Les Cheneaux Islands of Lake Huron (Lucchesi 1988), whereas I found that 203-mm length limits would have little effect on size structure for yellow perch in Wisconsin. Yield would be reduced under 191- and 244-mm length limits for yellow perch in East and West Okoboji lakes, Iowa, because of moderate growth and high natural mortality (Boe 1984), which I also found for yellow perch in Wisconsin among all growth types when $M > 0.30$. Minimum length limits can only increase yield and numbers of fish reaching certain lengths if fishing mortality represents the majority of total mortality. If total mortality is largely comprised of natural mortality, MLLs would decrease yield and harvest, as for yellow perch in western Lake Superior (Bronte et al. 1993).

Pauly's (1980) meta-analysis, which resulted in the model I used for estimating M, did not include yellow perch or black crappie populations. However, M was significantly correlated to latitude, mean air temperature, and degree days for largemouth bass in North America (Beamesderfer and North 1995). Similar to previous attempts to simulate the effects of MLLs on panfish fisheries (Allen and Miranda 1995; Maceina et al. 1998; Isermann et al. 2007), my modeling did not account for population responses that could occur after changes in harvest regulations, such as changes in natural mortality rates (Allen et al. 1998; Boxrucker 2002), growth rates (Hurley and Jackson 2002), longevity (Newman and Hoff 2000), and fishing mortality for fish longer than the MLL (Larscheid and Hawkins 2005). For example, yellow perch and black crappie growth is often density dependent (Nelson and Walburg 1977; Henderson 1985; Guy and Willis 1995; Staggs and Otis 1996; Pierce et al. 2006), so size restrictions could reduce growth as a density-dependent response to higher fish densities (Serns 1978; Carline et al. 1984; Munger and Kraai 1997). My modeling also simulated a single cohort of fish that did not account for variability in growth and mortality among years or year-classes.

I was unable to calculate total mortality rates because both black crappies and yellow perch exhibited extreme variation in recruitment (i.e., adjacent year-classes differing by a factor of 5 or more), which violates one of the primary assumptions of a catch curve (Ricker 1975). This prevented me from being able to calculate estimates of F using Baranov's equation (Ricker 1975). Being able to estimate total mortality, natural mortality, and a fishing mortality rates is critical to the effective management of black crappie and yellow perch fisheries in Wisconsin. Typically, estimates of total instantaneous annual mortality (Z) are estimated using catch curves and instantaneous fishing mortality rates (F) are estimated using some form of mark-recapture study, which allows for calculation of M (i.e., $Z - F = M$; Colvin 1991; Parsons and Reed 1998; Isermann et al. 2005). However, estimates of fishing mortality rates are not available for black crappie and yellow perch fisheries in Wisconsin and Z is difficult to estimate from single year fyke-net samples due to the inherent recruitment variation exhibited by these two species (Sanderson et al. 1999; Isermann et al. 2002; Isermann et al. 2007). Allen (1997) demonstrated that catch curve analysis could be used for crappie fisheries with erratic recruitment to approximate total annual mortality within ± 10%, and managers should consider management recommendations in light of this level of estimation error. To make more informed decisions regarding crappie and yellow perch management in Wisconsin, total annual mortality and exploitation could be estimated from a suite of lakes ranging in latitude, lake size, fertility and other attributes during a 5 to10 year period. Exploitation can be estimated by two different ways, from population estimates coupled with creel surveys to estimate harvest (Goedde and Coble 1981) or a tag-return study (Colvin 1991; Larson et al. 1991; Miranda and Dorr 2000; Parsons and Reed 1998; Isermann 2005). Population estimates coupled with creel surveys to estimate harvest for panfish require large effort and are labor intensive which may not be feasible for the WDNR, even though creel surveys are routinely conducted in northern Wisconsin. A tag-return study provides another approach to estimate harvest which may be more feasible (Pegg et al. 1996; Larson et al. 2001; Isermann et al. 2005). Managers could decide which lakes they think experience high angler effort or existing observations of high harvest rates (fish/ha) to determine if lakes actually are experiencing high rates of exploitation. Tag-return studies could be conducted on these lakes as an initial effort to determine if exploitation is an important source of mortality in Wisconsin crappie and yellow perch fisheries, or if natural mortality is sufficiently high to negate potential benefits to yield and size structure that might be realized with more stringent regulation of harvest. While efforts to estimate mortality rates will require a major investment of

WDNR resources, these efforts will provide better information regarding the best management practices for crappies and yellow perch fisheries in the state.

Based on length frequencies of harvested fish, anglers are already imposing their own minimum length limits in Wisconsin. Most yellow perch and black crappies harvested by anglers were 178-mm or longer, with peak harvest at 203-mm and 229-mm for yellow perch and black crappies. My choice of 203-mm as a minimum harvestable length for crappies and yellow perch may not accurately predict yield under no length limit because most anglers do not harvest fish until they are longer than 203-mm TL. For example, if most Wisconsin anglers already select 203-mm and longer black crappies, yield would be much smaller under a 229-mm MLL than under no MLL. However, the Beverton-Holt model assumes knife-edge recruitment to harvestable size and I chose 203-mm because at least some anglers harvest fish of this length for both species. Based on length frequencies of harvested fish from creel surveys, I conclude that the assumption of knife-edge harvest selectivity is not realistic for black crappie and yellow perch fisheries in Wisconsin, but further research would be needed to define harvest selectivity curves for these species. Understanding angler harvest selectivity is necessary to more clearly determine effects of a harvest regulation and this selectivity has not been defined for crappie and yellow perch populations in Wisconsin.

Effectiveness of a regulation for meeting management objectives could also be negatively affected by relatively high post-release mortality, which I did not include in my modeling. For example, hooking mortality of walleyes caught by recreational anglers ranged from 0% to 12.2% on Mille Lacs, Minnesota (Reeves and Bruesewitz 2007). If effort is high and post-release mortality exceeds 20% for short-lived high-productive species such as black crappies or yellow perch, reduced effort would be required to protect fisheries from recruitment overfishing (Coggins et al. 2007), which is usually not a concern for crappie or yellow perch populations in Wisconsin. For white crappies in Columbus and Aliceville reservoirs, Mississippi, delayed mortality was low (3%) if crappies were caught from depths <10 m, but higher at depths of 13 (29%) and 16 m (67%; Hubbard and Miranda 1989), so release mortality could be a concern in some Wisconsin lakes where crappies are caught from deeper water.

Understanding angler motivations and attitudes would improve the process of selecting appropriate management objectives and associated harvest regulations for black crappies and yellow perch in Wisconsin. Specifically, changes in harvest regulations could attract or deter anglers depending on their motivations and perceptions of fishing opportunities (Allen and McGlade 1986; Johnson and Carpenter 1994; Beard et al. 2003). For example, angler effort in Wisconsin for walleyes was higher on lakes with larger creel limits, even though lakes with smaller creel limits had higher catch rates (Beard et al. 2003). Because Wisconsin anglers fished for walleyes on less-restrictive waters, more-restrictive waters could have less fishing pressure and mortality (Beard et al. 2003). Conversely, harvest regulations could increase angler use if the regulation creates an opportunity for quality fishing (Cox and Walters 2002). Moreover, if an exceptional fishery is created, increased fishing mortality may negate effectiveness of the regulation. Incorporating sociological factors into management decisions may improve the process of selecting harvest regulations for crappie and yellow perch fisheries in Wisconsin. Additionally, anglers targeting specific species can be categorized into definable groups that vary in their motivation to harvest fish and opinions of harvest regulations (Allen and

Miranda 1996). Identifying motivations and attitudes of Wisconsin panfish anglers should be completed before making future management decisions.

MANAGEMENT IMPLICATIONS

My modeling provides a framework for future efforts to identify which Wisconsin black crappie and yellow perch fisheries would benefit from more stringent harvest regulations. If the WDNR wants to reduce statewide harvest of black crappies and yellow perch to possibly increase size structure and to distribute harvest more broadly among anglers, daily creel limits would need to be 5 fish per day for both black crappies and yellow perch. However, a daily creel limit of 5 fish per day may be socially unacceptable. Consequently, a statewide daily creel limit of 10 black crappies and yellow perch is a more logical management approach. However, a statewide daily creel limit of 10 fish will have little effect on harvest because most anglers do not harvest more than 10 black crappies or yellow perch. A 5 fish daily creel limit should be used on lakes that experience high exploitation rates in order to reduce the possability of quality overfishing. During periods of high angler effort, reduced creel limits or MLLs alone may not effectively control harvest due to increases in effort, which has been demonstrated in previous studies (Cox and Walters 2002; Radomski 2003; Isermann et al. 2005). For lakes that have trophy potential and high exploitation, a 5 fish daily creel limit with one fish over 254-mm should be employed to protect and create trophy fisheries (i.e., lakes that consistently produce black crappies > 254-mm).

An alternative to reducing statewide daily creel limits would be implementing a statewide MLL. Based on percent harvest reductions for black crappie and yellow perch, a statewide 229-mm MLL for black crappies and a 203-mm MLL for yellow perch are reasonable statewide MLLs. A statewide 203-mm MLL for black crappies (7.13% reduction) and 178-mm MLL for yellow perch (5.67% reduction) are not reasonable MLLs for Wisconsin because they will most likely have an immeasurable effect on harvest because few fish were harvested less than those lengths. Whereas, statewide MLLs of 254- (69.07% reduction) and 279-mm (88.55% reduction) for black crappies and yellow perch (90.34%; 96.82% reduction) would drastically reduce the number of black crappies and yellow perch harvested and would be biologically unreasonable and socially unacceptable. Larger MLLs (i.e., MLLs > 229-mm for black crappies and 203-mm for yellow perch) would be needed to improve the number of fish reaching larger sizes, but should not be used on the statewide level due to the wide variation in growth.

It will remain difficult to manage yellow perch and black crappie fisheries due to recruitment variation. Based on catch at age data, most Wisconsin black crappie and yellow perch populations exhibit extreme variation in recruitment, which results in pulses of harvestable fish that may attract high angler effort. Effort at these times could be high enough to negate benefits of low bag limits or length limits (Isermann et al. 2005).

Future research should also attempt to develop a means to classify crappie and yellow perch populations based on easily measured population metrics and abiotic variables. Classification of this type will simplify the selection of harvest regulations. Also, by classifying black crappie and yellow perch populations, current harvest regulations can be evaluated for their potential benefits to improve yield and size structure in such populations. Lastly, in order to better understand the effects of MLLs, mortality rates must be known or estimated for individual or least a few water bodies in Wisconsin.

