

Exploitation and Length Limit Evaluation of Largemouth Bass in Three Georgia Small Impoundments

Timothy F. Bonvechio, Georgia Department of Natural Resources, Wildlife Resources Division, P.O. Box 2089, Waycross, GA 31502-2089

Bryant R. Bowen, Georgia Department of Natural Resources, Wildlife Resources Division, P.O. Box 2089, Waycross, GA 31502-2089

Jeremy M. Wixson, Georgia Department of Natural Resources, Wildlife Resources Division 1255 Perry Parkway, Perry, GA 31069

Micheal S. Allen, Program in Fisheries and Aquatic Science, School of Forest Resources and Conservation, University of Florida, 7922 NW 71st Street, Gainesville, FL 32653

Abstract: Recent studies on largemouth bass (*Micropterus salmoides*) fisheries indicate fishing mortality has declined significantly due to voluntary catch-and-release practices by anglers. We evaluated the relative abundance, growth, mortality, and exploitation of largemouth bass in three Georgia small impoundments. To assess exploitation, 100 largemouth bass were tagged during spring 2010 in Lake Lindsay Grace and Hugh M. Gillis Public Fishing Area and during spring 2011 in Dodge County Public Fishing Area. Monetary rewards for tag returns were either US\$5 or \$105 per fish, and these values were printed on the tags. Tag returns for the high-reward tags ranged from 30% to 47% across impoundments, whereas returns of the low-reward tags ranged from 13% to 26%. Annual exploitation (u) based on the high-reward tags ranged from 0.13–0.30 and total annual mortality (A) estimated from catch-curve analysis ranged from 0.38 to 0.55 across impoundments. Assuming mortalities were additive, annual natural mortality (v) estimates ranged from 0.08–0.42. Simulation modeling indicated that a protective slot limit could increase the number of trophy bass (i.e., 600 mm total length [TL]) available in all three impoundments, due to the estimated level of angler harvest. Despite high rates of voluntary catch-and-release documented across much of North America's black bass fisheries over recent decades, greater harvest rates were demonstrated in 2 of 3 Georgia small impoundments examined. To aid in less confusion for anglers and for ease of convenience for law enforcement, the same slot limit of 381–559 mm TL was recommended for all three impoundments due to the increase in trophy-size bass predicted with this protective slot limit.

Key words: harvest, trophy, *Micropterus salmoides*, mortality

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Largemouth bass (*Micropterus salmoides*) populations are some of the most heavily managed and comprise the most popular freshwater fisheries in North America (Allen et al. 2008, Carlson and Isermann 2010). In the past decade, agencies have used restrictive harvest regulations in some fisheries to increase the number of trophy-sized largemouth bass present (Wilson and Dincenzo 2002, Myers and Allen 2005, Carlson and Isermann 2010), though successful outcomes have been difficult to discern (Dotson et al. 2013). Regulations are usually length-based and include minimum, maximum, protective slot limits, and catch-and-release only (Anderson 1976, Wilde 1997, Paukert et al. 2007, Carlson and Isermann 2010). Typically, harvest regulations are enacted to influence certain predator-prey relationships or to increase growth rates, size structure, angler catch rates, or the numbers of large fish present (Redmond 1986, Wilde 1997, Noble and Jones 1999).

Wilde (1997) reviewed the effectiveness of largemouth bass

length-based harvest restrictions across 88 U.S. waterbodies and found that while relatively low (305–356 mm) minimum-length limits (MLL) improved angling catch rates, they often did not increase size structure. Conversely, protective-slot limits can improve the number of quality- and preferred-size largemouth bass. However, Parks and Seidensticker (2000) reported that a protective slot limit (356–457 mm) was unsuccessful at increasing the size structure of largemouth bass in Texas reservoirs. Clearly, responses of largemouth bass populations to length-limit regulations have varied across studies and are likely system specific.

Many high-quality black bass fisheries across North America have been affected by the voluntary release of fish by anglers (Quinn 1996, Noble 2002, Myers et al. 2008, Isermann et al. 2012). Increased voluntary release rates have reduced fishing mortality (F) of many largemouth bass fisheries with a likely overall effect of lowering total annual mortality (A) and increasing fish abundance

(Allen et al. 2008). This temporal shift in angler attitudes towards higher release rates is suspected to have increased largemouth bass abundances to the point of inducing density-dependent reductions in growth in some systems (Aday and Graeb 2012, Wright and Kraft 2012). Excessive catch-and-release by anglers has caused protective-slot limits to be ineffective (Noble and Jones 1999, Bonds et al. 2008). Thus, declines in fishing mortality due to voluntary release could render all harvest regulations ineffective (Allen et al. 2008). However, the level at which F is great enough to substantially alter population age and size structure remains unknown for most black bass fisheries.

