EVALUATION OF LARGEMOUTH BASS EXPLOITATION AND POTENTIAL HARVEST RESTRICTIONS AT RODMAN RESERVOIR, FLORIDA

By

KRISTIN RENE HENRY

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Rodman Reservoir is considered a premier largemouth bass fishery in Florida, but the large-fish (≥ 510-mm TL) potential of the reservoir could potentially be enhanced with a harvest restriction. I conducted a variable reward tagging study to estimate exploitation of largemouth bass at Rodman Reservoir. A total of 2,650 largemouth bass ≥ 345-mm TL were tagged from 2000-2002 using Hallprint® dart-style tags. Monetary rewards for tag returns ranged from $5-$100. Total mortality of largemouth bass was estimated from a catch curve and gender-specific growth rates were determined from annuli on sagittal otoliths. An age-structured model was used to simulate the response of the fishery to various harvest restrictions. Tag returns showed that 42% of the largemouth bass at Rodman Reservoir were caught in 2001; 11% of the population was harvested, whereas 31% of the population was caught and released. Total annual mortality was estimated at 49% and natural mortality at 38%. Length-specific exploitation rates increased with fish size, indicating a preference among anglers for

harvesting large fish. Simulations showed that harvest of memorable-sized fish was highest under a 510-mm minimum length limit. Overall total catch (fish ≥ 254-mm TL) and total catch of memorable-sized fish (≥ 510-mm TL) under the 510-mm minimum length limit were second only to a catch and release regulation. Therefore, a 510-mm minimum length limit would maximize angler catch rates but also allow anglers to harvest large (≥ 510-mm TL) fish.

INTRODUCTION

Largemouth bass Micropterus salmoides support some of the most important freshwater fisheries in the United States. The U.S. Fish and Wildlife Service estimates that approximately 11.3 million American anglers pursue black bass (U.S. Department of the Interior 2002). Freshwater fishing expenditures in Florida totaled an estimated $720 million in 1996, with 663,000 anglers targeting black bass. This is more than twice the number of anglers that target any other freshwater sportfish in Florida (U.S. Department of the Interior 1998).

Use of harvest restrictions has become an important part of maintaining and improving largemouth bass fisheries. Harvest restrictions typically include length limits, slot limits, and bag limits. Objectives of harvest restrictions are to manipulate predator-prey relationships, increase growth rates of abundant but stunted individuals, increase population size, increase the number of large fish, and/or increase angler catch rates (Noble and Jones 1993).

Wilde (1997) compiled data from 49 minimum length-limit evaluations and 42 slot-limit evaluations for largemouth bass at 88 lakes across the United States. He identified trends in the response of largemouth bass populations to minimum length and slot limits. Wilde (1997) found that minimum length limits increased catch rates of largemouth bass, whereas slot limits (305-381 mm TL) increased the relative abundance of quality and preferred-size largemouth bass. No evidence indicated that minimum length limits increased the proportion of large fish or that slot limits increased angler catch rates

(Wilde 1997). A length-limit evaluation at Lake Harris, Florida, found a 40% increase in angler catch rate two years after implementation (Benton and Douglas 1994). This increase concurred with the length limit trends described by Wilde (1997).

Managers and research scientists have used computer models to predict the impact of regulations on a fishery (Orth 1979; Zagar and Orth 1986; Beamesderfer and North 1995; Allen et al. 2002). Zagar and Orth (1986) modeled the effects of minimum length and slot limits on a hypothetical largemouth bass fishery to identify optimal regulations. They recommended a 356-mm minimum length limit to managers interested in maximizing biomass harvested or a 305-406 mm slot limit for creating trophy bass fisheries (Zagar and Orth 1986).

Models have been used to assess largemouth bass population responses to length limits on national and regional levels. Beamesderfer and North (1995) characterized largemouth bass populations within the Untied States by productivity level (i.e., low, average, or high growth and natural mortality rates) and simulated the effects of length limits at each productivity level. Beamsderfer and North (1995) found that population responses to length limits (e.g., changes in yield, harvest, and biomass) were strongly influenced by the productivity level of the population and that managers' options increase with population productivity. Allen et al. (2002) assessed the potential benefits of harvest restrictions based on growth and total mortality of 32 largemouth bass populations in Florida waters. They indicated that length limits would improve yield and total catch if growth was at least average and natural mortality was not substantially higher than exploitation; they also found that high length limits reduced harvest regardless of growth rate but improved angler catch rates.

Rodman Reservoir is a popular largemouth bass fishery with a reputation for producing trophy fish. According to the Florida Fish and Wildlife Conservation Commission (FFWCC) "Big Catch" program, a largemouth bass must be 3.6-kg or 610-mm TL to qualify for trophy status. During the spring of 2000 two largemouth bass were caught from the reservoir weighing 7.7-kg and 6.8-kg (Dan Canfield, Florida Lakewatch, personal communication). The state record is currently held at 7.8-kg (FFWCC); thus Rodman Reservoir has the ability to produce trophy bass.

The largemouth bass population at Rodman Reservoir, Florida has historically been managed under statewide regulations. Regulations during standard operating conditions (5.49-m above mean sea level) restrict angler harvest with a five fish bag limit and 356-mm length limit, and allow only one fish in the bag limit to exceed 550-mm TL. Additional regulations have been applied to the reservoir during periods of drawdown. Regulations for the 2001/2002 drawdown (3.35-m above mean sea level) maintained the five fish bag limit while increasing the length limit to 610-mm TL. Length limit exemptions, however, have been granted to tournament anglers by the FFWCC at all operating levels of the reservoir.

Anglers have expressed a desire for managers to further improve the largemouth bass fishery at Rodman Reservoir. In response, I evaluated the potential for harvest restrictions to enhance the largemouth bass fishery at Rodman Reservoir by identifying regulations that would increase angler catch rates and/or increase the occurrence of large fish ($\geq$ 510-mm TL) in the creel. The objectives of this study were to (1) estimate angler exploitation of largemouth bass using a reward-based tagging study; (2) estimate total annual mortality using catch curve analysis; (3) estimate age and growth using otoliths;

and (4) employ computer models, based on these estimates of exploitation, total annual mortality, and age and growth, to identify harvest restrictions that would increase overall total catch (fish ≥ 254-mm TL), total catch of large fish (≥ 510-mm TL), and harvest of large fish at Rodman Reservoir.