TABLE 1.–Panfish harvest regulations that differ from Wisconsin's statewide daily creel limit of 25 panfish (Guide to Wisconsin Hook and Line Fishing Regulations 2009-2010). Table includes number of water bodies with each special regulation.

Regulation	# Of Water bodies
Daily creel limit of 10 panfish	73
Daily creel limit of 25 panfish, only 10 can be bluegill	3
No daily creel limit on panfish	1
Daily creel limit of 15 panfish and MLL of 203-mm	1
Daily creel limit of 10 panfish and MLL of 203-mm	1
Daily creel limit of 25 panfish and: only 15 can be crappie from May 1-Nov. 30; daily creel limit of 15 panfish from Dec. 1-Mar. 5; daily creel limit of 0 panfish from Mar. 6-Opener	1

TABLE 2.–Asymptotic total length (L_∞) and instantaneous growth rate (K) for black crappie populations in 34 Wisconsin lakes. Location (county) and the WDNR water body identification code (WBIC) are reported for each lake. Growth types were assigned based on the relationship between L_∞ and K depicted in Figure 3.

Waterbody Name	County	WBIC	Year	L_∞	K	Growth
Long Lake	Fond du Lac	38700	2004	419	0.23	Slow
Bagley Flowage	Marinette	516800	2007	403	0.21	Slow
Oconto Falls Pond	Oconto	449300	2007	400	0.16	Slow
Noquebay Lake	Marinette	525900	2009	364	0.24	Slow
White Clay Lake	Shawano	326400	2009	363	0.25	Slow
Wolf Lake	Marinette	515500	2007	355	0.29	Slow
Weyauwega Lake	Waupaca	257700	2005	340	0.24	Slow
Cornell Lake	Chippewa	2171000	2010	333	0.22	Slow
Wilson Lake	Waushara	250000	2009	328	0.21	Slow
High Falls Reservoir	Marinette	540600	2010	326	0.21	Slow
Wausau Lake	Marathon	1437500	1990	351	0.36	Average
Nugget Lake	Pierce	2053400	1995	347	0.31	Average
Wyona Lake	Columbia	1267400	2008	330	0.27	Average
Fish Lake	Waushara	985000	2005	329	0.27	Average
Marion Millpond	Waupaca	294500	2005	322	0.27	Average
Post Lake, Lower	Langlade	397100	2008	318	0.25	Average
Hilbert Lake	Marinette	501200	2005	317	0.31	Average
Brule River	Florence	703900	2010	316	0.27	Average
Sailor Creek Flowage	Price	2252200	2010	315	0.28	Average
Phlox Pond	Langlade	336400	2009	314	0.25	Average
Post Lake, Upper	Langlade	399200	2008	311	0.27	Average
Swampsauger Lake	Oneida	1528700	2010	332	0.37	Fast
Squaw Lake	St Croix	2499000	1996	324	0.34	Fast
Dry Dam Lake	St Croix	2461600	2010	308	0.40	Fast
Kusel	Waushara	189600	1999	299	0.44	Fast
Big Trade Lake	Burnett	2638700	2001	299	0.42	Fast
Bear Lake	Barron	2105100	2008	292	0.34	Fast
Turtle Lake	Langlade	379300	2008	290	0.31	Fast
Shawano Lake	Shawano	322800	2010	285	0.28	Fast
Chain O'Lakes	Waupaca	261100	2000	272	0.55	Fast
Turtle Lake	St Croix	2502800	2010	267	0.43	Fast
Swamp Lake	Oneida	1522400	2001	264	0.35	Fast
Fish Lake	Dane	985100	2003	241	0.55	Fast

TABLE 3.–Time in years to reach four total lengths and asymptotic average weight (W_∞) for each growth category of black crappies and yellow perch.

		Minimum Length Limit (mm)				
Species	Growth	203	229	254	279	W_∞
Black crappie	Slow	3.55	4.30	5.20	6.36	800
	Average	3.48	4.32	5.41	6.99	563
	Fast	3.05	3.92	5.28	8.45	389
Yellow perch	Slow	4.59	5.64	6.97	8.80	584
	Average	4.47	5.69	7.47	10.84	386
	Fast	5.10	7.84	-	-	195

TABLE 4.–Asymptotic total length (L_∞) and instantaneous growth rate (K) for yellow perch populations in 28 Wisconsin lakes. Location (county) and the WDNR water body identification code (WBIC) used are reported for each lake. Growth types were assigned based on the relationship between L_∞ and K depicted in Figure 3.

Waterbody Name	County	WBIC	Year	L_∞	K	Growth
Clark Lake	Door	97700	2009	360	0.22	Slow
Dexter Lake	Wood	1369900	2004	348	0.21	Slow
Pensaukee Lake	Shawano	415000	2004	345	0.18	Slow
Crystal Lake	Sheboygan	45200	2001	345	0.18	Slow
Iola Lake	Waupaca	278800	2004	334	0.19	Slow
White Lake	Waupaca	272900	2008	334	0.21	Slow
Sea Lion Lake	Florence	672300	2005	331	0.20	Slow
Upper Post Lake	Langlade	399200	2008	326	0.18	Slow
Pleasant Lake	Waushara	106900	1999	323	0.21	Slow
Fourth Lake	Oneida	1572000	2007	315	0.19	Slow
Lake Noquebay	Marinette	525900	2009	328	0.23	Average
Lake Hallie	Chippewa	2150200	2010	320	0.31	Average
Phlox Pond	Langlade	336400	2009	308	0.19	Average
Lower Post Lake	Langlade	397100	2008	297	0.20	Average
Bear Lake	Oconto	471200	2009	295	0.28	Average
Turtle Lake	Langlade	379300	2008	285	0.24	Average
Gilmore Lake	Oneida	1589300	2009	282	0.22	Average
Manawa Pond	Waupaca	280400	2002	281	0.26	Average
Lily Lake	Forest	376900	2006	299	0.33	Fast
Lake Wausau	Marathon	1437500	1995	288	0.35	Fast
Kusel Lake	Waushara	189600	1999	270	0.35	Fast
Indian Lake	Oneida	1598900	2004	269	0.25	Fast
Wisconsin River	Portage	1409400	2009	262	0.29	Fast
Mildred Lake	Oneida	1004600	2005	245	0.31	Fast
Marion Millpond	Waupaca	294500	2005	243	0.26	Fast
Big Trade Lake	Burnett	2638700	2001	239	0.45	Fast
Horsehead Lake	Oneida	1588000	2010	225	0.35	Fast
High Falls Reservoir	Marinette	540600	2005	189	0.62	Fast

FIGURE 1.–Location of 186 lakes where creel surveys (N = 263) were available for estimating the effects of daily creel limits on black crappie and yellow perch harvest during 1998-2008.

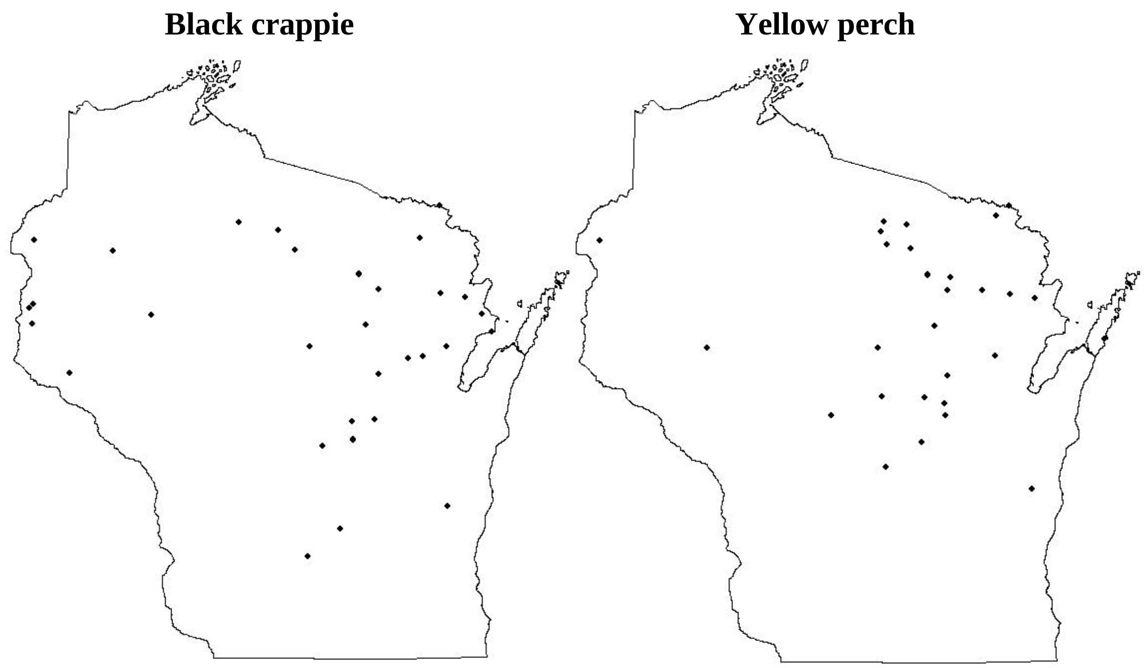


FIGURE 2.–Location of lakes where mean lengths at age from fyke net surveys were used to estimate von Bertalanffy growth parameters for black crappies (left) and yellow perch (right) in Wisconsin.

