North American Journal of Fisheries Management 22:1349–1357, 2002

Predictive Evaluation of Size Restrictions as Management Strategies for Tennessee Reservoir Crappie Fisheries

DANIEL A. ISERMANN,*[1] STEVE M. SAMMONS,[2] AND PHILLIP W. BETTOLI

U.S. Geological Survey,
Tennessee Cooperative Fishery Research Unit,[3]
Tennessee Technological University,
Box 5114, Cookeville, Tennessee 38505, USA

TIMOTHY N. CHURCHILL

Tennessee Wildlife Resources Agency,
Ellington Agricultural Center,
Post Office Box 40747,
Nashville, Tennessee 37204, USA

Abstract.—We evaluated the potential effect of minimum size restrictions on crappies *Pomoxis* spp. in 12 large Tennessee reservoirs. A Beverton–Holt equilibrium yield model was used to predict and compare the response of these fisheries to three minimum size restrictions: 178 mm (i.e., pragmatically, no size limit), 229 mm, and the current statewide limit of 254 mm. The responses of crappie fisheries to size limits differed among reservoirs and varied with rates of conditional natural mortality (CM). Based on model results, crappie fisheries fell into one of three response categories: (1) In some reservoirs (N = 5), 254-mm and 229-mm limits would benefit the fishery in terms of yield if CM were low (30%); the associated declines in the number of crappies harvested would be significant but modest when compared with those in other reservoirs. (2) In other reservoirs (N = 6), little difference in yield existed among size restrictions at low to intermediate rates of CM (30–40%). In these reservoirs, a 229-mm limit was predicted to be a more beneficial regulation than the current 254-mm limit. (3) In the remaining reservoir, Tellico, size limits negatively affected all three harvest statistics. Generally, yield was negatively affected by size limits in all populations at a CM of 50%. The number of crappies reaching 300 mm was increased by size limits in most model scenarios; however, associated declines in the total number of crappies harvested often outweighed the benefits to size structure when CM was 40% or higher. When crappie growth was fast (reaching 254 mm in less than 3 years) and CM was low (30%), size limits were most effective in balancing increases in yield and size structure against declines in the total number of crappies harvested. The variability in predicted size-limit responses observed among Tennessee reservoirs suggests that using a categorical approach to applying size limits to crappie fisheries within a state or region would likely be a more effective management strategy than implementing a single, areawide regulation.

The use of minimum size restrictions to manage fisheries for crappies *Pomoxis* spp. has increased across the United States in recent years (Colvin 1991a; Quinn 1996; Hale et al. 1999; Boxrucker 2001; Bister et al. 2002, this issue); however, the effectiveness of these regulations has been inconsistent (Allen and Miranda 1995). The efficacy of any size restriction is directly linked to the rates of growth, natural mortality, and exploitation of a population, as well as to the attitudes and motivations of the angling public (Reed and Davies 1991; Allen and Miranda 1995, 1996). Variability in population characteristics dictates that the response of fisheries to size limits vary among populations of the same species (Allen and Miranda 1995; Beamesderfer and North 1995; Guy and Willis 1995).

Management strategies for black crappies *P. nigromaculatus* and white crappies *P. annularis* in Tennessee have paralleled management strategies for these species across the country. Before 1997, harvest restrictions were liberal, consisting of creel limit of 30 crappies/d and no size restriction. In 1997, following a widespread increase in the

* Corresponding author: disermann@hotmail.com
[1] Present address: Department of Wildlife and Fisheries Sciences, South Dakota State University, Box 2140B, Northern Plains Biostress Laboratory 138, Brookings, South Dakota 57007, USA.
[2] Present address: Department of Fisheries and Allied Aquacultures, Auburn University, 203 Swingle Hall, Auburn, Alabama 36489, USA.
[3] The Unit is jointly funded by the U.S. Geological Survey, the Tennessee Wildlife Resources Agency, and Tennessee Technological University.

Received December 1, 2000; accepted April 29, 2002

TABLE 1.—Reservoir type (M = main stem, T = tributary), size, mean depth, and trophic state for the 12 Tennessee reservoirs used in evaluating crappie size limits, along with the sampling periods and gears used.