METHODS

Study Site

Rodman Reservoir is a 3,700-ha eutrophic system located in Putnam and Marion Counties, Florida. A relict of the Cross Florida Barge Canal project, Rodman Reservoir encompasses a 26-km flooded section of the Ocklawaha River stretching from the Eureka dam to the Senator George Kirkpatrick dam. Three distinct areas characterize the reservoir. Upstream the reservoir consists of floodplain forest and riverine habitat. A transition zone consisting of flats, stumps, and a submerged river channel follows leading into the main pool of the reservoir (Canfield et al. 1993). The reservoir has a mean depth of 2.11-m (Canfield et al. 1993). Six boat launches provide access to the reservoir.

Under normal operating conditions Rodman Reservoir is maintained at 5.49-m above mean sea level (msl). The reservoir is drawn down at three to five year intervals to control aquatic macrophytes. During drawdown periods the reservoir is reduced to 3.35-m above msl, decreasing the flooded area by approximately 2,000 hectares (R. Hujik, FFWCC, personal communication). The most recent drawdown event began December 1, 2001 and lasted until April 1, 2002. During this time a 610-mm minimum length limit was placed on the largemouth bass fishery. This temporary regulation was intended to prevent excessive harvest of largemouth bass during the drawdown.

Tagging Study

I divided the reservoir into four areas (Figure 1) and tagged an approximately equal number of fish in each area. Area one included water north of the barge canal, west of the state route 19 bridge, and east of the Kenwood entrance. Area two included all water south of the barge canal and east of the Kenwood entrance. Area three included water between the Kenwood entrance and the power lines at Orange Springs and Area four include all water between the power lines and the entrance to Paynes Landing (Figure 1). No fish were tagged upstream of Paynes Landing.

Fish were collected for tagging with a boat electrofisher and from angler tournaments. Largemouth bass were captured using a 4.88-m jon boat outfitted for electrofishing with a Coffelt VVP-15 electrofisher, as well as a Smith-Root SR-18H electrofishing boat outfitted with a 9.0 GPP electrofisher. Both systems output DC current at five to seven amps. All largemouth bass 345-mm TL and greater were measured to the nearest millimeter total length (TL), tagged, and released into approximately the same area from which they were captured. Tournament-caught fish ≥ 345-mm TL were measured to the nearest millimeter, tagged, and released into the barge canal between Areas 1, 2, and 3 (Figure 1). I assumed, based on previous age-and-growth data for largemouth bass at Rodman Reservoir (Allen et al. 2002), that all tagged fish 345-355 mm TL would recruit to the fishery (≥ 356-mm TL) within four months of tagging.

Largemouth bass were tagged with 103-mm long plastic Hallprint® dart tags with a barb (18-mm long) and orange streamer (85-mm long). The monetary reward value, return address, and a tag specific identification number were printed on the streamer of each tag. Tags were injected into the body of the fish below the spiny dorsal fin rays using a hollow stainless steel needle. When injected the barb of the tag hooked behind a pterygiophore and the streamer extended in a posterior direction at a 45-degree angle to the body.

Largemouth bass were tagged during two tagging periods to allow estimates of exploitation in 2001 and 2002. The length of each tagging period was dictated by the amount of time it took to tag approximately 1,300 fish. Tagging period one lasted from November 2000 to March 2001 and tagging period two lasted from December 2001 to January 2002. Fish were tagged with either one tag (single-tagged) or two tags (double-tagged) during both tagging periods. Double-tagged fish were later used to estimate tag loss rates. Single-tagged fish had a monetary reward value of either $5 or $50 and double-tagged fish had a monetary reward value of $10 (2-$5 reward tags), $55 (1-$5 and 1-$50 reward tag), or $100 (2-$50 reward tags). Double-tagged fish worth $100 were only released during tagging period-2. The variable-rewards offered for tag returns were later used to estimate the reporting rate of tags. No tournament fish were double tagged, due to a desire to minimize the handling time of these fish. Tag returns from double-tagged fish were considered as a single return.

Press releases to local newspapers and reward signs were used to inform the public about the study. Reward signs (Appendix 1) were posted at fishing access points around the reservoir and at local bait and tackle shops. Mailer envelopes with tag-return forms were available at local bait and tackle shops and were provided to anglers upon request. Tag-return forms requested the angler name, address, social security number (required to receive reward), date and location fish was caught, approximate length, fate of the fish (i.e., harvested or released), and if the fish was caught during a tournament (Appendix 2).

Age-and-Growth

Age and growth of largemouth bass at Rodman Reservoir were estimated using fish collected with electrofishing in January 2002. All largemouth bass collected during 20-minute electrofishing transects were measured to the nearest millimeter total length. Five fish per centimeter group up to 39-cm TL and all fish ≥ 40-cm TL, excluding fish > 5.9-kg, were collected and returned to the laboratory where weight and gender were determined, and otoliths were removed.

Sagittal otoliths were removed from sub-sampled fish and read in whole-view under a dissecting microscope by three independent readers. Otoliths that were 3-years or older and otoliths with reader discrepancies when examined in whole-view were sectioned (Hoyer et al. 1985). Two to four 0.50-mm sections were cut from the focus of each otolith using a South Bay Technology low speed diamond wheel saw (model 650). Sections from each fish were mounted on a half-frosted slide using Thermo Shandon synthetic mount. Sectioned otoliths were read under a compound microscope by a minimum of two independent readers. Sectioned otoliths with reader discrepancies were re-read by the original readers as well as one additional reader. If the discrepancy remained, the otolith was discarded. Crawford et al. (1989) found the formation of annuli to occur as early as April for largemouth bass in Florida lakes, therefore because fish were collected for age-and-growth in January I assumed a January birth date and assigned each fish an age one year greater than the number of rings observed on the otolith.