Simulation modeling by Dotson et al. (2013) predicted the probability of an angler catching a trophy-sized largemouth bass (e. g., 610 mm total length [TL]) could be improved with more restrictive length limits, such as a large minimum length limit, low maximum length limit, or large protective slot limits. These large restrictive limits protect multiple ages, which cumulatively result in more fish reaching trophy size. A restrictive maximum length limit of 305-mm maximum TL was four times more likely to improve the size structure and electrofishing of largemouth bass CPUE (≥ 381 mm TL) in Minnesota (Carlson and Isermann 2010). In some areas of North America, anglers may consider harvest to be an important motivation for fishing and thus exploitation rates could still be substantially higher (Wilson and Dicenzo 2002, Beardmore et al. 2011). Stringent regulations might not be a favorable management recommendation if harvest is desired by anglers.

Our objectives in this study were to measure relative abundance, growth, and mortality for largemouth bass in three Georgia small impoundments for use in a simulation model (Allen et al. 2009) to explore several length limit options for improving these fisheries. Two of the three impoundments examined, Hugh M. Gillis and Dodge County, are part of the Georgia Department of Natural Resources (GADNR) Public Fishing Area (PFA) system. Currently 10 PFAs are located across the state of Georgia. These PFA impoundments are intensively managed by GADNR biologists to achieve high productivity. In response to highly specialized anglers communicating a greater emphasis on potential opportunities for trophy-size fish (Wilson and Dicenzo 2002, Beardmore et al. 2011), GADNR is evaluating the possibility for more trophy largemouth bass opportunities on its PFA systems. As a result, increasing the number trophy largemouth bass catches was an important management goal for all three reservoirs examined during this study.

Methods

The study was conducted at Lake Lindsay Grace and the Hugh M. Gillis and Dodge County PFAs which are three small impound-

Table 1. Characteristics of reservoirs sampled including county and city, surface area, secchi disc readings, current minimum-length limit (MLL), bag limit, weight of lake-record largemouth bass (Record), impoundment date, electrofishing months, and use of fertilizer/lime.

	Lake Lindsay Grace	Hugh M. Gillis Public Fishing Area	Dodge County Public Fishing Area
County/City	Wayne/Jesup	Laurens/Dublin	Dodge/Eastman
Surface area (ha)	95	44	42
Secchi depth (m)	2.5	<1.0	<1.0
MLL (mm TL)	305	356	356
Bag limit	10	5	5 (1 fish over 21 inches per day)
Record (kg)	6.93	5.28	7.06
Impoundment	Mid-1960's	2001	1993
Electrofishing sample month	Feb/March 2010	March 2010	March 2011
Fertilizer/lime	no	yes	yes

ments in central and southeastern Georgia. Hugh M. Gillis and Dodge County lie in relatively close proximity to each other in central Georgia and are similar in size. Lake Lindsay Grace is owned by Wayne County and can be characterized as an older, lower productivity, tannic stained system that only receives nutrient loading from runoff of local cattle farms (Table 1). These impoundments were chosen due to a history of trophy-sized largemouth bass caught, anglers requesting a size-limit change due to perception of angler overharvest, and/or the managing biologist of the impoundment having considered the largemouth bass population to be overcrowded. Furthermore, Dodge County PFA has also been proactively managed since 2004 with a strict bag limit of one fish over 21 inches (527 mm TL), in an effort to protect the trophy fishery that had developed in the first 10 years of impoundment.

Largemouth bass were collected from each lake using a boom-mounted electrofishing boat with a 5000-W generator; electrical output was approximately 4 to 6 A of DC. Electrofishing pedal time was recorded on each impoundment for relative abundance purposes (CPUE) but was not standardized by a set time per transect. A passive-tagging study was conducted (Allen and Hightower 2012) where 100 largemouth bass above each minimum-length limit (305 or 356 mm total length [TL]; Table 1) from each impoundment were tagged with 81-mm Hall-print PDB dart tags. Tagging was conducted during spring 2010 in Lake Lindsay Grace and Hugh M. Gillis and in spring 2011 on Dodge County PFA. Subsequently, the exploitation study ran 1 yr from the time the last tagged fish entered the water in the spring for each impoundment.

A combination of high-reward and low-reward tags was used to encourage participation and negate problems with reporting rate (Pollock et al. 2001, Pollock et al. 2002). Monetary rewards printed on the tags were either US\$5 or \$100. Thirty fish in each impound-

ment were double tagged with a \$5 and \$100 tag to evaluate tag retention. The remaining 70 fish were tagged with a single \$5 tag. The high-reward value was based on Nichols et al. (1991) who estimated that a minimum of \$100 reward was required to generate a 100% reporting rate. Meyer et al. (2012) documented a 98.9% reporting rate for \$100 tags for several species of fish in a multiple lakes study in Idaho. Each tag for our study was numbered, brightly colored, and had the word "REWARD" and the value (\$5 or \$100) printed on it, along with the address of the local GADNR office. The public was made aware of the ongoing study with signage and tag-return forms located at the boat ramps of each impoundment. Anglers were asked to indicate whether the fish was harvested or released on the form and were contacted via telephone if harvest or release was not indicated.