Reservoir	Reservoir type	Size (ha)	Mean depth (m)	Trophic state	Sampling period	Sampling gear
Barkley	M	23,458	4.6	Eutrophic	Oct 1998–1999	Electrofishing, trap nets
Cherokee	T	12,272	12.3	Mesotrophic	Oct 1998	Trap nets
Chickamauga	M	14,337	5.0	Eutrophic	Oct 1999	Electrofishing
Dale Hollow	T	11,219	18.7	Oligotrophic	Nov 1999	Gill nets
Douglas	T	12,393	10.1	Mesotrophic	Oct 1997	Trap nets
Kentucky	M	64,922	5.2	Eutrophic	Oct 1998	Electrofishing, trap nets
Normandy	T	1,307	11.2	Eutrophic	May 1998–1999	Electrofishing
Norris	T	13,851	15.7	Oligotrophic	Dec 1998	Trap nets
J. Percy Priest	T	5,751	8.5	Eutrophic	May 1999	Electrofishing
Tellico	T	6,503	7.6	Mesotrophic	May 1999	Electrofishing
Watts Bar	T	16,038	7.9	Eutrophic	Oct 1999	Electrofishing
Woods	T	1,612	5.7	Eutrophic	May 1999	Electrofishing

use of size restrictions to manage crappies (Quinn 1996), the Tennessee Wildlife Resources Agency (TWRA) implemented a statewide crappie size limit of 254 mm and a creel limit of 30 crappies/d. The effectiveness of size limits as a management strategy for Tennessee reservoir crappie fisheries had not been evaluated before our study.

The objectives of our evaluation were (1) to predict and compare the effect of three minimum size limits on the harvest of crappie populations in 12 Tennessee reservoirs, and (2) to address the use of a statewide size restriction as an approach for managing crappie fisheries.

Study Sites

Analyses were conducted for 12 Tennessee reservoirs (>1,000 ha) in the Cumberland River and Tennessee River drainages (Table 1). Study reservoirs were chosen based on the percentage of anglers pursuing crappies in TWRA creel surveys from 1994 to 1998. At least 10% of total angling effort was targeted at crappies on all study reservoirs except Dale Hollow and Norris reservoirs. Reservoir data were obtained from reports provided by the agency managing each reservoir and TWRA.

Methods

Crappie sampling.—Between August 1997 and December 1999, crappies were collected once or twice from each reservoir using boat electrofishing gear (pulsed DC) or trap nets (Table 1). Trap-net samples were obtained during TWRA's annual fall sampling program and followed TWRA Reservoir Sampling Protocols (TWRA 1998). Electrofishing samples were collected in fall or spring from up to 10 sites encompassing the length of the reservoir. Electrofishing samples were specifically designed to obtain large numbers of fish ($N > 100$); therefore, samples were not standardized by transect length or time. Only the Tennessee portions of Barkley, Dale Hollow, and Kentucky reservoirs were sampled.

Total length (mm) and weight (g) were recorded for each crappie collected. Sagittal otoliths were removed from up to 10 black and 10 white crappies in each 25-mm size-group for age analysis. Aging procedures were similar to those reported in Heidinger and Clodfelter (1987). Ages were assigned to fish that were not aged using age–length keys (Ricker 1975) and FISHCALC89 software (Missouri Department of Conservation 1989). Both crappie species were combined in estimating growth and mortality for size-limit modeling because crappies were not managed on a species-specific level in Tennessee.

Model parameters.—Growth was analyzed by calculating mean total lengths-at-age and subsequently estimating the parameters of the von Bertalanffy (1938) model. In reservoirs where multiple gear types were used at the same time of year, data from each gear were combined in estimating mean lengths at age. Age data from fall samples were corrected by adding 0.8 to each age before fitting the growth model. Intercepts (t_0), asymptotic lengths (L_∞), growth constants (K), and the time in years required by crappies in each reservoir to reach lengths of 229 mm and 254 mm ($t_{r\text{-}229}$, $t_{r\text{-}254}$) were derived from the von Bertalanffy model. Regressions of $\log_{10}$ transformed weight on length were also computed for each reservoir. The parameters t_0, L_∞, and K from the von Bertalanffy equation and the intercept (a) and slope (b) of the regression relationship were used as parameters in size-limit models.

Size-limit modeling.—A modeling approach

TABLE 2.—Parameters used in Beverton–Holt equilibrium yield models and times at recruitment for 12 Tennessee reservoir crappie fisheries. Asymptotic lengths (L_∞), intercepts (t_0), and growth constants (K) were derived from von Bertalanffy growth models. The intercept (a) and slope (b) from the regression of $\log_{10}$ transformed weight on length is reported for each reservoir. Times at recruitment are the estimated times in years required for the crappies in each reservoir to reach 229 mm ($t_{r\text{-}229}$) and 254 mm ($t_{r\text{-}254}$).