Analysis

Tagging Study

Tag returns were adjusted for tag loss, tagging-related mortality, and non-reporting, prior to estimating total annual catch and angler exploitation. Tag returns and electrofishing recaptures of double-tagged fish were used to estimate tag loss. Anglers that returned single tags from double-tagged fish were contacted by phone to verify that only one tag was present at the time of capture. The time between tagging and recapture was recorded for all double-tagged fish. I assumed that tag retention was linearly related to time-at-large and developed two models, as per Miranda et al. (1997), to estimate the logistic probability of tag loss (logit(*l*)) based on the period (P) in which the fish were tagged:

$$\text{logit}(l) = a + b_1(\text{time}) \tag{1}$$

where a is the intercept estimate, b_1 is the parameter estimate, and time is the number of days between tagging and recapture. Tag returns from double-tagged fish were assigned a dummy variable of 1 to indicate a single tag loss or 2 to indicate no tag loss. The dummy variables and associated estimates of time at large (time) for tag returns from double-tagged fish tagged in each period (P) were then used in Procedure LOGISTIC (SAS 1996) to calculate estimates of a and b_1 for each tagging period. Once the parameter estimates were obtained for equation 1, I estimated the logistic probability of tag loss (logit(*l*)) for each tagging period and year based on the average time fish from a given tagging period (P) were at large in year (y). These logistic probabilities were then used in the following equation to calculate the probability of a single tag loss (p) for fish tagged in period P and recaptured during year y (Miranda et al. 1997):

$$p = \frac{e^{\text{logit}(l)}}{\left(1 + e^{\text{logit}(l)}\right)} \tag{2}$$

I assumed that all tag loss events were independent and subsequently estimated the probability of a fish losing two tags as the square of the probability of a single tag loss

(p^2). Estimates of p and p^2 were then subtracted from 1 to predict tag retention rates for single-tagged fish (1-p) and double-tagged fish (1-p^2). The total number of single-tagged (N_{single}) and double-tagged (N_{double}) fish from each tagging period and year were then adjusted based on their respective retention rates.

Tag-related mortality was estimated based on the results of a cage study, which was conducted within the reservoir. A 2-m x 1-m x 1-m cage with 10-cm plastic bar mesh was used to hold 3 to 16 fish per cage trial. Six to nine cage trials were conducted per tagging period with each trial lasting a minimum of 40-hours. All cage trials were conducted in Area 3 (Figure 1) of the reservoir. At the end of each trial fish were checked for survival and released. Trials were conducted using fish captured via electrofishing (trials = 11) as well as those collected at tournaments (trials = 4). The total number of tagged fish were separated by capture method and tagging period, adjusted for the appropriate tag-related mortality rate, and recombined.

Reporting rates of high-dollar reward tags in 2001 were estimated based on a linear-logistic model created by Nichols et al. (1991):

$$\lambda_{\mathrm{H}} = e^{(-0.0045+0.0283(\mathrm{H}))} \Big/ \left(1 + e^{(-0.0045+0.0283(\mathrm{H}))}\right) \tag{3}$$

where H is the dollar value of a fish tagged with a high-dollar reward (i.e., \$50, \$55, or \$100) and λ_H is the reporting rate of tags from high-reward fish. This model was originally created to estimate the reporting rate of duck bands based on the monetary reward value of the band. Because the model was created in 1988, the reward values (H) were converted from 2001 standards to the 1988 monetary equivalents based on the Consumer Price Index (Nichols et al. 1991). The 1988 monetary equivalents used in equation 3 were \$33.40, \$36.71, and \$66.80 for \$50, \$55, and \$100 rewards, respectively

(U.S. Department of Labor 2002). Reporting rate estimates calculated from equation 3 were most precise at high-reward values (Nichols et al. 1991). Therefore, I used equation 3 to estimate reporting rates of high-reward fish then calculated the reporting rate of low-reward tags based on the assumption that all tagged fish had an equal probability of recapture regardless of reward-value (equations 4 & 5).

I estimated the total number of H reward fish caught (C_H) from the reservoir in 2001 using the following equation:

$$C_H = R_H / \lambda_H \tag{4}$$

where R_H is the number of tags returned in 2001 from fish tagged with a high-reward. Equation 4 was repeated for all values of H. I then estimated the number of low-reward fish caught (C_L) from the reservoir in 2001 using the following ratio:

$$\frac{C_{50}}{T_{50}} = \frac{C_L}{T_L} \tag{5}$$

where L is the dollar value of a fish tagged with a low-reward (i.e., \$5, \$10), C_{50} is the estimated number of \$50-reward fish caught from the reservoir, and T_{50} and T_L are the original number of fish tagged with a \$50-reward and a low-reward (L) respectively, adjusted for the appropriate rates of tag loss (p, p^2) and tagging mortality. Equation 5 was repeated for all values of L. I then substituted R_L (the number of tag returns from low-reward value fish) and C_L into equation 4 to estimate a reporting rate for low-reward fish (λ_L) in 2001. This process was repeated for all low-reward values (i.e., \$5 and \$10). Reporting rate estimates for all reward values were varied by ± 50% to simulate possible error associated with the reporting rate estimates.

Total annual catch (TAC) and total quarterly catch (TQC) of largemouth bass in 2001 were calculated as follows:

$$TAC_{2001} = \frac{\left(\sum C_{\mathrm{L},2001} + \sum C_{\mathrm{H},2001}\right)}{\left(\sum T_{\mathrm{L},\mathrm{P}_1} + \sum T_{\mathrm{H},\mathrm{P}_1}\right)} \tag{6}$$

$$TQC_{q,2001} = \frac{\sum C_{\mathrm{L},q,2001} + \sum C_{\mathrm{H},q,2001}}{\left(\sum T_{\mathrm{L},\mathrm{P}_1} + \sum T_{\mathrm{H},\mathrm{P}_1}\right) - \left(\sum C_{\mathrm{L},i,2001} + \sum C_{\mathrm{H},i,2001}\right)} \tag{7}$$

where 2001 denotes the year in which the fish were caught, P_1 denotes the period in which the fish were tagged (i.e., P_1 = period 1), q represents the quarter in which the fish were caught (i.e., q_1 = January 1st to March 31st, q_2 = April 1st to June 30th, etc.), and i represents all quarters previous to q within 2001.