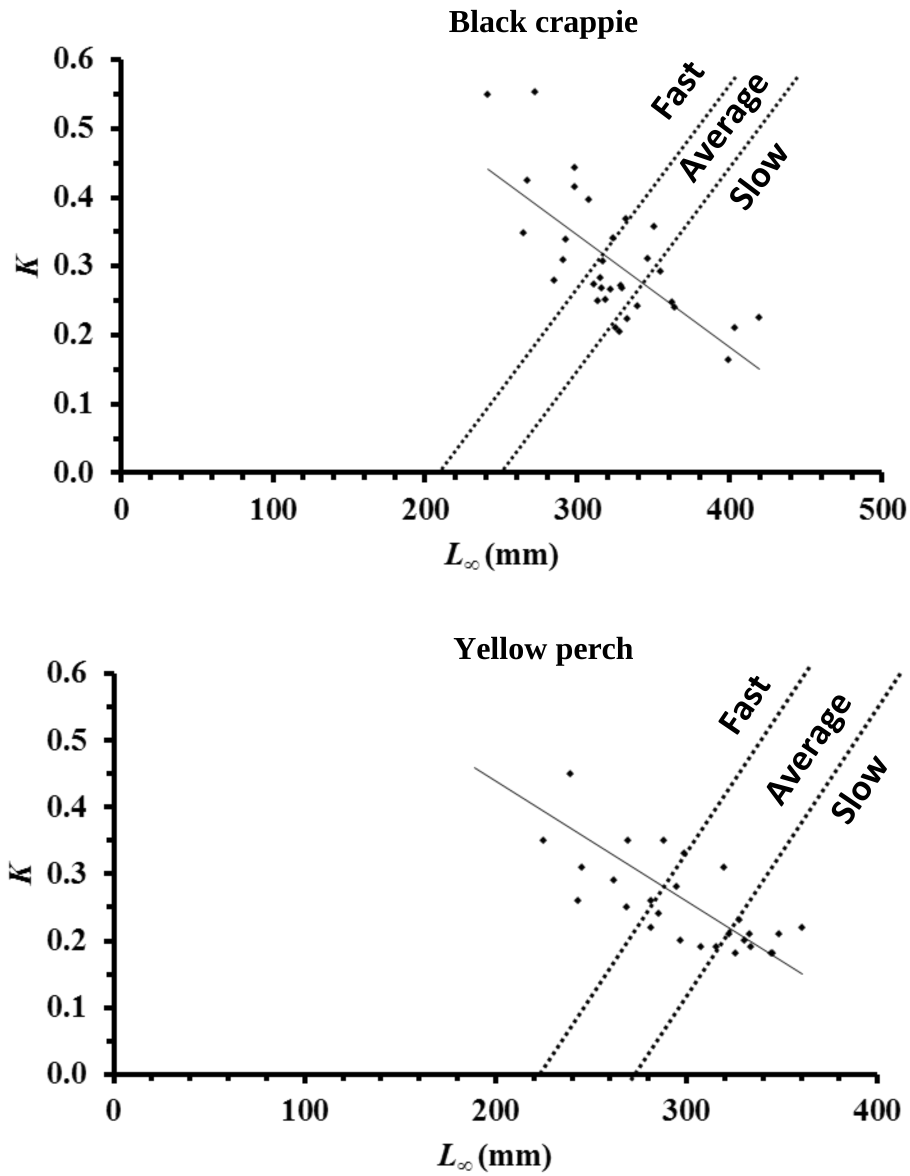


FIGURE 3.–Growth divisions for black crappies (upper) and yellow perch (lower) based on the bivariate distribution of asymptotic total length (L_∞) and instantaneous growth rate (K) for 34 (black crappies) and 28 (yellow perch) lakes in Wisconsin. The solid line represents the linear trend of instantaneous growth rate (K) against asymptotic total length (L_∞). The dashed lines represent perpendicular divisions of the linear trend using the 33rd and 66th percentiles of asymptotic total length (L_∞) and instantaneous growth rate (K).

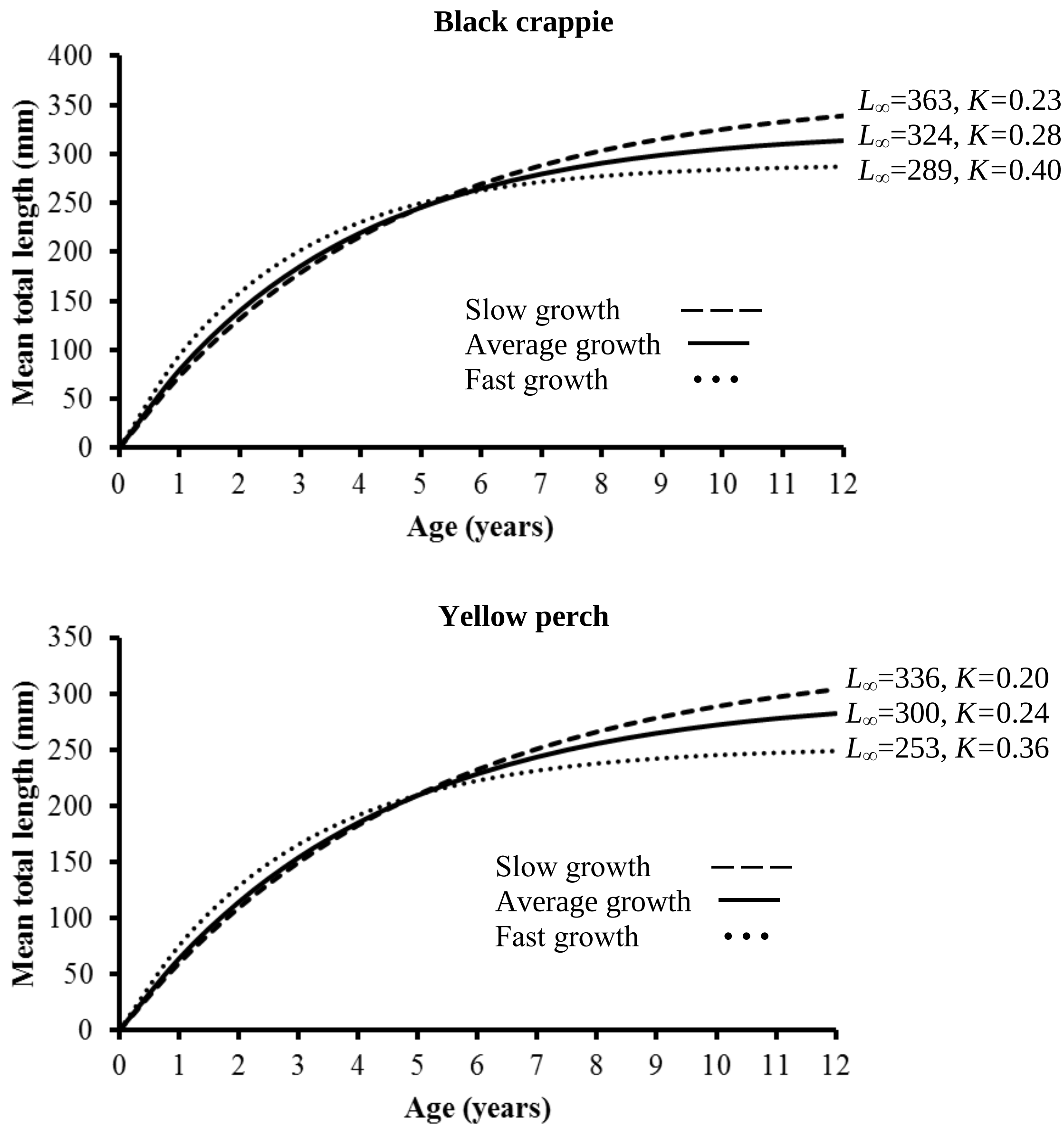
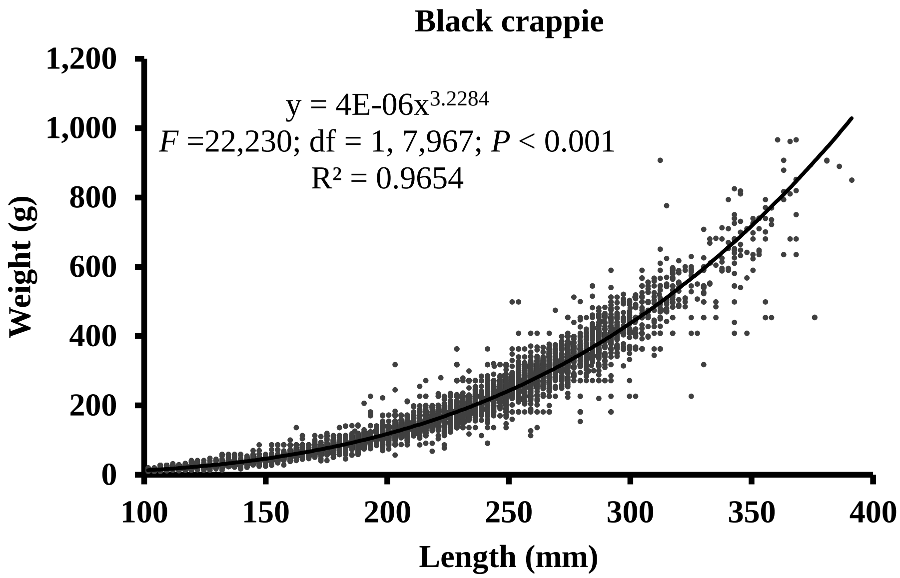


FIGURE 4.–Slow, average, and fast growth trajectories for Wisconsin black crappies (upper) and yellow perch (lower) populations based on the divisions in Figure 3. Asymptotic total lengths (L_∞) and instantaneous growth rates (K) were averaged within each growth category to develop three mean growth trajectories based on 34 lakes for black crappies and 28 lakes for yellow perch.



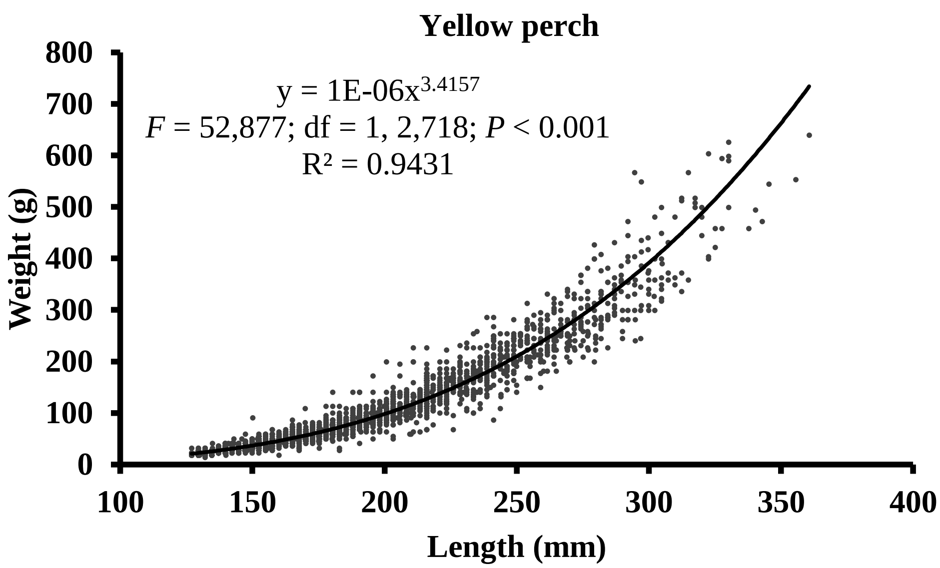


FIGURE 5.–Weight-length relationship for 7,969 Wisconsin black crappies (upper) and 2,719 yellow perch (lower) captured during spring fyke surveys on 149 (upper) and 63 (lower) water bodies from 1990-2010.