Reservoir	L_∞ (mm)	t_0	K	a	b	$t_{r\text{-}229}$	$t_{r\text{-}254}$
Barkley	342	0.1304	0.3637	−5.32	3.18	3.17	3.86
Cherokee	396	0.1432	0.2884	−6.14	3.56	3.14	3.70
Chickamauga	335	0.1397	0.5281	−5.47	3.25	2.32	2.83
Dale Hollow	325	−0.0022	0.5433	−5.37	3.24	2.24	2.80
Douglas	343	0	0.4644	−5.88	3.44	2.37	2.91
Kentucky	314	0.1425	0.4686	−5.50	3.27	2.93	3.67
Normandy	336	0.1245	0.5305	−5.13	3.13	2.28	2.78
Norris	334	0.0122	0.4025	−5.53	3.29	2.88	3.56
J. Percy Priest	301	0	0.7181	−5.08	3.09	1.99	2.59
Tellico	262	0	0.7356	−5.79	3.34	2.82	4.74
Watts Bar	325	−0.1826	0.4360	−5.31	3.17	2.61	3.31
Woods	367	0	0.4851	−5.25	3.15	2.02	2.43

similar to Allen and Miranda (1995) and Maceina et al. (1998) was used to predict the effects of three size restrictions (178, 229, and 254 mm) on crappie harvest. Based on observations made by Colvin (1991b) and Miranda and Frese (1991), a 178-mm size restriction was used to simulate no size limit, under the assumption that crappies shorter than 178 mm would not be harvested by anglers. An adaptation of the Jones' modification to the Beverton–Holt equilibrium yield model (Ricker 1975) was used to predict size-limit effects in the simulated crappie population in terms of yield (kg), number harvested, and number reaching 300 mm. Modeling was conducted using Fishery Analyses and Simulation Tools (FAST) software developed by Slipke and Maceina (2001). Each model simulation was run with 100 recruits entering the population at time zero (t_0). Models were run assuming a type II fishery (Ricker 1975), where natural and fishing mortalities were additive and occurred simultaneously. All equations utilized in the model were described in Maceina et al. (1998).

Model simulations were run over a 30–50% range of conditional natural mortality (CM), based on estimates of 49% (Allen and Miranda 1995) and 28% (Maceina et al. (1998). Current crappie exploitation estimates were not available for all study reservoirs; therefore, we compiled estimates of crappie exploitation rates for systems larger than 400 ha across the United States to obtain a suitable range of conditional fishing mortalities (CF) for modeling. Based on the reported range of exploitation estimates (Sammons et al. 2000), model simulations were run over a 30–60% range of CF, which approximately encompassed a 20–50% range of exploitation. Because current crappie exploitation rates were lacking for Tennessee reservoirs, harvest and size-structure statistics were averaged over the range of CF to describe size-limit effects.

Results

Input parameters used in the models are reported in Table 2. On average, crappies in Tennessee reservoirs reached 229 mm in 2.56 years and 254 mm in 3.27 years (Table 2). In some populations, von Bertalanffy growth models resulted in estimates of t_0 that deviated substanially from the expected value of zero. Consequently, in four reservoirs (Douglas, J. Percy Priest, Tellico, and Woods), t_0 was fixed at zero in deriving growth model parameters. Additionally, relatively fast-growing age-1 crappies collected by electrofishing were not used in modeling growth in J. Percy Priest and Tellico reservoirs. In general, the responses of Tennessee reservoir crappie fisheries to size limits fell into three categories. To simplify the presentation of results, predicted size-limit effects are presented for one reservoir representative of each of the three response categories.

In one group of reservoirs, (Cherokee, Chickamauga, Douglas, Normandy, and Woods), as represented by Douglas Reservoir (Figure 1), size limits (229 mm and 254 mm) slightly increased average yield over no limit at CM = 30%; little variation in yield existed among size-limit scenarios at CM = 40%. Increases in average yield were generally less than 20%. At both levels of CM, average number of crappies harvested decreased by as much as 64% under a 254-mm limit, and the number of crappies reaching 300 mm increased 80% or more. The number of crappies