Due to time constraints, I was unable to obtain a full year of tag return data for 2002 and therefore unable to estimate reward-specific reporting rates for 2002. However, assuming that reporting rates did not vary significantly between years, I was able to use the 2001 reporting rate estimates to calculate an estimate of the total number of largemouth bass per reward value caught ($C_{H,q,2002}$, $C_{L,q,2002}$) from the reservoir in the first three quarters of 2002 (equation 4). Quarterly estimates of C_H and C_L were then used to estimate TQC of largemouth bass in 2002.

$$TQC_{q,2002} = \frac{\sum C_{\mathrm{L},q,2002} + \sum C_{\mathrm{H},q,2002}}{\sum_{\mathrm{P}} \left(\sum T_{\mathrm{L}} + \sum T_{\mathrm{H}}\right) - \left(\sum C_{\mathrm{L},i,2002} + \sum C_{\mathrm{H},i,2002}\right) - X} \tag{8}$$

$$X = v\left(\sum T_{\mathrm{L},\mathrm{P}_1} + \sum T_{\mathrm{H},\,\mathrm{P}_1}\right) + \left(\sum C_{\mathrm{L},2001} + \sum C_{\mathrm{H},2001}\right) \tag{9}$$

where 2002 denotes the year in which fish were caught, i represents all quarters previous to q within 2002, and X is a correction term that accounts for the reduced number of season-1 fish present in the population at the start of 2002 due to natural mortality (v) (see below) and tag removal in the previous year. Equation 9 assumes that all tags were removed from fish caught by an angler in 2001, regardless of fate. Angler harvest of tagged fish during the last month of the fourth quarter of 2001 and the entire first quarter of 2002 was limited by the temporary 610-mm minimum length limit placed on the largemouth bass fishery during the 2001/2002 reservoir drawdown.

Total harvest of largemouth bass per reward value (H_L, H_H) was estimated by adjusting the number of fish reported by anglers as harvested for non-reporting. Tag returns from fish with an unknown fate were divided proportionally among the known fate groups prior to reporting rate adjustments. Estimates of H_L and H_H were used in equation 6 in place of C_L and C_H to estimate total annual exploitation (u) (Ricker 1975) of largemouth bass in 2001. The total annual exploitation rate was then subtracted from the total annual catch rate to estimate the total annual catch and release rate for the reservoir.

<u>Age-and-Growth</u>

Data from the timed electrofishing transects was used to estimate total annual mortality and gender-specific growth rates. I created a gender-specific age length key from the subsampled largemouth bass collected during January 2002. Age-1 largemouth bass of unknown gender were randomly assigned a gender based on the assumption that sexually dimorphic growth rates are not evident in largemouth bass until age-2 (Schramm and Smith 1987). I used a gender-specific age length key to assign a gender and age to each individual in the whole sample (all fish captured during timed electrofishing transects, January 2002). Gender-specific age frequencies were calculated and a catch curve was fit for each gender. Age-1 fish were not included in the catch curve because these fish had not fully recruited to the gear (Bayley and Austen 2002). Due to a low sample size of older fish (< 5 fish per age-class over the age of 6) weighted catch curves were fit to age-frequency plots. The instantaneous rate of total mortality (Z) was estimated from the slope of the catch curve for each gender (Ricker 1975). I used the following equations to estimate total annual mortality (A) and the annual rate of natural mortality (v) for each gender (Ricker 1975):

$$A = 1 - e^{-Z} \tag{10}$$

$$v = A - u \tag{11}$$

I used the following equations to estimate mean-length-at-age (MLA) and variance (σ^2) for each gender (DeVries and Frie 1996):

$$MLA = \frac{\sum f_i x}{\sum f_i} \tag{12}$$

$$\sigma^2 = \frac{\left(\left(\sum f_i\right)\left(\sum f_i x^2\right) - \left(f_i x\right)^2\right)}{\left(\left(\sum f_i\right) \times \left[\left(\sum f_i\right) - 1\right]\right)} \tag{13}$$

where x is a given centimeter group and f_i is the number of gender *i* fish of a given age in centimeter group *x*. I used the von Bertalanffy growth model (Ricker 1975) to describe gender-specific growth rates:

$$MLA = L_\infty \left(1 - e^{-k(\text{age} - t_0)}\right) \tag{14}$$

Parameter estimates (L_∞, k, t_o) were obtained for equation 14 using Procedure NLIN (SAS 1996) and were based on previously calculated estimates of mean-length-at-age (equations 12 & 13). The growth models were used to estimate mean total-length-at-age (TLA) for each gender. Weight-length equations were created for male and female largemouth bass at Rodman Reservoir based on the subsample of fish collected in 2002 (Ricker 1975):

$$W = aL^b \tag{15}$$

where W is the weight of the fish, L is the length of the fish, *a* is the intercept, *b* is the shape parameter. Parameters were estimated from the $\log_e$ transformed model:

$$\log(W) = \log a \cdot b \log(L) \tag{16}$$

Regulation Simulations

I used the Inland Fisheries Regulation Simulator (IFREGS) model described by Allen and Miranda (1998) to simulate the response of the fishery to four minimum length limits; 254-mm TL, 356-mm TL, 457-mm TL, and 510-mm TL, three slot limits; 381-510-mm TL, 381-559-mm TL, and 381-610-mm TL, a maximum length limit; 457-mm TL, and a complete catch and release regulation. The model required estimates of gender-specific total length-at-age, gender and age specific rates of exploitation and natural mortality, and parameter estimates from gender-specific weight-length equations to forecast the annual age-structure of the population under a given harvest restriction. Gender-specific estimates of mean TL-at-age were obtained from the von Bertalanffy growth models (equation 14). Estimates of TL-at-age were used to describe annual incremental growth. Within year growth was assumed to be linear. Gender and age specific exploitation rates were obtained by calculating length specific exploitation rates for quality (300-379 mm TL), preferred (380-509 mm TL), and memorable (510+ mm TL) size fish (Anderson and Neumann 1996) and assigning these exploitation rates to each gender based on mean total-length-at-age (equation 14). Gender and age specific natural mortality rates were obtained by subtracting the gender and age specific exploitation rates from total annual mortality (equation 11) and the parameter estimates for the gender-specific weight-length equations were obtained from equation 15.

Gender and age specific exploitation rates were used to estimate total harvest (fish ≥ 254-mm TL) and harvest of quality, preferred, and memorable size fish. Gender and age specific natural mortality estimates were combined with exploitation estimates to describe total annual mortality and to predict the number of fish in the population each year. The parameter estimates from the gender-specific weight-length equations were used to transform fish lengths to fish weights in order to predict the annual biomass of the population.