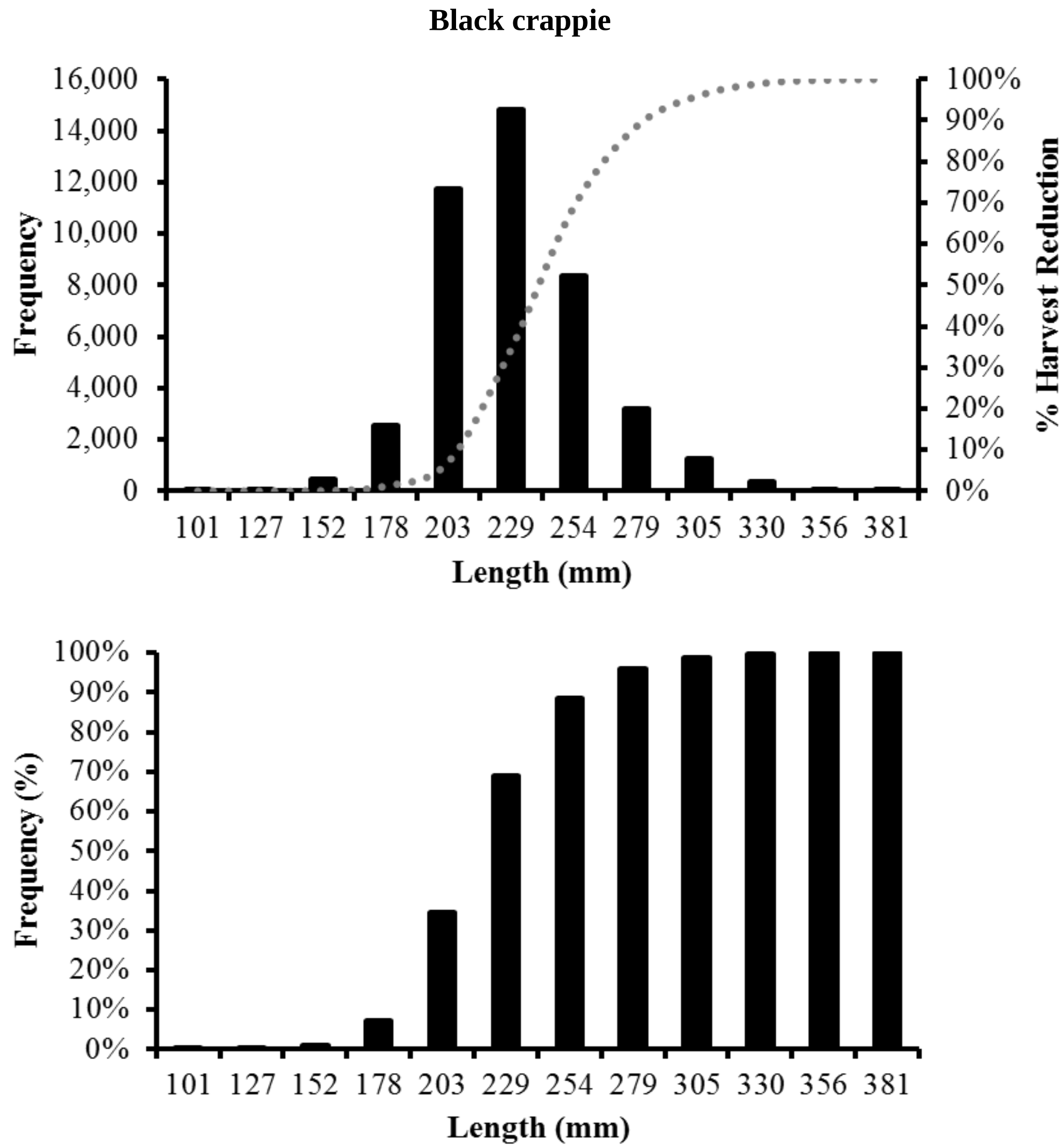


FIGURE 6.–Length frequency, percent harvest reduction (upper), and cumulative length frequency (lower) of black crappie harvested by anglers from 186 Wisconsin water bodies during 1998-2008. Lengths of harvested black crappies were obtained during creel surveys. Dotted line indicates black crappie harvest reductions (upper) expected under statewide minimum length limits in Wisconsin.

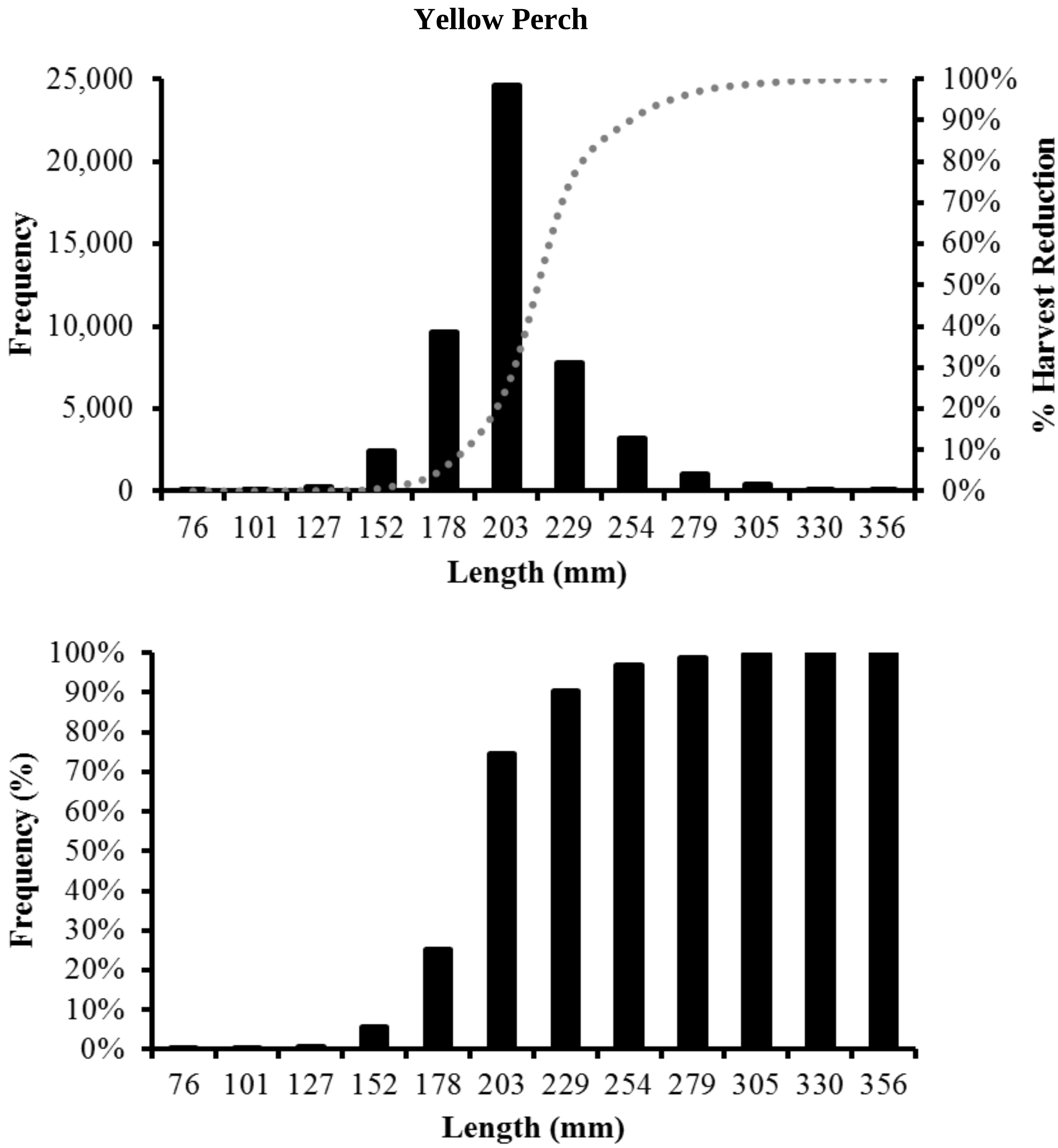
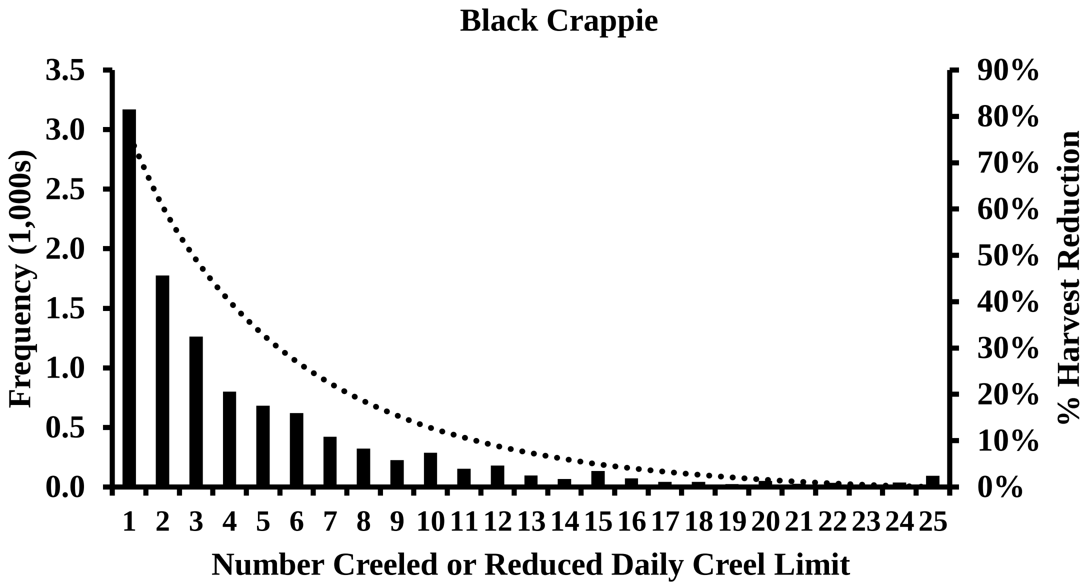


FIGURE 7.–Length frequency, percent harvest reduction (upper), and cumulative length frequency (lower) of yellow perch harvested by anglers from 186 Wisconsin water bodies during 1998-2008. Lengths of harvested yellow perch were obtained during creel surveys. Dotted line indicates yellow perch harvest reductions (upper) expected under statewide minimum length limits in Wisconsin.