Passive tagging estimates of annual exploitation rate (u) for all three impoundments were obtained following Allen and Hightower (2012):

$$u = (C/T)$$

where C is the corrected number of tagged fish harvested and T is the corrected number of tagged fish in the population. Values of C were corrected for non-reporting on the low reward tags and values of T were corrected for short-term tag loss and tagging-associated mortality. Reporting rate of high-reward tags was assumed to be 100%, and the number of low-reward tags returned was adjusted based on the assumption that capture rate of fish by anglers was not influenced by reward value following (Pollock et al. 2002):

$$\lambda = \frac{(C_s/T_s)}{(C_H/T_H)}$$

where λ is the estimated reporting rate for low reward tags, C_s is the number of low reward tagged fish reported by anglers, T_s is the number of fish tagged with low reward tags, C_H is the number of high reward tagged fish reported by anglers, and T_H is the number of fish tagged with high reward tags. We calculated upper and lower binomial confidence intervals around all our exploitation estimates using Wilks' likelihood ratio statistic (Hilborn and Mangel 1997).

Short- and long-term tag retention and post-tagging survival were evaluated using a series of 24-h cage trials (Guy et al. 1996), angler return data, and electrofishing recaptures of double-tagged fish (Allen and Hightower 2012). Multiple cage trials were conducted using 1.6- \times 1.6- \times 1-m cages with 12-cm mesh. Both single- and double-tagged fish were subjected to cage trials and fish were chosen for the trials with a random number generator. Five cage trials were conducted on Lake Lindsay Grace that varied from 25 to 49 hours in length (mean 44 hours). The number of largemouth bass in each trial varied between 4 and 9 and averaged 5. At the

end of each trial, fish were evaluated for tag loss and survival and then released. We assumed tag retention results would be similar across study areas.

Age and growth of largemouth bass were assessed in each impoundment. For age and growth, a target of five largemouth bass per cm group <305 mm total length TL were sacrificed and all largemouth bass \geq 305 mm TL were sacrificed unless 10 fish were obtained per cm group \geq 305 mm TL. Fish were placed on ice in the field and returned to the laboratory, where they were measured (TL, mm), weighed (g), sexed, and sagittal otoliths were removed for aging. Two fish (>635 mm TL) from Lake Lindsay Grace, two fish (605 mm TL) from Hugh M. Gillis, and two fish (>630 mm TL) from Dodge County were double tagged and released for inclusion in the exploitation study due to their rarity and value as trophy-sized largemouth bass (Gabelhouse 1984). Age was assessed using the methods of Hoyer et al. (1985) and Buckmeier and Howells (2003). Otoliths were read double blind by two independent readers, and when a discrepancy occurred between the readers, a third reader was used to confirm the age. The fish was omitted if no consensus could be reached (Bonvechio and Bonvechio 2006). To ensure high precision, the same three readers were used throughout the study following Bonvechio et al. (2005).

Similar to methods of Bonvechio and Allen (2005), an age-length key (Ricker 1975) was used to estimate the age frequency of subsampled fish. The age frequency of each species of fish below and above the specified length was combined to estimate the total number of fish at each age. Furthermore, we estimated age-frequency for each sample and performed a weighted catch-curve analyses (Ricker 1975). An analysis of covariance (ANCOVA) was conducted using PROC GLM (SAS 2008) to determine if the slopes of the catch-curves (i.e., instantaneous annual mortality, Z) differed across the impoundments ($P \leq 0.05$).

We modified a simple age-structured population model incorporating a Beverton and Holt stock recruitment curve with female growth rates in Microsoft Excel to assess the most suitable length-limit regulation for each impoundment (Allen et al. 2009, Rogers et al. 2010). Female growth rates were used because female largemouth bass typically exhibit more rapid growth and attain much larger sizes than males (Carlander 1977, Schramm and Smith 1988). The model was based on an initial 1000 recruits at age-1 and accounted for discard mortality (fish that die after being released) from catch-and-release fishing practices. Population-level impacts due to catch-and-release mortality can be significant (Kerns et al. 2012) and only recently have been included in population models (Allen and Hightower 2012). Our population model inputs required growth estimates from the von Bertalanffy equation, and estimates of annual mortality (Z), exploitation (u), and natu-

Table 2. Population parameters obtained in the study. Only high reward exploitation estimates were used in the age structured simulation model to determine best size limit outcomes.