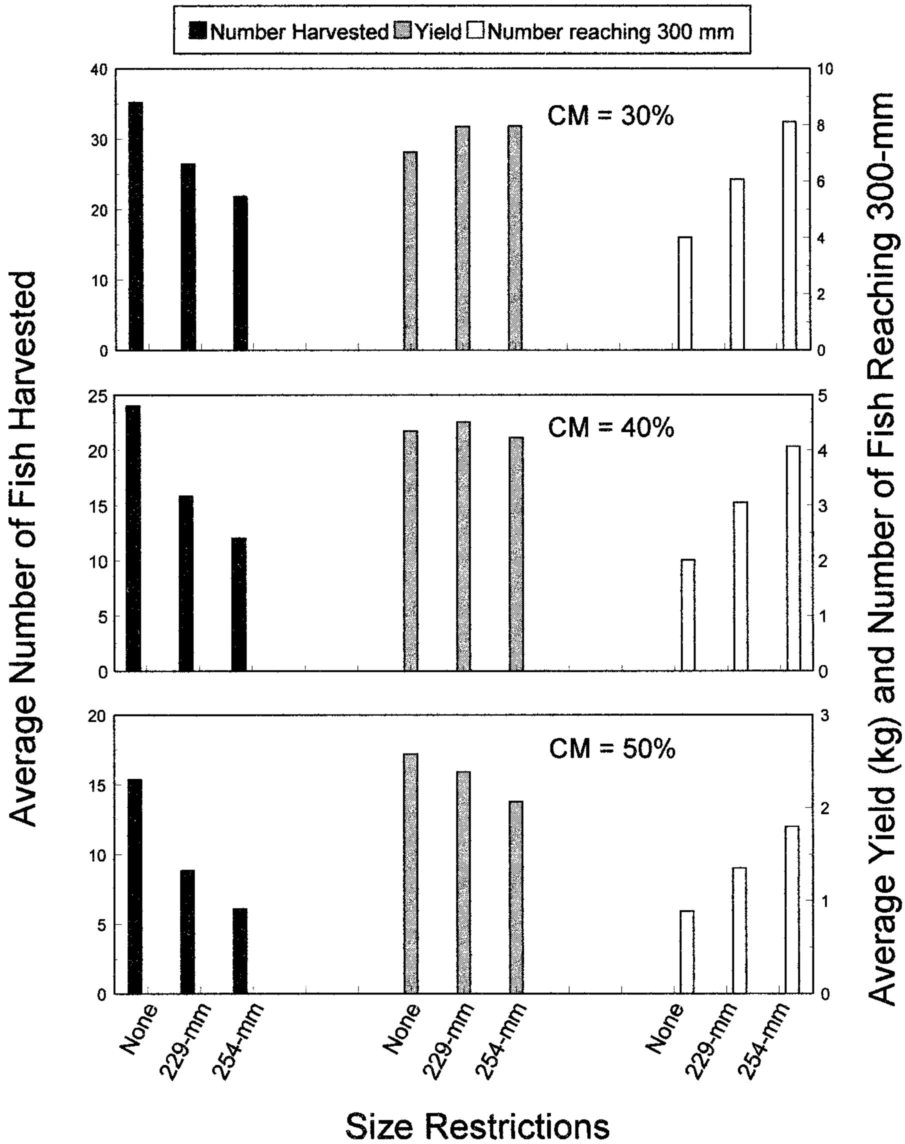

FIGURE 1.—Simulated effects on crappies in Douglas Reservoir, Tennessee, including the number harvested, yield, and number reaching 300 mm, under three different size restrictions and at three levels of conditional natural mortality (CM). Data were averaged over a 30–60% range of conditional fishing mortality.

reaching 300 mm was improved by size limits at higher rates of CM (50%); however, yield and the number of crappies harvested were negatively affected by size limits. Yield and the number of crappies reaching 300 mm would be improved in these fisheries under a 254-mm limit if CM was close to 30%; improvements could be realized at rates of CM as high as 40%. Increases in the number of crappies reaching 300 mm would be outweighed by declines in yield and number harvested at higher levels of CM. In all scenarios, a 229-mm limit, compared with no size limit, provided similar or higher yields than the current 254-mm limit, produced less severe declines in the average number of crappies harvested, and increased the number of crappies reaching 300 mm.