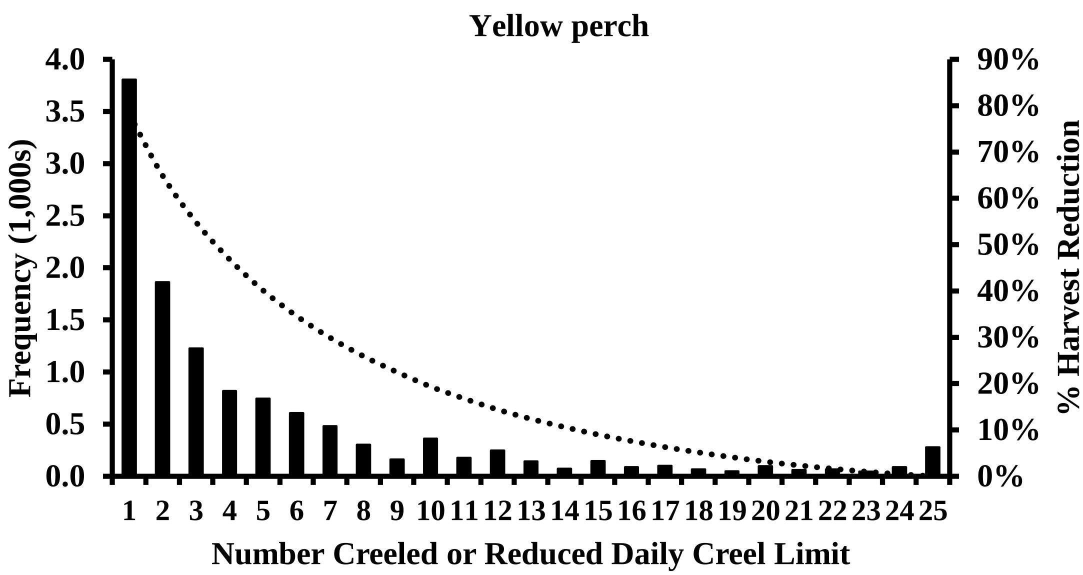


FIGURE 8.–Number of anglers harvesting a specific number of black crappies (upper) and yellow perch (lower) based on creel survey interviews conducted on 186 Wisconsin lakes during 1998-2008. Dotted line indicates black crappie (upper) and yellow perch (lower) harvest reductions expected under daily creel limits less than the current statewide daily creel limit of 25 panfish per day in Wisconsin.

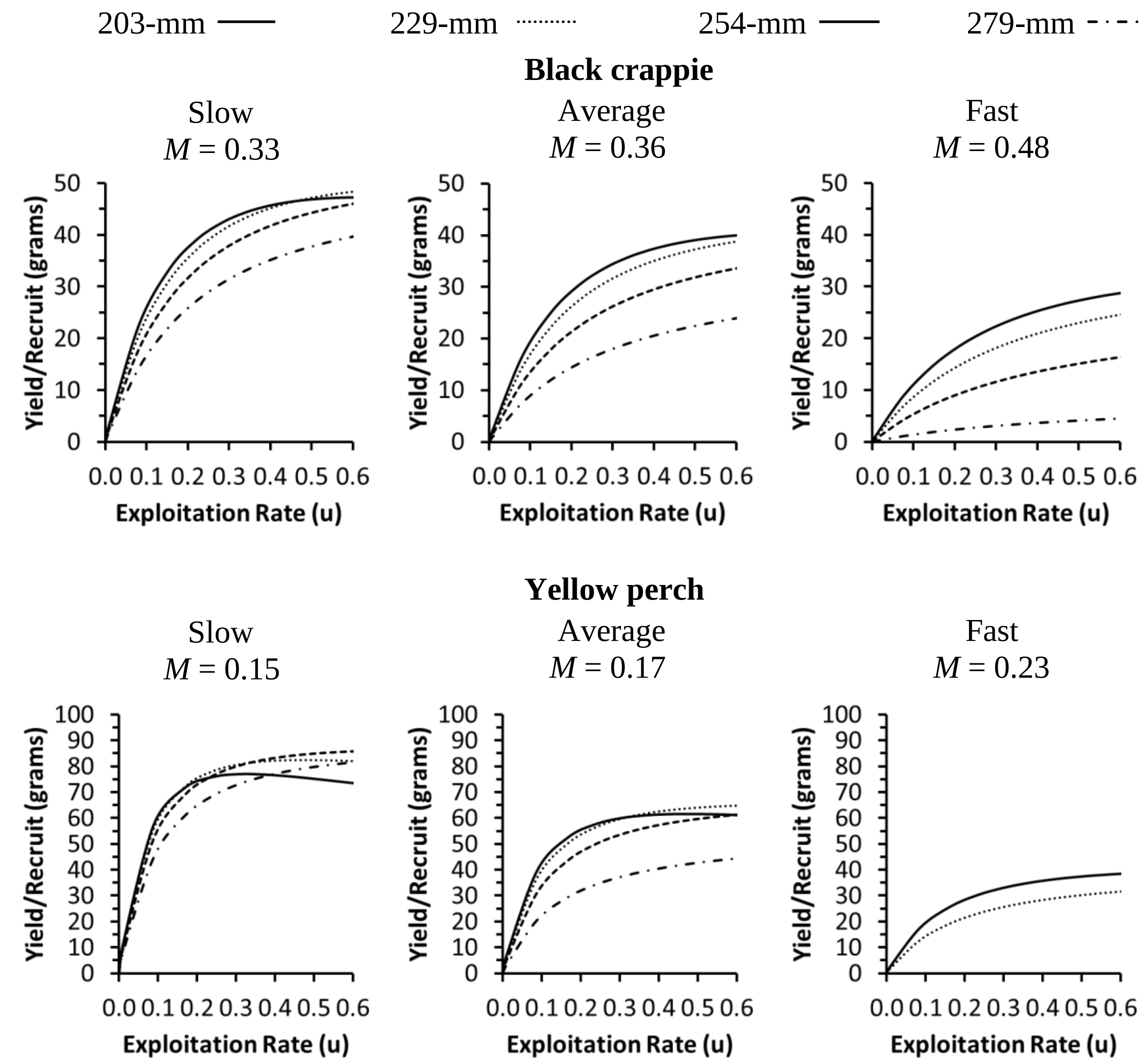


FIGURE 9.–Yield per recruit (g) for slow-, average-, and fast-growing black crappie (upper) and yellow perch (lower) populations under four minimum length limit scenarios.

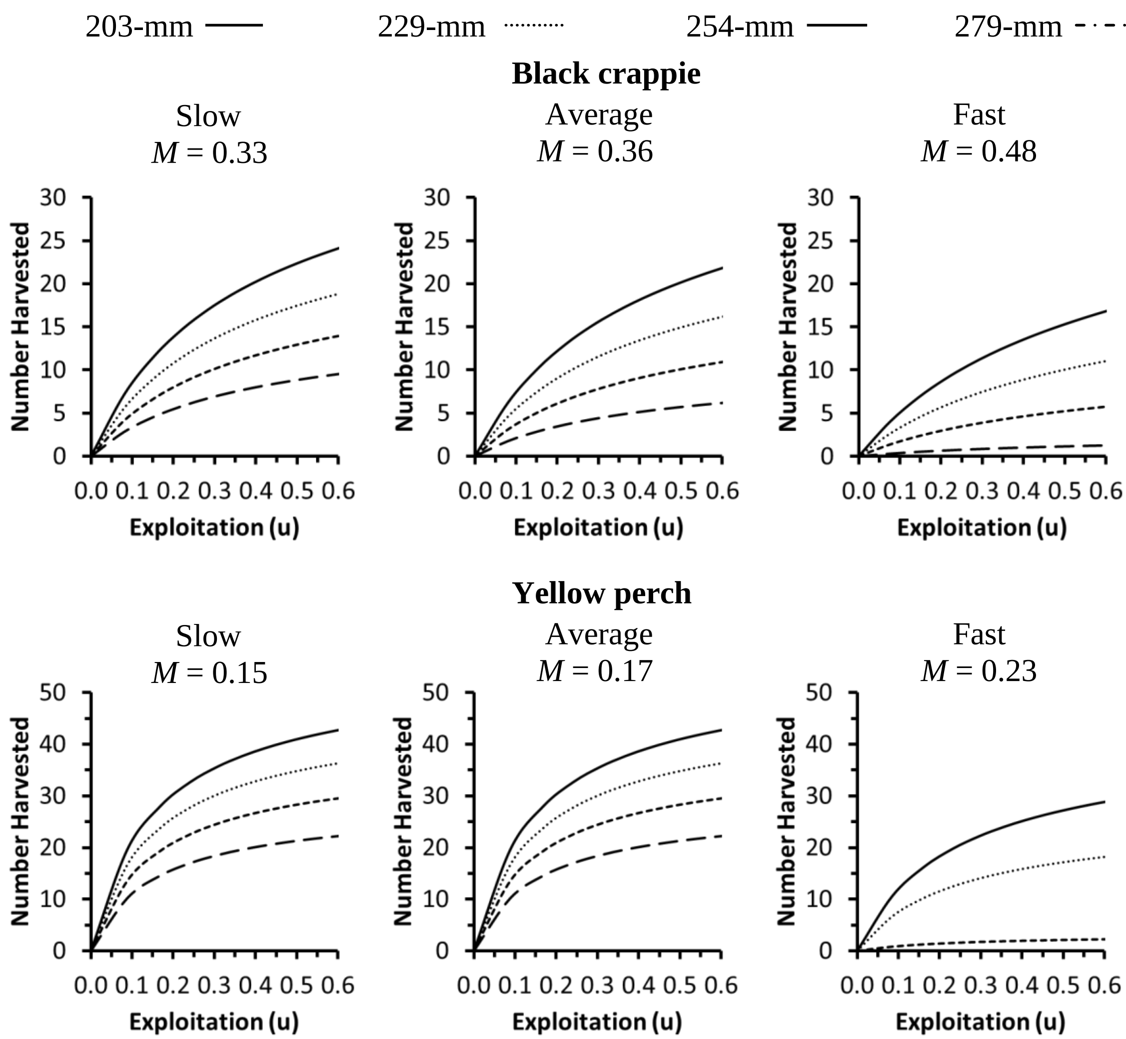


FIGURE 10.–Number of black crappies (upper) and yellow perch (lower) harvested under four minimum length limits for slow-, average-, and fast-growing populations.