Z = instantaneous rate of (total) mortality, A = annual mortality rate, F = instantaneous rate of fishing mortality, u = annual exploitation, v = natural mortality, M = instantaneous rate of natural mortality obtained, m used = conditional rate of fishing mortality used in model, DM used = discard mortality, von-Bertalanffy growth parameters included L_{∞} = asymptotic length, K = Brody growth coefficient, t_0 = time coefficient.

	Lake Lindsay Grace	Hugh M. Gillis PFA	Dodge County PFA
Z	0.49	0.55	0.80
A	0.38	0.42	0.55
F	0.38	0.35	0.19
u	0.30	0.27	0.13
v	0.08	0.15	0.42
M	0.10	0.20	0.61
m used	0.20	0.20	0.40
DM used	0.10	0.10	0.10
von-Bertalanffy			
L_{∞}	705	605	632
K	0.14	0.32	0.201
t_0	-0.673	0.019	-0.702

ral mortality (M) (Table 2). Female von Bertalanffy growth curve models (Ricker 1975) were calculated for each impoundment using FAST (Slipke and Maceina 2006). Growth curves were not extrapolated past the maximum age obtained in the samples for each impoundment. Based on Allen et al. (2008), we assumed instantaneous rate of natural mortality (M) was between 0.2 and 0.4 in the model. However, if M was calculated below 0.2, M was set at 0.2. Likewise, if M was calculated higher than 0.4, then M was set at 0.4. A constant discard mortality rate of 0.1 was used for each of the impoundments (Table 2). Eight size limits were modeled: 305-mm MLL, 356-mm MLL, 381-mm MLL, 406-mm MLL, 457-mm MLL, 381–559-mm protective-slot limit (slot), 406–559-mm slot, and 406–610-mm slot. Only the results of the current length limits for each waterbody and the limits with the most favorable outcomes were compared. As a result of the trophy-fish management goals of these impoundments, traditional model outputs such as yield-per-recruit or total catch were not very meaningful, but rather number of harvestable fish and number of trophy-sized fish in the population were the metrics of interest.

Results

A combined total of 56 electrofishing transects encompassing 51.04 hours was recorded across the small impoundments. Transect time varied from 900 to 11,801 seconds per transect. Electrofishing (CPUE) (fish h^{-1}) of largemouth bass varied considerably across impoundments from 16.1 ± 1.6 SE for Lake Lindsay Grace to 55.3 ± 7.0 SE for Hugh M. Gillis to 217.8 ± 40.5 SE for Dodge County. For all 3 populations combined, a total of 3446 largemouth bass were collected. For Lake Lindsay Grace, a total of 456

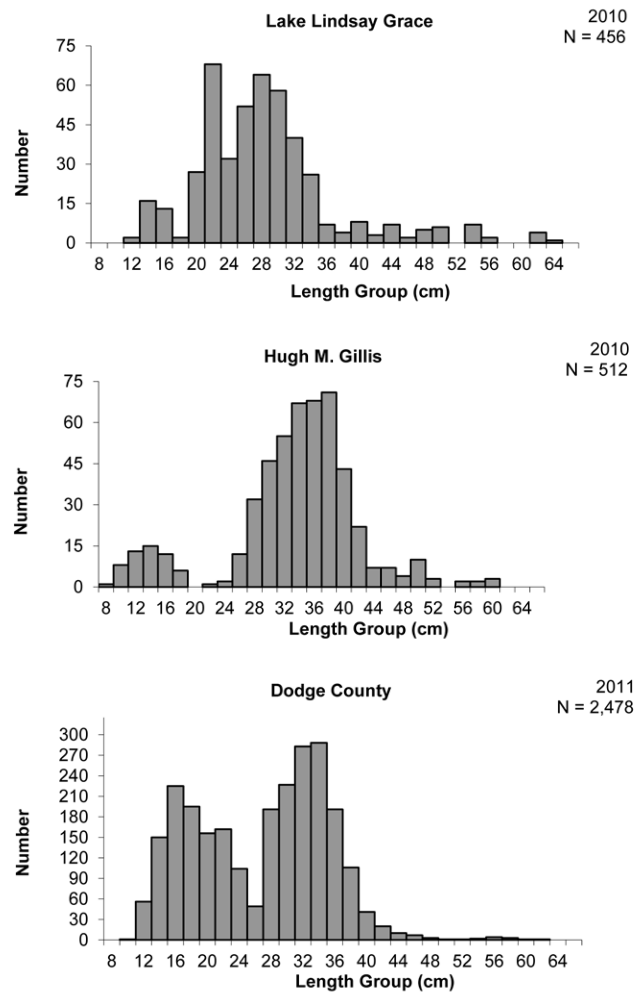


Figure 1. Length-frequency distributions (2-cm length groups) of largemouth bass collected at Lake Lindsay Grace (top panel), Hugh M. Gillis (middle panel), and Dodge County (bottom panel). Notice the varying scales on the Y-axes.

largemouth bass were collected and sizes ranged from 120 to 640 mm TL (Figure 1). For Hugh M. Gillis, a total of 512 largemouth bass were collected and sizes ranged from 91 to 605 mm TL (Figure 1). We collected 2478 largemouth bass ranging in size from 117 to 632 mm TL from Dodge County (Figure 1). For all populations combined, a total of 526 largemouth bass were aged of which 256 were males and 270 were females.