Size limits were less effective in increasing

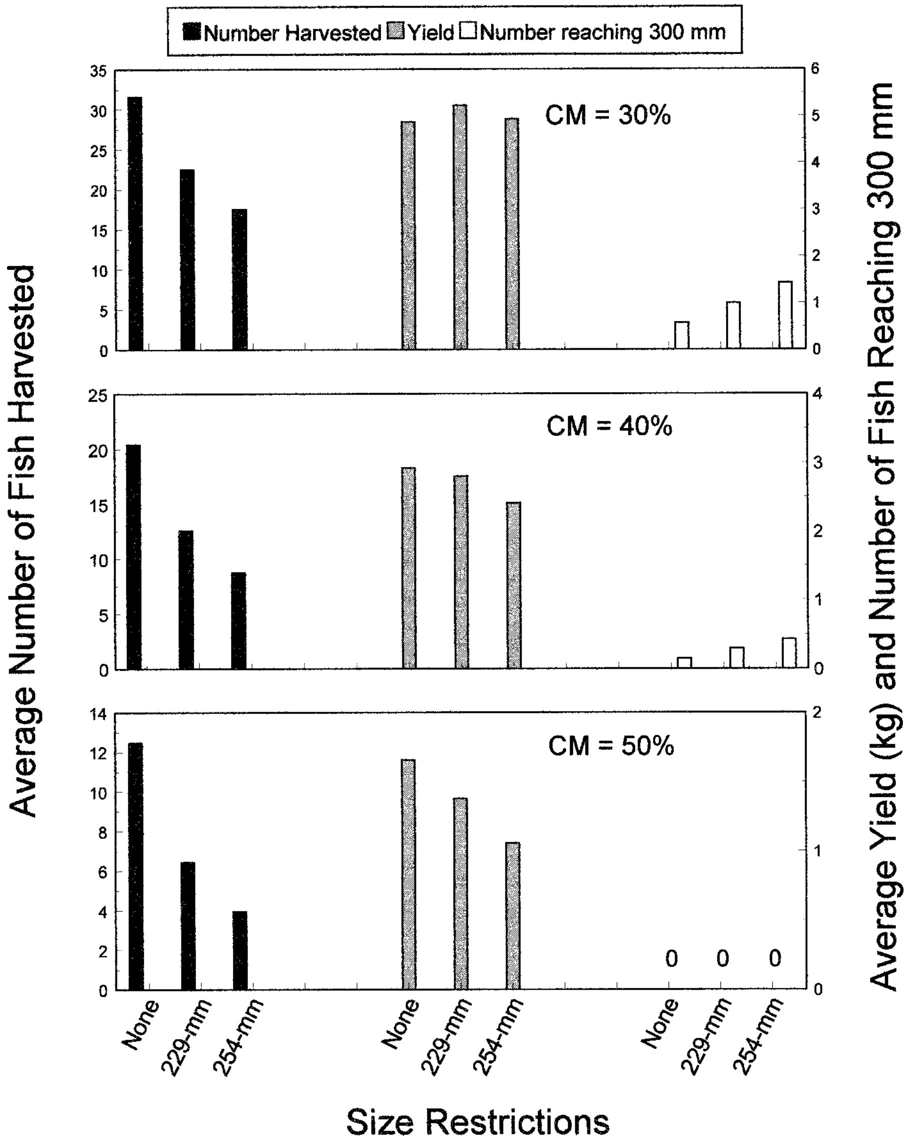

FIGURE 2.—Simulated effects on crappies in Kentucky Reservoir, Tennessee. See Figure 1 for additional details.

yield in Barkley, Dale Hollow, J. Percy Priest, Kentucky, Norris, and Watts Bar reservoirs, as represented by Kentucky Reservoir (Figure 2). These fisheries showed little differences in average yield among size limits when CM was 30%. At CM of 40%, yields with no size limit and the 229-mm limit were similar, and slightly higher than yields under the 254-mm limit. Yields were highest under no size limit when CM was 50%. A 254-mm limit increased the average number of crappies reaching 300 mm (>100% increase) in all model scenarios; however, severe declines (decreases >50%) in the average number of crappies harvested occurred when CM was 40% or more. In terms of number harvested and yield, a 229-mm limit would be more beneficial to these fisheries than the current 254-mm limit; however, increases in the number of crappies reaching 300 mm were greatest under the larger restriction.

The remaining response category, represented by only Tellico Reservoir (Figure 3), showed no size-limit-related benefits in yield. In all model