The model simulated length limits by protecting fish from harvest if they were below a minimum length limit or within a slot limit. The model assumed that all fish ≥ 254-mm TL were susceptible to harvest if they were not protected by a regulation. I ran each simulation for 50-years with 1000 fish recruiting to age-1 (500-males, 500-females). I used the predicted number of quality, preferred, and memorable size fish harvested as well as the predicted total number of fish harvested from the 50th simulation year to compare the effectiveness of each regulation for maximizing harvest. Estimates of overall total catch (all fish ≥ 254-mm TL) and total catch of quality, preferred, and memorable size fish were calculated based on the age structure predicted for the 50th simulation year under a given harvest restriction. Gender and age specific total catch rates applied to the age structures were obtained by calculating length-specific exploitation rates for quality, preferred, and memorable size fish and assigning these catch rates to each gender based on mean TL-at-age. The predicted age structure for the 50th simulation year under each harvest restriction was then multiplied by the appropriate total catch rates to obtain estimates of overall total catch and total catch of quality, preferred, and memorable size fish.

In order to account for potential error associated with my reporting rates, all simulations were repeated using gender-specific exploitation and natural mortality rates associated with ± 50% variability in reporting rate. Previous studies that used multiple methods (e.g., postcard surrogates, phone interviews, creel surveys, or surreptitiously implanted tags) to estimate reporting rates have shown reporting rate variability to range from ± 11% to ± 52% (Larson et al. 1991; Maceina et al. 1998; Miranda et al. 2002). Therefore, simulations that used mortality estimates associated with ± 50% variation in reporting rate accounted for potential high variability in my reporting rate estimates. Simulation results were compared to identify inconsistencies that would result from incorrectly estimating the reporting rate of tags.

RESULTS

Tagging Study

Tagging-period one ran from November 28, 2000 to March 31, 2001, 50 sampling trips were made to the reservoir during this time. Forty-four trips were dedicated to electrofishing and the remaining 6 trips were spent tagging fish collected at tournaments. A total of 1,368 largemouth bass were tagged during tagging period-1, 1,014 of these fish were collected by electrofishing, and 354 fish were collected at tournaments. Tagging period two ran from November 10, 2001 to January 9, 2002, 15 sampling trips were made to the reservoir during this time. Fourteen of these trips were spent electrofishing and the remaining trip was spent tagging fish at a tournament. A total of 1,270 largemouth bass were tagged during period-2, 1,258 of these fish were collected by electrofishing and the remaining 12 were collected at a tournament. Electrofishing catch rates were higher in tagging period-2 this was likely due to the reservoir drawdown.

A summary of the number of fish tagged per period and reward value is presented in Table 1. About half of the fish were tagged with $5 reward tags in both tagging periods. A low number (n = 6) of $55 reward fish were released during period-1. A total of 406 and 486 largemouth bass were double-tagged (reward value = $10, $55, $100) during periods 1 & 2, respectively (Table 1).

Annual tag loss rates for single and double tagged fish are presented in Table 2. Fish tagged in period-1 were at large an average of 87 days (range = 1 to 337 days) before recapture in 2001 and 421 days (range = 329 to 528 days) before recapture in

2002. Fish tagged in period-2 were at large and average of 66 days (range = 0 to 250 days) before recapture in 2002 (Table 2). Based on the period tagged and the average time at large, tag loss ranged from 4% to 26% for single-tagged fish and from 0.2% to 6.6% for double-tagged fish (Table 2). Tag loss was positively related to time at large.

Cage trials were conducted during both tagging periods, 9 trials (6 electrofishing trials, 3 tournament trials) were conducted in 2001 and 6 in 2002 (5 electrofishing trials, 1 tournament trial). On average 10 fish (range = 3 to 16) were caged per trial and each trial lasted an average of 50 hours (range = 43 to 79). A total of 145 fish were caged over the course of the study, all of which survived, resulting in a tag related mortality rate of 0%. Therefore, the original number of fish (N) tagged in each period did not have to be adjusted for tagging mortality. An estimated 1,314 tagged fish from period-1 remained in the reservoir after tag loss in 2001 and about 1,246 tagged fish from period-2 remained after tag loss in 2002. Period-1 fish present in the reservoir in 2002 were adjusted for tag loss ($p = 0.2576$, $p^2 = 0.0663$) based on an average of 421 days at large. They were also adjusted for natural mortality v = 0.38 (described below) and angler removal of tags (n = 546) in 2001. Based on these adjustments I estimated that 382 largemouth bass tagged in period-1 were present in the reservoir in 2002 (Table 1).

Tag returns were collected from January 1, 2001 to September 30, 2002. Tags from 260 fish were returned in 2001 and tags from 231 fish were returned in the first three quarters of 2002. During 2001, the percent return of tags ranged from 16% ($5 reward) to 33% ($55 reward) (Table 1). Estimated reporting rates were positively correlated with monetary reward values and ranged from 39% ($5 reward) to 87% ($100 reward) (Table 1).

During 2001, 67 tagged fish were reported by anglers as harvested and 180 tagged fish were reported as released. During the first three quarters of 2002, 24 tagged fish were reported by anglers as harvested and 203 were reported as released. Thirteen fish had an unknown fate in 2001 and 4 fish had an unknown fate in 2002. These fish were divided among the known-fate categories (i.e., kept or released) based on the proportion of fish in each reward category that were reported as kept or released. Total annual catch, annual exploitation, and annual catch and release rates for largemouth bass in 2001 were 0.42, 0.11, and 0.31, respectively. Thus, about 26% (i.e., 0.11 / 0.42 = 0.26) of the largemouth bass caught from the reservoir in 2001 were harvested and about 74% were released. Tag returns from 2002 showed that the total catch, exploitation, and catch and release rates for the first three quarters of 2002 were 0.30, 0.03, and 0.27, respectively, indicating that about 90% of the fish caught in the first three quarters of 2002 were released.

Length-specific estimates of exploitation, total catch, and natural mortality were calculated for 2001 based on three length categories; quality (356-379-mm TL), preferred (380-509-mm TL), and memorable (≥ 510-mm TL). Annual exploitation rates of quality, preferred, and memorable fish were 0.08, 0.12, and 0.20, total annual catch rates were 0.38, 0.42, and 0.40, and natural mortality rates were 0.41, 0.37, and 0.29, respectively. Anglers harvested 22%, 28%, and 50% of all the quality, preferred, and memorable size fish, respectively, that were caught in 2001. Regulations during the first year of the tagging study (2001) prevented anglers from harvesting fish < 356-mm TL, because these fish were protected from harvest ($u = 0$) estimates of exploitation, total annual catch, and natural mortality used in the simulation models for fish 254-355-mm TL were therefore based on the calculated exploitation (u = 0.08), total annual catch (TC = 0.38), and natural mortality (v = 0.41) rates associated with quality sized fish.