Total annual mortality (A) ranged from 0.38 on Lake Lindsay Grace ($n=456$) to 0.55 on Dodge County ($n=2502$), and no missing year classes were observed in any of the impoundments (Figure 2). Total annual mortality was similar among the three impoundments (ANCOVA, $F=1.21$; $P=0.321$). Predictions of mean total length at age of female largemouth bass from von-Bertalanffy growth equations revealed that growth was fastest at Hugh M. Gillis, followed by Dodge County, with the slowest growth observed at Lake Lindsay Grace (Tables 2 and 3). It took only 4.42 yrs for a

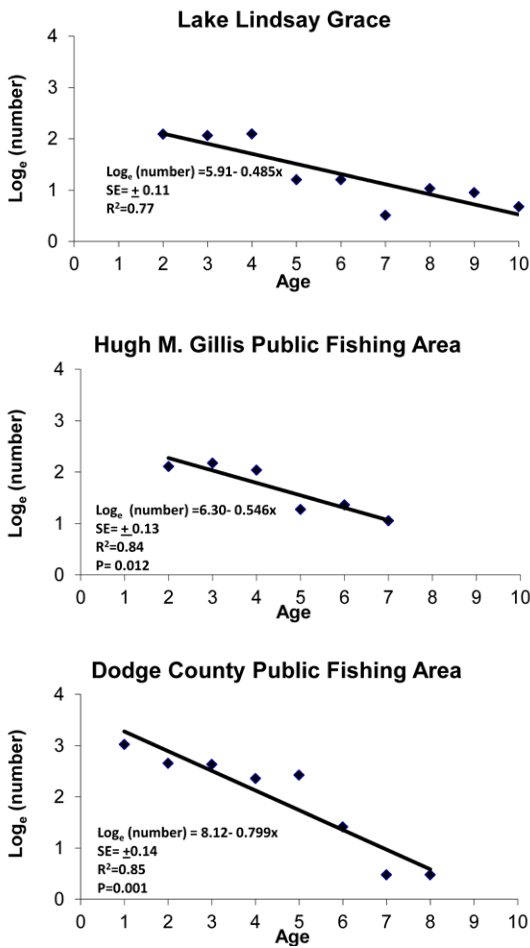


Figure 2. The three panels depict catch curves of the natural log (Ln) number of fish at each age plotted against the ages of largemouth bass collected at Lake Lindsay Grace (top) and Hugh M. Gillis Public Fishing Area (middle) in 2010, and Dodge County Public Fishing Area (bottom) in 2011. The linear regression equations are also shown. Ages were not included in the catch curve if sample size was low (<3 fish). Age 0 and age-1 fish were not included for Lake Lindsay Grace and Hugh M. Gillis because they might not have fully recruited to the gear. Similarly, age-0 fish were not included in the Dodge County catch-curve. The standard error (SE) for each slope coefficient is shown.

female largemouth bass to reach 457 mm TL on Hugh M. Gillis while it took 5.69 yrs on Dodge County and 6.79 yrs on Lindsay Grace.

Tagged largemouth bass experienced 0% mortality in all cage studies and exhibited 100% short-term tag retention. Also, there was no documented case of tag loss for the double-tagged, high-reward fish throughout the study for all three impoundments combined (Table 4). Of the 90 double-tagged fish, 20 were recaptured by electrofishing in the spring they were tagged and released back into the reservoirs. Furthermore, 67 double-tagged fish were reported caught by anglers, or recaptured with electrofishing, with both tags still present up to 1142 days after being released. As a result, we have no evidence to indicate that any significant tag loss

Table 3. Predicted mean total length (mm) for male and female largemouth bass in three Georgia small impoundments. Predictions are from von Bertalanffy growth equations for each population. *n* is the total number of fish aged.

Age	Lindsay Grace (<i>n</i> = 132)		Hugh M. Gillis (<i>n</i> = 150)		Dodge County (<i>n</i> = 244)	
	Males	Females	Males	Females	Males	Females
1	158	151	142	161	200	183
2	217	225	312	281	285	265
3	266	290	337	369	332	332
4	308	345	383	433	359	387
5	343		393	479	374	431
6	372	435	404	513	382	468
7	397	471	445	538		498
8	418	503				522
9	435	530	465	569		542
10		553		579		

Table 4. Number of largemouth bass tagged (*n*) with each tag reward type (Low-\$5; High-\$105) in each study impoundment as well as adjusted number tagged (T), number returned (R), reporting rate (λ), number kept, adjusted number kept and annual exploitation (*u*). Lower and upper binomial likelihood confidence intervals (CI) were calculated for high and low reward exploitation estimates.