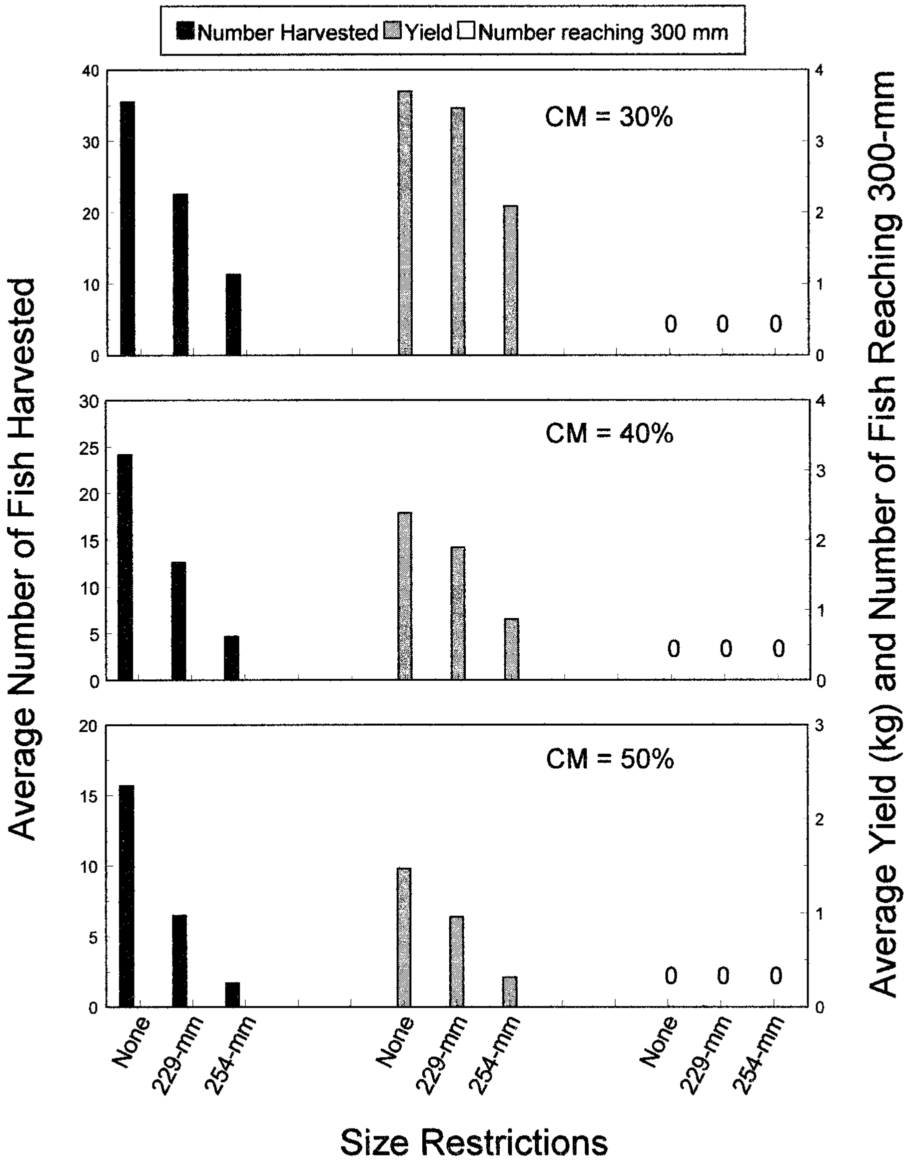

FIGURE 3.—Simulated effects on crappies in Tellico Reservoir, Tennessee. See Figure 1 for additional details.

scenarios no crappies reached 300 mm in the simulated population. Additionally, the average number of crappies harvested was reduced by size limits in all simulations.

Discussion

Many evaluations of crappie size limits have yielded results similar to our findings. In systems where crappie growth is adequate and CM is relatively low, size limits have the potential to increase yield and improve size structure (Colvin 1991a; Webb and Ott 1991; Allen and Miranda 1995; Maceina et al. 1998; Boxrucker 2001). Conversely, high rates of CM or slow growth frequently negate expected size limit benefits (Larson et al. 1991; Reed and Davies 1991; Allen and Miranda 1995; Mitzner 1995; Hale et al. 1999). In addition, reducing crappie harvest via size limits could further reduce growth in previously slow-growing populations (Bister et al. 2002). It is important to note that the Beverton–Holt model we used does not account for density-dependent reductions in growth that could result from size limit implementation; therefore, to validate model results the response of a fishery to a size limit should be reevaluated after the limit has been in place. Long-term analyses are often necessary to determine size-limit effects on population characteristics (Allen and Pine 2000).

The main factors affecting size limit success in Tennessee crappie population models were growth and CM; most populations that recruited to 254 mm before age 3 appeared to benefit from both size limits at low to intermediate levels of CM. Under low and intermediate levels of CM, populations (except Cherokee Reservoir) that recruited to the 254-mm limit at ages 3 or 4 appeared to be better served by the 229-mm limit; these populations typically recruited to the 229-mm limit before age 3. Slow growth of crappies in Tellico Reservoir precluded size-limit success; this fishery would be best managed by no size limit.

Regardless of growth rate, size limits were not predicted to benefit crappie fisheries when CM was 50% or greater. Similar trends were reported by Allen and Miranda (1995) and Maceina et al. (1998). Despite the influence of CM on size-limit responses, growth alone provided a powerful tool in predicting size-limit success. Based on our models, crappies must reach 254 mm by or before age 3 for a 229-mm or 254-mm length limit to provide any benefit to yield, and in most cases these predicted benefits were slight (<20%). Although not specifically analyzed in this paper, exploitation rates did affect size-limit success in a predictable manner. Size-limit benefits to yield and the number of crappies reaching 300 mm, when present, were more apparent as exploitation increased. In general, size-limit improvments were apparent only when crappie exploitation rates in the models exceeded 40%.