Altering reporting rate estimates by ± 50% to account for possible variability associated with the reporting rate estimates affected the estimates total annual catch, exploitation, and natural mortality. Increasing reporting rate estimates by 50% resulted in lower estimates of total annual catch and exploitation and a higher estimate of natural mortality, reducing reporting rates by 50% had opposite effects. Increasing reporting rates by 50% resulted in total annual catch rates of 0.26, 0.28, and 0.28, annual exploitation rates of 0.06, 0.08, and 0.14, and natural mortality rates of 0.43, 0.41, and 0.35 for quality, preferred, and memorable size fish, respectively. Decreasing reporting rates by 50% resulted in total annual catch rates of 0.76, 0.83, and 0.82, annual exploitation rates of 0.17, 0.23, and 0.41, and natural mortality rates of 0.32, 0.26, and 0.08 for quality, preferred, and memorable size fish, respectively.

Quarterly tag returns were used to estimate total quarterly catch of largemouth bass in all quarters of 2001 and in the first three quarters in 2002. TQC rates ranged from 3% (Quarter-3, 2002) to 22% (Quarter-2, 2001) (Table 3). TQC rates in the first (TQC = 16%) and second (TQC = 22%)) quarters of 2001 were higher than TQC rates in the third (TQC = 7%)) and fourth (TQC = 3%)) quarters of 2001, indicating a decline in catch after June 30, 2001. The TQC rate of largemouth bass in the first quarter of 2001 (16%) was less than the TQC rate in the first quarter of 2002 (20%) (Table 3). Additionally, TQC rates in the second (22%) and third (7%) quarters of 2001 were higher than TQC rates in the second (10%) and third (3%) quarter of 2002 (Table 3).

This chapter discusses what a style is, how it is applied, and how it should be used to create your thesis or dissertation.

Age-and-Growth

Seventeen 20-minute electrofishing transects and one 10-minute electrofishing transect were conducted from January 7, 2002 to January 9, 2002. A total of 1,239 largemouth bass were collected and measured (whole-sample). Three hundred and twenty two largemouth bass (sub-sample) collected during sampling efforts, ranging from 80-603 mm TL, were returned to the laboratory to be measured, weighed, and gender and age determined. Female largemouth bass in the whole sample did not exceed 600-mm TL, whereas males did not exceed 530-mm TL. Female largemouth bass reached a mean length of 587 ± 20-mm TL by age-10, whereas male largemouth bass reached a mean length of 435 ± 6-mm TL by age-10 (Figure 2).

Gender specific values of number-at-age were used for catch curve analysis. Age classes 7, 9, and 10 were underrepresented (< 5 fish) for both, male and female largemouth bass. No eight year-old fish were collected. Gender specific rates of total annual mortality calculated from the slopes of the catch curves were 0.46 and 0.51 for male and female largemouth bass, respectively. Analysis of covariance showed that there were no significant differences between the slopes ($p = 0.6473$) or y-intercepts ($p = 0.8200$) of the gender-specific catch curves, indicating that total annual mortality was not significantly different between genders. Thus, gender-specific number-at-age values were pooled and catch curve analysis was repeated for the pooled sample (Figure 3). Total annual mortality for all fish was 0.49. Length-specific estimates of natural mortality mentioned above were calculated based on length-specific exploitation rates and the pooled estimate of total annual mortality (equation 11). Lengths and weights pertaining to the sub-sampled fish were used to create the following gender-specific weight-length equations for male (equation 20) and female (equation 21) largemouth bass, respectively:

$$W = \left(4.42 \times 10^{-6}\right) L^{3.207} \tag{20}$$

$$W = \left(4.66 \times 10^{-6}\right) L^{3.196} \tag{21}$$

Regulation Simulations

Results of the simulations are summarized in Figures 4 and 5. Total annual harvest of largemouth bass ≥ 254-mm TL and total harvest of quality-sized fish were greatest under a 254-mm minimum length limit (Figure 4A & 4B). Total harvest of preferred-sized fish was greatest under a 356-mm minimum length limit (Figure 4C) and total harvest of memorable-sized fish was greatest under a 510-mm minimum length limit (Figure 4D). Overall total catch and total catch of preferred and memorable sized fish were greatest under a catch and release regulation (Figure 5A, 5C, and 5D). The 510-mm minimum length limit resulted in the second highest overall total catch and total catch of preferred and memorable sized fish (Figure 5A, 5C, and 5D). The 457-mm minimum length limit, the 510-mm minimum length limit, and the catch and released regulation all maximized the total catch of quality-sized fish (Figure 5B).

Assuming anglers would not harvest fish < 254-mm TL, simulating the effects of a 254-mm minimum length limit on the fishery was essentially equivalent to simulating no length limit. Using this regulation as a benchmark to identify the success of alternate harvest restrictions revealed that the catch and release regulation, the 510-mm minimum length limit, and the 457-mm minimum length limit were the top three regulations for maximizing the overall total catch of largemouth bass as well as the total catch of quality, preferred, and memorable size fish. The catch and release regulation yielded the highest increase in total catch, increasing the overall total catch by 32% and increasing the total catch of quality, preferred, and memorable sized fish by 8%, 54%, and 103%, respectively compared to no length limit. The 510-mm minimum length limit was the next most effective regulation for maximizing total catch, increasing the overall total catch by 18% and increasing total catch of quality, preferred, and memorable sized fish by 8%, 46%, and 100%, respectively. The 457-mm minimum length limit followed with a 17% increase in the overall total catch and an 8%, 41%, and 77% percent increase in the total catch of quality, preferred, and memorable size fish, respectively.