Impoundment	Tag Type	<i>n</i>	T	R	λ	Number kept	Adjusted kept	<i>u</i>	Lower CI	Upper CI
Lindsay Grace	Low	70	70	14	0.43	9	21	30%	20%	42%
	High	30	30	14	1.0	9	9	30%	15%	48%
Hugh M. Gillis	Low	70	70	9	0.43	5	12	17%	9%	17%
	High	30	30	9	1.0	8	8	27%	13%	44%
Dodge County	Low	70	70	18	0.70	9	13	19%	10%	29%
	High	30	30	11	1.0	4	4	13%	4%	29%
Total		300	300	75	1.0	44	67	22%	17%	28%

occurred during the study, and assumed that tag-loss rates were negligible.

For the low-reward tags, lambda (λ) estimated the reporting rate was 43% for both Lake Lindsay Grace and Hugh M. Gillis and 70% for Dodge County. Returns were considered high for the high-reward tags, ranging from 30%–47% across the three impoundments. In contrast, unadjusted returns of the low-reward tags ranged from 13%–26%. Therefore, *u* was estimated using data from high-reward tags and was 0.13 at Dodge County PFA, 0.27 at Hugh M. Gillis PFA, and 0.30 at Lake Lindsay Grace (Table 2). Assuming fish mortalities were additive and using total annual mortality from catch curves, these estimates translate to natural mortality *v* estimates of 0.08 at Lake Lindsay Grace, 0.15 at Hugh M. Gillis

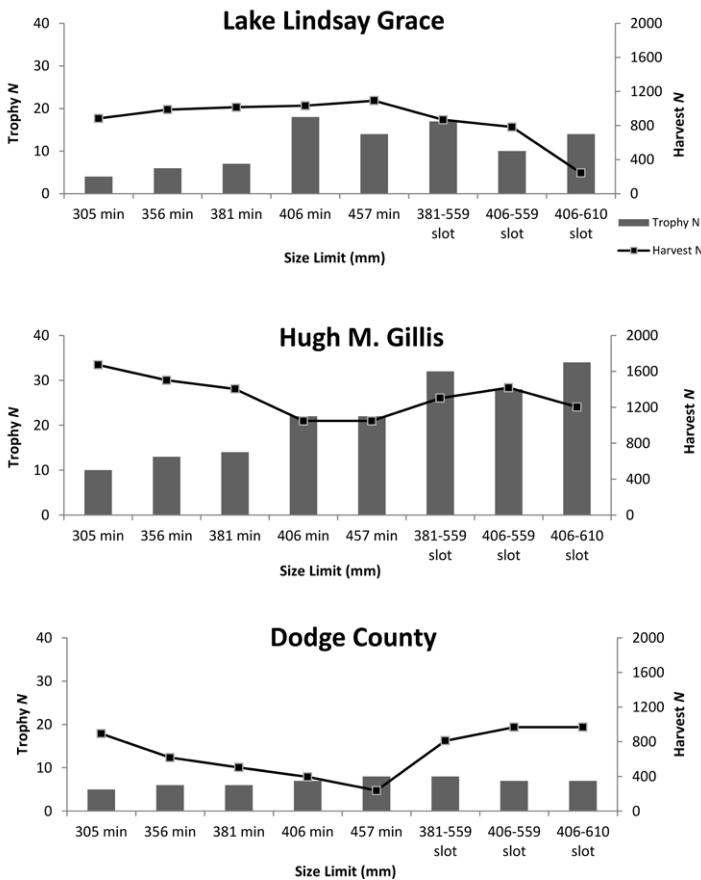


Figure 3. Double axis graph depicting the modeling results for eight different length limits on the largemouth bass populations in Lake Lindsay Grace (top), Hugh M. Gillis Public Fishing Area (middle) and Dodge County Public Fishing Area (bottom): 305-mm MLL (305 min), 356-mm MLL (356 min), 381-mm MLL (381 min), 406-mm MLL (406 min), 457-mm MLL (457 min), 381–559-mm protective-slot limit (381–559 slot), 406–559-mm slot (406–559 slot), and 406–610-mm slot (406–610 slot). The number of trophy-sized fish available to be caught is on the first y-axis (Trophy *N*) with the dark vertical bars and the number of harvestable fish is on the second y-axis (Harvest *N*) with thin horizontal line.