As in other evaluations (Webb and Ott 1991; Hale et al. 1999; Boxrucker 2001), size limits were predicted to improve crappie size structure in Tennessee reservoir populations; however, severe reductions in the number of crappies harvested normally outweighed size structure improvements at intermediate to high levels of CM (40–50%). Model simulations indicated that a 229-mm limit would probably provide benefits in yield similar to a 254-mm limit and less severe reductions in the number of crappies harvested; however, a 254-mm limit provided greater increases in the number of fish reaching 300 mm.

The use of a statewide length limit to regulate crappie harvest assumes that crappie population characteristics are similar among regulated waters and that the responses of these fisheries to such a regulation would be homogenous among systems. Studies have demonstrated variability in crappie population dynamics across waters in the same region (Guy and Willis 1995; Allen et al. 1998a), suggesting that ecosystem-specific management may prove more beneficial (Guy and Willis 1995). Based on the three categories of predicted size-limit responses observed among Tennessee reservoir crappie populations, managing crappie fisheries within a state or region on a categorical basis may provide a more effective management strategy than the use of a single, area-wide regulation.

Many factors could affect the results of the modeling we used in this evaluation. The assumption of consistent crappie recruitment in large reservoirs may be invalid (Colvin 1991b; Miranda and Allen 2000); however, long-term data concerning crappie recruitment patterns are lacking for many systems in Tennesse and other states. In addition, some of the reservoirs included in our evaluation were stocked with crappies (Isermann et al. 2002, this issue). The effect of variable natural recruitment or stocking success on the response of fish populations to size restrictions is not well understood. Allen and Pine (2000) demonstrated that variable recruitment could make detection of size-limit effects problematic. It is also likely that rates of crappie growth and mortality vary over time within a given water because of intraspecific and interspecific interactions and environmental conditions, but recrutiment fluctuations may override the effects of variable growth and mortality in determining harvest characteristics (Allen and Miranda 1998). Lastly, the relationship between fishing and natural mortality rates of crappies may not be additive, as assumed in the model (Allen et al. 1998b). Size-limit-related reductions in fishing mortality that result in compensatory increases in natural mortality could reduce size-limit effectiveness (Allen et al. 1998b; Boxrucker 2002, this issue). Ideally, estimates of recruitment variability, growth, and mortality from long-term monitoring should be used when incorporating the use of predictive models to evaluate size-limit effects. Unfortunately, these data are frequently not available because of budgetary and logistic constraints. The predicitive modeling approach described here provides managers dealing with limited data resources at least some insight into the potential effects that proposed regulations could have on their fishery.

Management Implications

Petering et al. (1995) and Allen and Miranda (1996) demonstrated that some anglers in Ohio and

Mississippi were willing to accept reduced crappie catch rates if the average size of harvested crappies improved. Models indicated that a 254-mm limit would be a useful management tool in some Tennessee reservoirs if anglers were interested in harvesting fewer, but larger crappies. However, we contend that the majority of crappie fisheries remain harvest-oriented; therefore, anglers would probably view severe declines in the number of crappies harvested as unsatisfactory (Allen and Miranda 1996; Boxrucker 2002). In most of the 12 study reservoirs, a 229-mm limit provided a more reasonable tradeoff between reduced harvest and increases in the number of crappies reaching 300 mm, which would probably satisfy the motives of a broader range of anglers. Size limits would probably be detrimental to populations like Tellico Reservoir, where relatively few fish reached 229 or 254 mm. Initial angler approval of Tennessee's 254-mm statewide length limit was high (74%, Jakus et al. 1999); however, as mentioned previously, detecting population shifts resulting from size limit implementation may require long-term analysis (Allen and Pine 2000). Angler approval of the 254-mm limit should be reevaluated in the future. Finally, it is difficult to ascertain what level of change in harvest statistics will be recognized by anglers.

Acknowledgments

Primary funding for this project was provided by TWRA. Additional funding was provided by the U. S. Geological Survey and the Center for the Management, Utilization and Protection of Water Resources at Tennessee Technological University. Thanks are extended to the students and staff at the Tennessee Cooperative Fishery Research Unit for their assistance during this evaluation. The cooperation of numerous TWRA reservoir management personnel was greatly appreciated, especially J. Riddle, T. Broadbent, J. Negus, M. Thurman, and M. Jolley. Thanks are extended to J. Boxrucker, S. Hale, B. Kinman, A. Mauldin, and T. Mosher for providing crappie exploitation estimates for the waters they manage. The manuscript was improved by comments from J. Boxrucker, P. Michaletz, S. Miranda, D. Willis, and one anonymous reviewer.