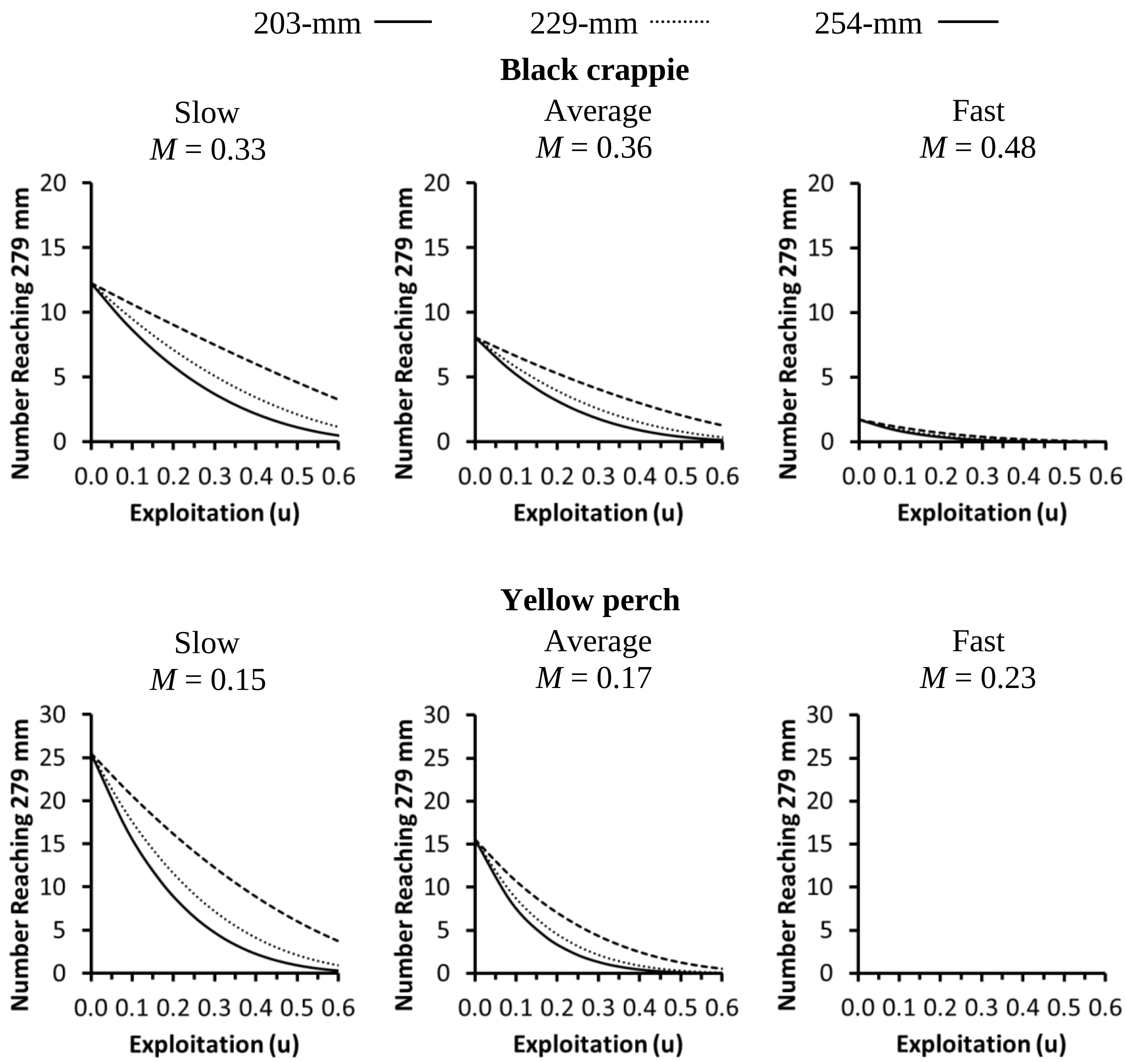


FIGURE 11.–Number of black crappies (upper) and yellow perch (lower) reaching 279 mm under three minimum length limits for slow-, average-, and fast-growing populations.

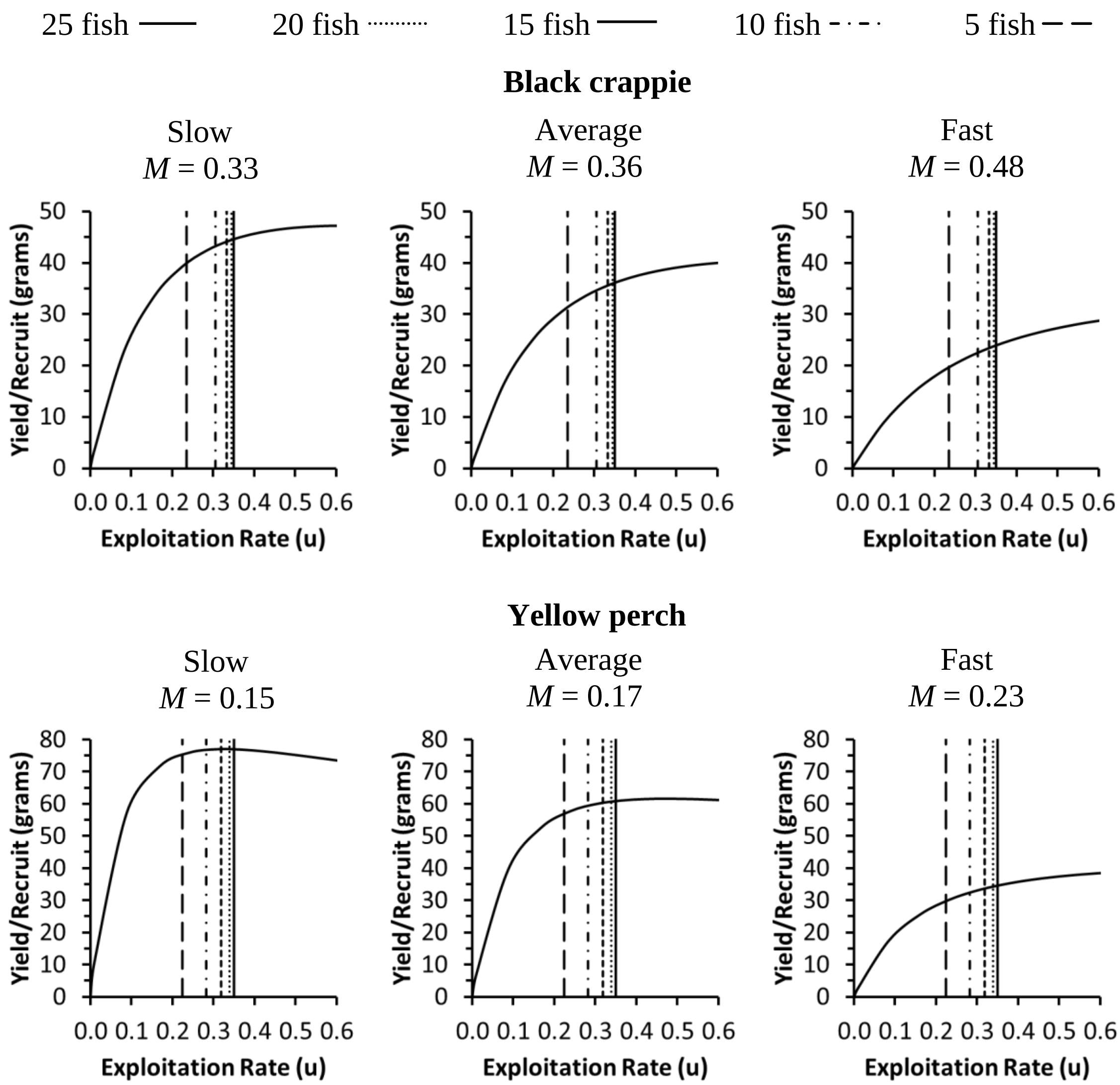


FIGURE 12.–Yield per recruit (g) for slow-, average-, and fast-growing black crappie (upper) and yellow perch (lower) populations under five reduced daily creel limits.

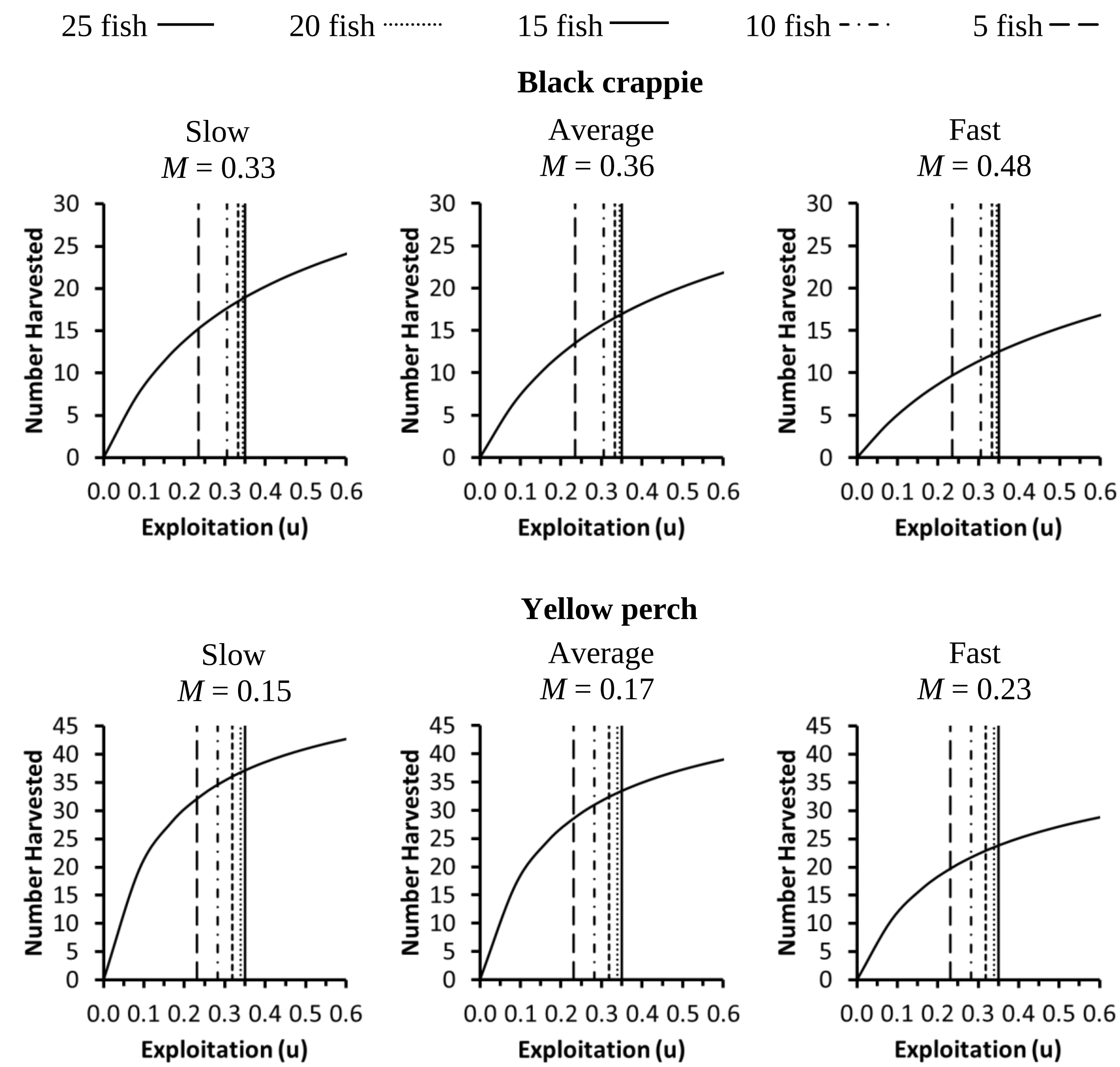


FIGURE 13.–Number of black crappies (upper) and yellow perch (lower) harvested under no minimum length limit for slow-, average-, and fast-growing populations.