PFA, and 0.42 at Dodge County PFA. Confidence intervals around the mean exploitation estimates showed adequate precision with most estimates within 10% of the mean value (Table 3). Estimates of annual u on the low reward tags varied considerably for two of the small impoundments: 0.17 at Hugh M. Gillis, 0.19 at Dodge County, and 0.30 at Lake Lindsay Grace. Across all three reservoirs combined, our estimate of exploitation was 0.22. Only Lake Lindsay Grace provided an identical estimate of u (0.30) between the low and high reward tags.

The precise effects of length limits on largemouth bass were expected to vary among study sites. Modeling for Lake Lindsay Grace predicted that the current 305-mm MLL allowed for more harvestable largemouth bass compared to the entire slot limits modeled, but very few trophy-sized bass remained in the fishery under this

scenario (Figure 3). The 381–559 mm slot predicted a 425% increase in the number of trophy-sized largemouth bass available with only a 2% decline in the number of harvestable bass when compared to the current regulation (Figure 3). The 356-mm and 381-mm MLLs showed a 50% and 75% increase in trophy-sized fish compared to the 305-mm MLL. However, those increases were inconsequential compared to predicted increases in the numbers of trophy-sized largemouth bass in the population under the different slot limits (Figure 3). The model predicted that the 406-mm MLL would increase trophy-sized fish 450%, but was deemed to be unacceptable to anglers due to the lack of harvest opportunity of small individuals in the population. Furthermore, growth may become even slower due to the potential for overcrowding to occur under this scenario.

Modeling for Hugh M. Gillis PFA predicted that the current 356-mm MLL allowed for greater numbers of harvestable largemouth bass but very few trophy-sized bass, which was similar to the results from the models in Lake Lindsay Grace (Figure 3). All three slot limits predicted large increases of 215% to 261% for trophy-sized fish in Hugh M. Gillis PFA with only slight declines of 5% to 20% in the number of harvestable fish. Dodge County modeling results revealed any of the three slot limits modeled allowed for a 131% to 157% increase in harvestable bass when compared to the current 356-mm MLL (Figure 3). In addition, increases in the number of trophy-sized bass of 117% to 133% were revealed for any of the three slot limits in comparison to the current 356-mm MLL regulation.

Discussion

High voluntary catch-and-release rates in largemouth bass fisheries can limit the utility of harvest regulations to improve fisheries (Allen et al. 2008, Myers et al. 2008). Our data indicates that u rates of 0.27 and 0.30 for largemouth bass in two of the three Georgia small impoundments examined were considerably higher than an average u rate of 0.18 previously reported by Allen et al. (2008). The third impoundment, Dodge County, did not exhibit high u (0.13), but modeling outputs for any of the alternative protective slot limits were more favorable than the current (356) mm MLL despite the elevated levels of M dictated from the total mortality assessment. As a result of this study, all three small impoundments examined have the potential for length limit changes to improve numbers of trophy-sized largemouth bass and total catch as long as growth is average or better and M is not substantially higher than u (Allen et al. 2002).

Allen et al. (2008) reviewed estimates of u and total mortality (Z) of largemouth bass in a number of North American populations and found that mean fishing mortality declined from 35% over

1976–1989 to 18% over 1990–2003. Although there are published estimates of largemouth bass u that were much greater (0.48–0.56; Ager 1979, Edwards et al. 2004) than what we found in this study, u in two impoundments in our study approximated those reported by Allen et al. (2008) in the period from 1976 to 1989. In contrast, our estimate of largemouth bass u in Dodge County PFA was similar to the average that Allen et al. (2008) found from 1990–2003. Thus, two of our study impoundments do not appear to have experienced the nationwide decline of u reported by Allen et al. (2008). However, the Allen et al. (2008) study was conducted on larger lakes and reservoirs that may have more complex habitat and predator-prey relations (Willis and Neal 2012). Our study was conducted on small impoundments and these systems undoubtedly may be more easily manipulated than larger reservoirs (Willis and Neal 2012).

The reliability of model predictions from length-limit simulations strongly depend on the accuracy of u estimates. Many previous u studies on black bass fisheries have been hindered due to high variability associated with reporting rates (Miranda et al. 2002), high tag loss (Keefer and Wilson 1995), tag failure (J. Hakala, GADNR, unpublished data), or tagging mortality during the study. The high number of tag returns and electrofishing recaptures from the present study supported that angler participation was high and that tagging mortality was negligible and did not affect our u estimates. It is likely that the use of high-reward tags reduced variability with angler reporting rates and doubts that anglers participated in our study as recommended by Pollock et al. (2001). Undoubtedly, high rewards ensured high angler participation, but double tagging of fish also increased returns compared to only single-tagged fish (Muoneke 1992). Likewise, visible signs with mail-in flyers were posted at each of the boat ramps to encourage reporting rates of tagged fish caught. We believe retention of tags was high because the proper tag was chosen based on Renfro et al. (1997) who found 98% retention on largemouth bass using the identical tag type. To further reduce the chance of anchor tag loss, we used one experienced tagger during our study (Guy et al. 1996). Furthermore, based on our experience of no instance of tag loss among the recaptured double-tagged fish, the Hall-print dart tags have high retention in black basses (*Micropterus* spp.) when used by experienced taggers.