References

Allen, M. S., M. V. Hoyer, and D. E. Canfield, Jr. 1998a. Factors related to black crappie occurrence, density, and growth in Florida lakes. North American Journal of Fisheries Management 18:864–871.

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

Allen, M. S., and L. E. Miranda. 1996. A qualitative evaluation of specialization among crappie anglers. Pages 141–151 *in* L. E. Miranda and D. R. DeVries, editors. Multidimensional approaches to reservoir fisheries management. American Fisheries Society, Symposium 16, Bethesda, Maryland.

Allen, M. S., and L. E. Miranda. 1998. An age-structured model for erratic crappie fisheries. Ecological Modelling 107:289–303.

Allen, M. S., L. E. Miranda, and R. E. Brock. 1998b. Implications of compensatory and additive mortality to the management of selected sportfish populations. Lakes and Reservoirs: Research and Management 3:67–79.

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

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

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

Boxrucker, J. 2001. Changes in crappie population structure following restrictive regulations. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 53(1999): 80–90.

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.

Colvin, M. A. 1991a. 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.

Colvin, M. A. 1991b. Population characteristics and angler harvest of white crappies in four large Missouri reservoirs. North American Journal of Fisheries Management 11:572–584.

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

Hale, R. S., M. E. Lundquist, R. L. Miller, and R. W. Petering. 1999. Evaluation of a 254-mm length limit on crappies in Delaware Reservoir, Ohio. North

American Journal of Fisheries Management 19: 804–814.

Heidinger, R. C., and K. Clodfelter. 1987. Validity of the otolith for determining growth of walleye, striped bass, and smallmouth bass in power plant cooling ponds. Pages 241–251 *in* R. C. Summerfelt and G. E. Hall, editors. Age and growth of fish. Iowa State University Press, Ames.

Isermann, D. A., P. W. Bettoli, and S. M. Sammons. 2002. Initial post-stocking mortality, oxytetracycline marking, and year-class contribution of black-nosed crappies stocked into Tennessee reservoirs. North American Journal of Fisheries Management 22:1399–1408.

Jakus, P., D. Dadakas, B. Stephens, and J. M. Fly. 1999. Fishing and boating by Tennessee residents in 1997 and 1998. University of Tennessee, Department of Agricultural Economics and Rural Sociology, Human Dimensions Research Lab, Knoxville.

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.

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

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

Miranda, L. E., and W. Frese. 1991. Can fishery scientists predict angler preferences? Pages 375–379 *in* D. Guthrie, J. M. Hoenig, M. Holliday, C. M. Jones, M. J. Mills, S. A. Moberly, K. H. Pollock, and D. R. Talhelm, editors. Creel and angler surveys in fisheries management. American Fisheries Society, Symposium 12, Bethesda, Maryland.

Missouri Department of Conservation. 1989. FISHCALC89, version 1.0. Missouri Department of Conservation, Jefferson City.

Mitzner, L. R. 1995. Effect of environmental factors and harvest regulations upon the crappie (*Pomoxis*) sportfishery at Rathbun Lake. Iowa Department of Natural Resources, Technical Bulletin 5, Des Moines.

Petering, R. W., G. L. Isbell, and R. L. Miller. 1995. A survey method for determining angler preference for catches of various fish length and number combinations. North American Journal of Fisheries Management 15:732–735.

Quinn, S. P. 1996. Trends in regulatory and voluntary catch-and-release fishing. Pages 152–162 *in* L. E. Miranda and D. R. DeVries, editors. Multidimensional approaches to reservoir fisheries management. American Fisheries Society, Symposium 16, Bethesda, Maryland.

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.

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

Sammons, S. M., P. W. Bettoli, and D. A. Isermann. 2000. Crappie population dynamics and stocking success in Tennessee reservoirs. Tennessee Wildlife Resources Agency, Fisheries Report 00-13, Nashville.

Slipke, J. W., and M. J. Maceina. 2001. Fisheries analysis and simulation tools (FAST), version 1.0. Auburn University, Auburn, Alabama.

TWRA (Tennessee Wildlife Resources Agency). 1998. Reservoir fisheries assessment guidelines. TWRA, Nashville.

von Bertalanffy, L. 1938. A quantitative theory of organic growth. Human Biology 10:181–213.

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.