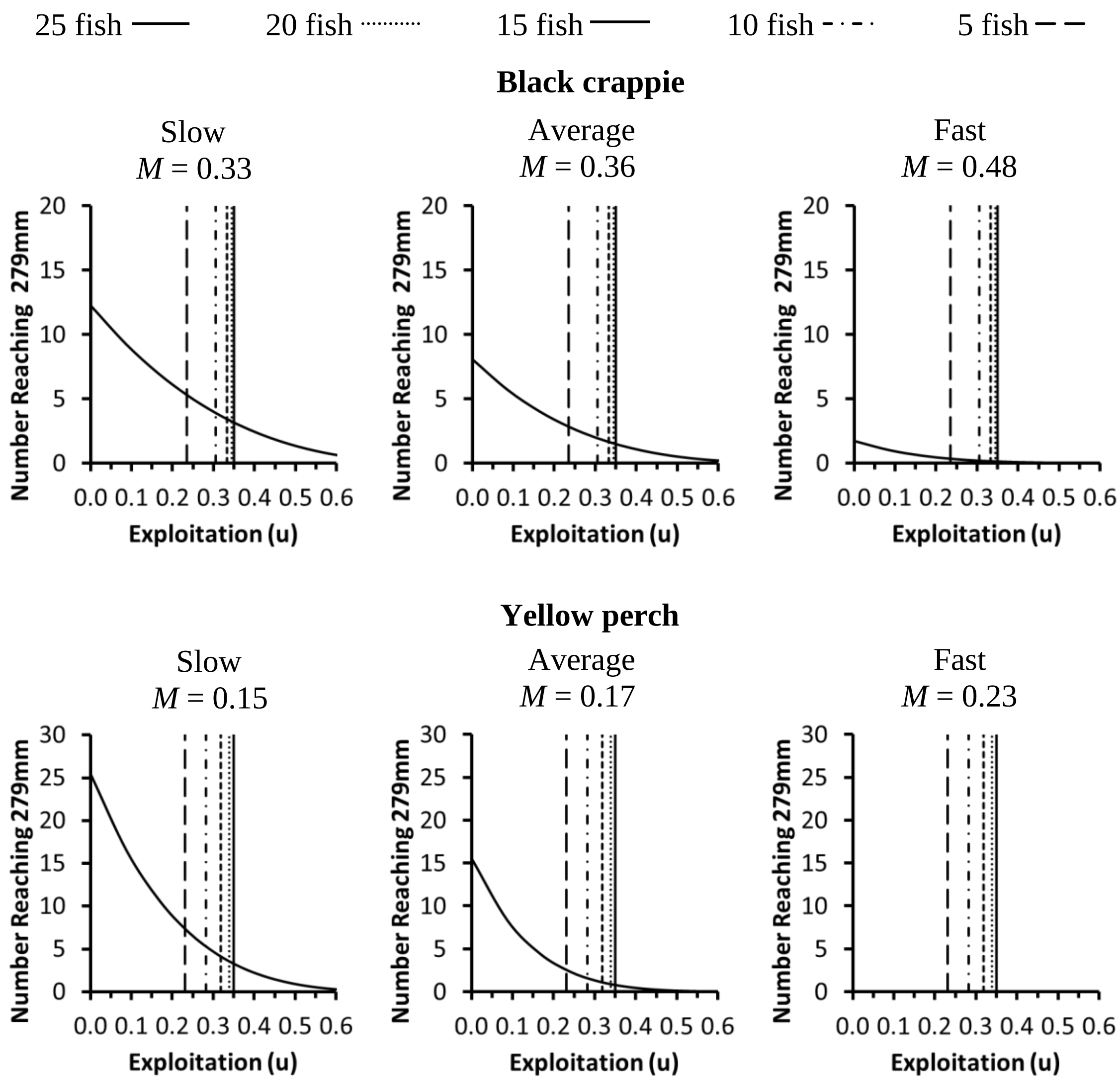


FIGURE 14.–Number of black crappies (upper) and yellow perch (lower) reaching 279-mm under five reduced daily creel limits for slow-, average-, and fast-growing populations.

LITERATURE CITED

Allen, M. S., and L. E. Miranda. 2001. Quasi-cycles in crappie populations are forced by interactions among population characteristics and environment. Canadian Journal of Fisheries and Aquatic Sciences 58: 594-601.

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.

Angyal. R., R. Glass, and O. E. Maughan. 1987. The characteristics of the white crappie population of Sooner Lake, Oklahoma. Proceedings of the Oklahoma Academy of Science 67:1-10.

Baccante, D. B. 1995. Assessing catch inequality in walleye angling fisheries. North American Journal of Fisheries Management 15:661-665.

Beam, J. H. 1983. The effect of annual water level management on population trends of white crappie in Elk City Reservoir, Kansas. North American Journal of Fisheries Management 3: 34–40.

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

Beard, T. D. Jr., and J. M. Kampa. 1999. Changes in bluegill, black crappie, and yellow perch populations in Wisconsin during 1967–1991. North American Journal of Fisheries Management 19:1037–1043.

Becker, G. C. 1983. Fishes of Wisconsin. The University of Wisconsin Press, Madison.

Bister, T. J, D. W. Willis, A. D. Knapp, and T. R. St. Sauver. 2002. Evaluation of a 23-cm (9-in) minimum length limit on black and white crappies in Lake Alvin, South Dakota. North American Journal of Fisheries management 22:1364-1368.

Boe, S. J. 1984. Exploitation, annual mortality, and yield per recruit of yellow perch Perca flavescens Mitchill from the Okoboji lakes, Iowa. Master's thesis. Iowa State University, Ames.

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

Boxrucker, J., and E. Irwin. 2002. Challenges of crappie management continuing into the 21st century. North American Journal of Fisheries Management 22:1334-1339.

Brock, R. E. 1994. Growth, fishing and natural mortalities of crappies in two Mississippi Lakes. Master's thesis. Mississippi State University. Starkville.

Bronte, C. R., J. H. Selgeby, and D. V. Swedberg. 1993. Dynamics of a yellow perch population in western Lake Superior. North American Journal of Fisheries Management 13:511–523.

Brown, T.G., Runciman, B., Bradford, M.J., and Pollard, S. 2009. A biological synopsis of yellow perch (Perca flavescens). Canadian Manuscript Report of Fisheries and Aquatic Sciences 2883: 28.

Carline, R. F., B. L. Johnson, and T. J. Hall. 1984. Estimation and interpretation of proportional stock density for fish populations in Ohio impoundments. North American Journal of Fisheries Management 4:139–154.

Carlton, F. E. 1975. Optimum sustainable yield as a management concept in recreational fisheries. American Fisheries Society Special Publication 9:45-49.

Coggins, L. G., M. J. Catalano, M. S. Allen, W. E. Pine, and C. J. Walters. 2007. Effects of cryptic mortality and the hidden costs of using length limits in fishery management. Fish and Fisheries 8:196-210.

Colvin, M. A. 1991. Evaluation of minimum-size limits and reduced daily limits on the crappie populations and fisheries in five large Missouri reservoirs. North American Journal of Fisheries Management 11:585-597.

Cook, M. F., T. J. Goeman, P. J. Radomski, J. A. Younk, and P. C. Jacobson. 2001. Creel limits in Minnesota: a proposal for change. Fisheries 26(5):19-26.

Cooper, G. P., and W. C. Latta. 1954. Further studies on the fish population and exploitation by angling in Sugarloaf Lake, Wastenaw County, Michigan. Papers of the Michigan Academy of Science, Arts and Letters 39:209-223.

Cox, S. P., and C. Walters. 2002. Modeling exploitation in recreational fisheries and implications for effort management on British Columbia rainbow trout lakes. North American Journal of Fisheries Management 22:21–34.

Dorr, B., I. A. Munn, and K. O. Meals. 2002. A socioeconomic and biological evaluation of current and hypothetical crappie regulations in Sardis Lake, Mississippi: an integrated approach. North American Journal of Fisheries Management 22:1376-1384.

Ellison, D. G. 1984. Trophic dynamics of a Nebraska black crappie and white crappie population. North American Journal of Fisheries Management 4:355-364.

Forney, J. L. 1971. Development of dominant year classes in a yellow perch population. Transactions of the American Fisheries Society 100: 739-749.

Fox, A. C. 1975. Effects of traditional harvest regulations on bass populations and fishing. Pages 392-398 *in* R.H. Stroud and H. Clepper, eds. Black bass biology and management. Sport Fishing Institute, Washington, D.C.

Gabelhouse, D. W., Jr. 1984b. An assessment of crappie stocks in small midwestern private impoundments. North American Journal of Fisheries Management 4: 371–384.

Goedde, L. E., and D. W. Coble. 1981. Effects of angling on a previously fished and unfished warm water fish community in two Wisconsin lakes. Transactions of the American Fisheries Society 110:594-603.

Guy, C. S. & Willis, D. W. 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 length limit on crappies in Delaware Reservoir, Ohio. North American Journal of Fisheries Management 19:804-814.

Hammers, B. E., and L. E. Miranda. 1991. Comparisons of methods for estimating age, growth, and related population characteristics of white crappies. North American Journal of Fisheries Management 11:492-498.