Simulations based on exploitation and natural mortality rates associated with ± 50% error in reporting rate showed similar trends with regards to overall total harvest, total harvest of preferred and memorable sized fish, overall total catch, and total catch of quality, preferred, and memorable sized fish. However, simulation results associated with a 50% increase in reporting rate estimates showed that several regulations (254-mm minimum length limit, 457-mm maximum length limit, 381-510 mm slot limit, 381-559 mm slot, and 381-610 mm slot) would maximize total harvest of quality-sized fish.

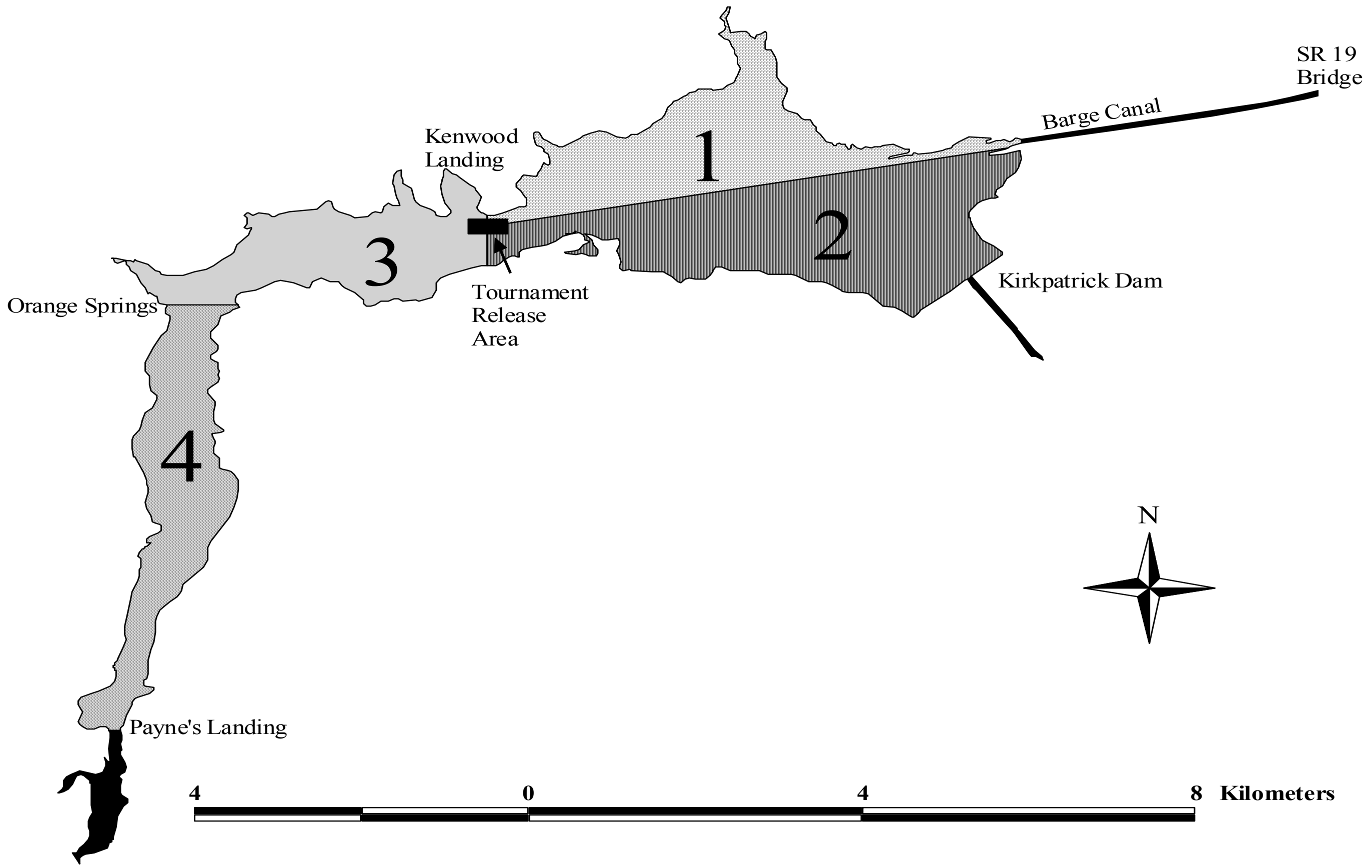


Figure 1. Rodman Reservoir located in Putnam and Marion Counties, Florida. Areas 1-4 represent designated capture and release areas for the tagging study.

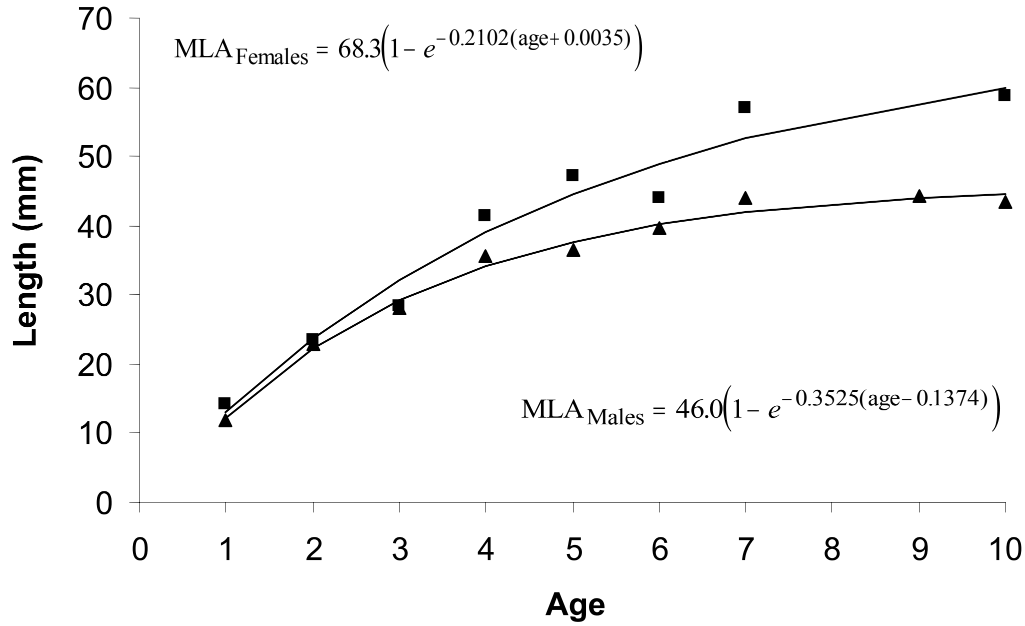


Figure 2. Von Bertalanffy growth models fit to mean-length-at-age values for male (triangles) and female (squares) largemouth bass collected from Rodman Reservoir in January 2002.