In Lake Lindsay Grace, our modeling predicted a 4-fold increase in the number of trophy-sized largemouth bass with the 381–559 mm slot with only a slight decline in harvestable bass to be harvested when compared to the current 305-mm MLL. Thus, this slot limit has the potential to produce more trophy-sized fish with little to no negative effect on harvest. Similarly, the best regulation for maintenance of a trophy largemouth bass fishery in Hugh M. Gillis PFA was the 406- to 610-mm slot. However, the

406- to 559-mm slot appeared to be the best compromise of increasing numbers of trophy-sized fish without a large decline in the number of harvestable fish. Ultimately, because relatively high harvest of largemouth bass by anglers was demonstrated on Lake Lindsay Grace and Hugh M. Gillis, any protective slot limit is likely to increase the number of trophy sized bass available over time in comparison to the current minimum size limit.

For Dodge County, increases in trophy largemouth bass were detected from our simulation model but the responses were not as strong as Lake Lindsay Grace or Hugh M. Gillis. This was not surprising, considering v was near the upper end reported ranges for largemouth bass (Carlander 1977), and u was considered moderate, given the range reported by Allen et al. (2008). We believe our simulations results on Dodge County would have been similar to the other two impoundments had v been modeled at 0.2 instead of 0.4 and u was higher. Instead, the natural mortality calculated for the Dodge County largemouth bass population was similar to those reported for Alabama and Georgia sunfish populations (Sammons et al. 2006, Sammons and Maceina 2009). Because only average angler harvest was demonstrated on Dodge County and largemouth bass abundance is considered to be high, bass removal via electrofishing of 10–20 fish ha⁻¹, has been recommended for this highly productive system in an effort to reduce abundance and possibly natural mortality. In addition, the protective slot limit of 381–559 mm TL should help direct harvest to more abundant, smaller fish and may help increase the intermediate growth rates. Finally, a more liberal bag limit of 10 fish per person has been implemented with the slot, of which only one fish can exceed 559 mm TL.

Our study may have resulted in different outcomes if conducted over more than one fishing season. Pollock et al. (2001) warned that high-reward tagging studies should be conducted in multiple years because angler behavior might skew results more so during the first year of a study compared to subsequent years. In particular, angler expectations of a large reward sometimes diminish over time, or anglers may perceive that returning tags may lead to unwanted regulation changes for that fishery (Taylor et al. 2006).

Many studies have addressed largemouth bass mortality following being caught and released (Schramm et al. 1987, Meals and Miranda 1994, Wilde 1998, Muoneke and Childress 2004). Muoneke and Childress (2004) reviewed catch and release fishing with a meta-analysis on 32 taxa encompassing 274 populations and found that mortalities were highly variable (median 11%, mean 18%, range 0–95%), occasionally exceeding 30% for largemouth bass. Furthermore, Coggins et al. (2007) found that if F was high and discard mortality exceeded 0.2 for short lived high productivity species or about 0.05 for long lived low productivity species, then measures to reduce F (i.e., effort) would be required to pro-

protect a fishery from recruitment overfishing and maximize fishery efficiency. Because largemouth bass in our study appeared to fall between the two species types described by Coggins et al. (2007), we chose 0.10 as our DM constant for use in our age-structured model. Undoubtedly, mortality of fish caught and released by anglers is an important consideration in recreational fisheries where length limits can cause large numbers of fish to be released (Coggins et al. 2007) and future model simulations have begun to incorporate DM (Allen and Hightower 2012).

Angler attitudes regarding black bass harvest often vary spatially (Champeau and Thomas 1993, Bonds et al. 2008, Myers et al. 2008, Isermann et al. 2012). Socio-economic factors can drive u of fish in lower income areas as potential sources of higher bass harvest levels (Wilson and Dicenzo 2002). The considerable variation in exploitation estimates that we found in our study is similar to Isermann et al. (2012) study of black bass in Minnesota lakes. Although black bass exploitation has declined across North America since 1990 (Allen et al. 2008, Isermann et al. 2012), this study demonstrated that relatively high u may exist in some cases (Beardmore et al. 2011). Based on our results, a 381- to 559-mm slot is recommended for all three reservoirs due to the increase in trophy-size bass with this protective slot limit. This study serves as an example of using age structured data combined with results of a high-reward tag exploitation study to evaluate catch and harvest on small impoundments and to explore possible harvest restrictions. If time and monetary resources are available, the authors recommend that future exploitation studies on black bass fisheries incorporate a larger number of high reward tags be distributed over a multiple year study. As a result, managers can benefit from this scenario through manipulation of size limits after some simple population modeling.

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