Hansen, M. J., M. D. Staggs, and M. H. Hoff. 1991. Derivation of safety factors for setting harvest quotas on adult walleyes from past estimates of abundance. Transactions of the American Fisheries Society 120: 620-628.

Henderson, B. A. 1985. Factors affecting growth and recruitment of yellow perch, *Perca flavescens* Mitchill, in South Bay, Lake Huron. Journal of Fish Biology 26: 449-458.

Hubbard, W. D. and L. E. Miranda. 1989. Mortality of white crappie after catch and release. Proceedings of the Annual Conference of the Southeaster Association of Fish and Wildlife Agencies 43:49-55.

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

Isermann, D. A., and A. J. Carlson. 2009. Can minimum length limits improve size structure in Minnesota black crappie populations. Investigational Report 552, Minnesota Department of Natural Resources, Federal Aid in Fish Restoration, Project F-26-R, St. Paul.

Isermann, D. A., D. W. Willis, B. G. Blackwell, and D. O. Lucchesi. 2007. Yellow perch in South Dakota: Population variability and predicted effects of creel limit reductions and minimum length limits. North American Journal of Fisheries Management 27:918-931.

Isermann, D. A., D. W. Willis, B. G. Blackwell, D. O. Lucchesi, and B. G. Blackwell. 2005. Seasonal harvest, exploitation, size-selectivity, and catch preferences associated with winter yellow perch anglers on South Dakota lakes. North American Journal of Fisheries Management 25:827-840.

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

Kempinger, J. J., W. S. Churchill, G. R. Priegel, and L. M. Christenson. 1975. Estimate of abundance, harvest and exploitation of the fish population of Escanaba Lake, Wisconsin, 1946-69. Wisconsin Department of Natural Resources Technical Bulletin 84, Madison.

Larscheid, L.G. 1992. Contribution of stocked walleye and population dynamics of walleye in Spirit and East and West Okoboji lakes. Annual Report. Iowa Department of Natural Resources, Federal Aid in Sport Fish Restoration, Project F-15-R, Study 2, Des Moines.

Larscheid, J. G., and M. J. Hawkins. 2005. Evaluation of special regulations for managing walleyes in Iowa's natural lakes. Completion Report. Iowa Department of Natural Resources, Federal Aid in Sport Fish Restoration, Project F-160-R, Des Moines.

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.

Lucchesi, D. O. 1988. A biological analysis of the yellow perch population in the Les Cheneaux Islands, Lake Huron. Michigan Department of Natural Resources, Fisheries Division, Fisheries Research Report 1958, Ann Arbor.

Maceina, M. J., O. Ozen, M. S. Allen, and S. M. Smith. 1998. Use of equilibrium yield models to evaluate length limits for crappies in Weiss Lake, Alabama. North American Journal of Fisheries Management 18:854–863.

McClanahan, Dee R, and M. J. Hansen. 2003. A statewide mail survey to estimate 2000-2001 angler catch, harvest, and effort in Wisconsin. Wisconsin Department of Natural Resources, Fisheries Management Report 151, Madison.

Miller, R. L. 1991. Crappie management investigations. Ohio Department of Natural Resources, Division of Wildlife, Federal Aid in Sport Fish Restoration, Project F-29-R-29 to R-30, Final Report, Columbus.

Mills, E. L., Sherman, R., and D. S. Robson. 1989. Effect of zooplankton abundance and body size on growth of age-0 perch (*Perca flavescens*) in Oneida Lake, New York, 1975-86. Canadian Journal of Fish and Aquatic Science 46: 880-886)

Ming, A. 1971. A review of literature on crappies in small impoundments. Missouri Department of Conservation, Federal Aid in Fish Restoration, Project F-1-R-20, Job 1, Jefferson City.

Mitzner, L. R. 1981. Influence of floodwater storage on abundance of juvenile crappie and subsequent harvest at Lake Rathbun, Iowa. North American Journal of Fisheries Management 1: 46–50.

Mosher, T. D. 1985. Assessment of while crappie growth and survival at two Kansas state fishing lakes. Kansas Game and Fish Commission, Dingell-Johnson/Pittman-Roberison Comprehensive Option, Project FW-9-P-(l-4). Emporia.

Munger, C. R., and J. E. Kraai. 1997. Evaluation of length and bag limits for walleyes in Meredith Reservoir, Texas. North American Journal of Fisheries Management17:438–445.

Nate, N. A. 2004. Variability in fish growth rates in relation to physical and landscape characteristics of Michigan and Wisconsin inland lakes. Doctoral dissertation, Michigan State University, East Lansing. 109 pages.

Nelson, W. R., and C. H. Walburg. 1977. Population dynamics of yellow perch (*Perca flavescens*), sauger (*Stizostedion canadense*), and walleye (*S. Vitreum*) in four main stem Missouri River reservoirs. Journal of the Fisheries Research Board of Canada 34:1748-1763.

Newman, S. P., and M. H. Hoff. 2000. Evaluation of a 16-inch minimum length limit for smallmouth bass in Pallette Lake, Wisconsin. North American Journal of Fisheries Management 20:90-99.

Noble, R. L., and T. W. Jones. 1999. Managing fisheries with regulations. Pages 455-477 in C. C. Kohler and W. A. Hubert, eds. Inland Fisheries Management in North America. American Fisheries Society, Bethesda.

NOAA (National Oceanic and Atmospheric Administration). 2005. National climatic data center. U.S. Department of Commerce, NOAA Satellite and Information Service. Available: http://lwf.ncdc.noaa.gov/oa/ncdc.html. (December 2010).

Parsons, B. G., and J. R. Reed. 1998. Angler exploitation of bluegill and black crap-pie in four west-central Minnesota lakes. Investigational Report No. 468, Section of Fisheries, Minnesota Department of Natural Resources, St. Paul.

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. Journal du Conseil international pour l'Exploration de la Mer.39:175–192.

Pegg, M. A., J. B. Layzer, and P. W. Bettoli. 1996. Angler exploitation of anchor-tagged saugers in the lower Tennessee River. North American Journal of Fisheries Management 16:218–222.

Pine, W. E., III, and M. S. Allen. 2001. Differential growth and survival of weekly age-0 black crappie cohorts in Florida lake. Transactions of the American Fisheries Society 130: 80-91.

Pope, K. L. 1996. Factors affecting recruitment of black crappies in South Dakota waters. Doctoral dissertation. South Dakota State University, Brookings.

Powell, T. G. 1973. Effect of northern pike introductions on an overabundant crappie population. Colorado Division of Wildlife, Special Report Number 31, Denver.

Radomski, P. 2003. Initial attempts to actively manage recreational fishery harvest in Minnesota. North American Journal of Fisheries Management 23:1329-1342.

Rasmussen, P. W., M. D. Staggs, T. D. Beard, Jr., and S. P. Newman. 1998. Bias and confidence interval coverage of creel survey estimators evaluated by simulation. Transactions of the American Fisheries Society 127:469–480.

Reed, J. R., and W. D. Davies. 1991. Population dynamics of black crappies and white crappies in Weiss Reservoir, Alabama: implications for the implementation of harvest restrictions. North American Journal of Fisheries Management 11:598-603.

Reed, J. R., and B. G. Parsons. 1999. Angler opinions of bluegill management and related hypothetical effects on bluegill fisheries in four Minnesota lakes. North American Journal of Fisheries Management 19:515-519.

Reeves, K. A., and R. E. Bruesewitz. 2007. Factors influencing the hooking mortality of walleyes caught by recreational anglers on Mile Lacs, Minnesota. North American Journal of Fisheries Management 27: 443-452.

Ricker, W. E. 1975. Computation and interpretation of biological statistics. Fisheries Research Board of Canada Bulletin 191.

Sammons, S. M., Bettoli, P. W., and V. A. Greear. 2001, Early life history characteristics of age-0 white crappies in response to hydrology and zooplankton densities in Normandy Reservoir, Tennessee. Transactions of the American Fisheries Society 130: 442-449.

Sanderson, B. L., T. R. Hrabik, J. J. Magnuson, and D. M. Post. 1999. Cyclic dynamics of yellow perch (*Perca flacvescens*) population in an oligotrophic lake: evidence for the role of intraspecific interactions. Canadian Journal of Fisheries and Aquatic Sciences 56:1234-1542.

Scott, W. B., and E. J. Crossman. 1973. Freshwater Fishes of Canada. Bulletin of the Fisheries Research Board of Canada 184.

Serns, S. L. 1978. Effects of a minimum size limit on the walleye population of a northern Wisconsin lake. Pages 390–397 in R. L. Kendall, editor. Selected coolwater fishes of North America. American Fisheries Society, Special Publication 11, Bethesda, Maryland.

Shuter, B. J., D. A. Schlesinger, and A. P. Zimmerman. 1983. Empirical predictors of annual surface water temperature cycles in North American lakes. Canadian Journal of Fisheries and Aquatic Sciences 40:1838–1845.

Siefert, R. E. 1968. Reproductive behavior, incubation and mortality of eggs, and postlarval food selection in the white crappie. Transactions of the American Fisheries Society 97: 252–259.

Snow, H. E. 1982. Hypothetical effects of fishing regulations in Murphy Flowage, Wisconsin. Wisconsin Department of Natural Resources, Technical Bulletin 131, Madison.

Staggs, M. D., and K. J. Otis. 1996. Factors affecting first-year growth of fishes in Lake Winnebago, Wisconsin. North American Journal of Fisheries Management 16:608-618.

Trautman, M. B. 1957 The fishes of Ohio with illustrated keys. Ohio State University Press, Columbus, Ohio.

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.

Weigel, B. M. (unpublished). Statewide mail survey to estimate 2006-2007 angler effort, catch, and harvest in Wisconsin. Wisconsin Department of Natural Resources, Fisheries Research, Madison.

Wisconsin Department of Natural Resources (WDNR). 2010. Wisconsin record fish list. Wisconsin Department of Natural Resources Madison, Wisconsin. Available: http://dnr.wi.gov/fish/record/wirecordfish.pdf (April 2011).

WDNR Bureau of Fisheries Management. 2009. Guide to Wisconsin hook and line fishing regulations 2009-2010. Wisconsin Department of Natural Resources

Madison, Wisconsin. Available:
http://dnr.wi.gov/fish/regulations/2009/documents/fhregs0910.pdf (April 2011).

Zale, A. V., and K. C. Stubbs. 1991. Development of a white crappie fishery in a stage-fill impoundment in Oklahoma. Oklahoma Department of Wildlife Conservation, Federal Aid in Sport Fish Restoration. Project F-41-R-13. Final Report Oklahoma City.