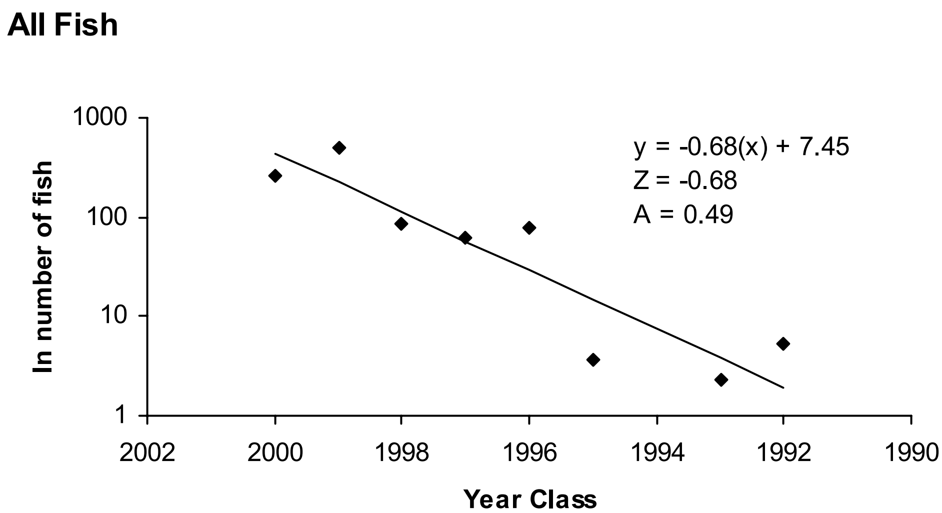


Figure 3. Weighted catch curve based on number-at-age data for all fish collected during electrofishing transects conducted at Rodman Reservoir in January 2002. Total annual mortality of largemouth bass was 49%. A weighted catch curve was fit to the data because the 1992 to 1995 year-classes were underrepresented (≤ 5 fish).

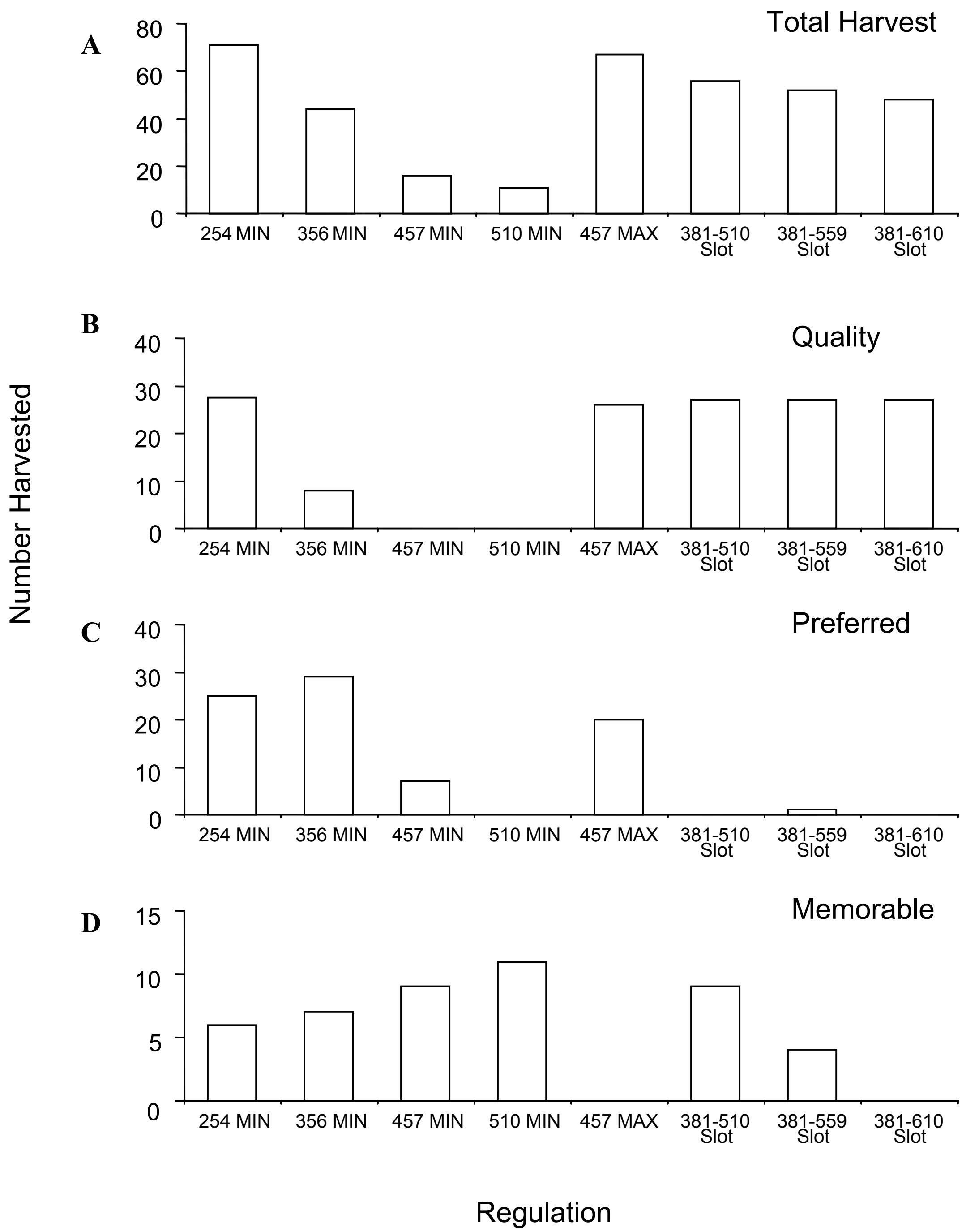


Figure 4. Estimated annual harvest of all fish ≥ 254-mm (A) and quality (300-379-mm) (B), preferred (380-509-mm) (C), and memorable (≥ 510-mm) (D) sized fish based on 50-year simulations run in IFREGS. All estimates are based on 1,000 fish recruiting to age-1.

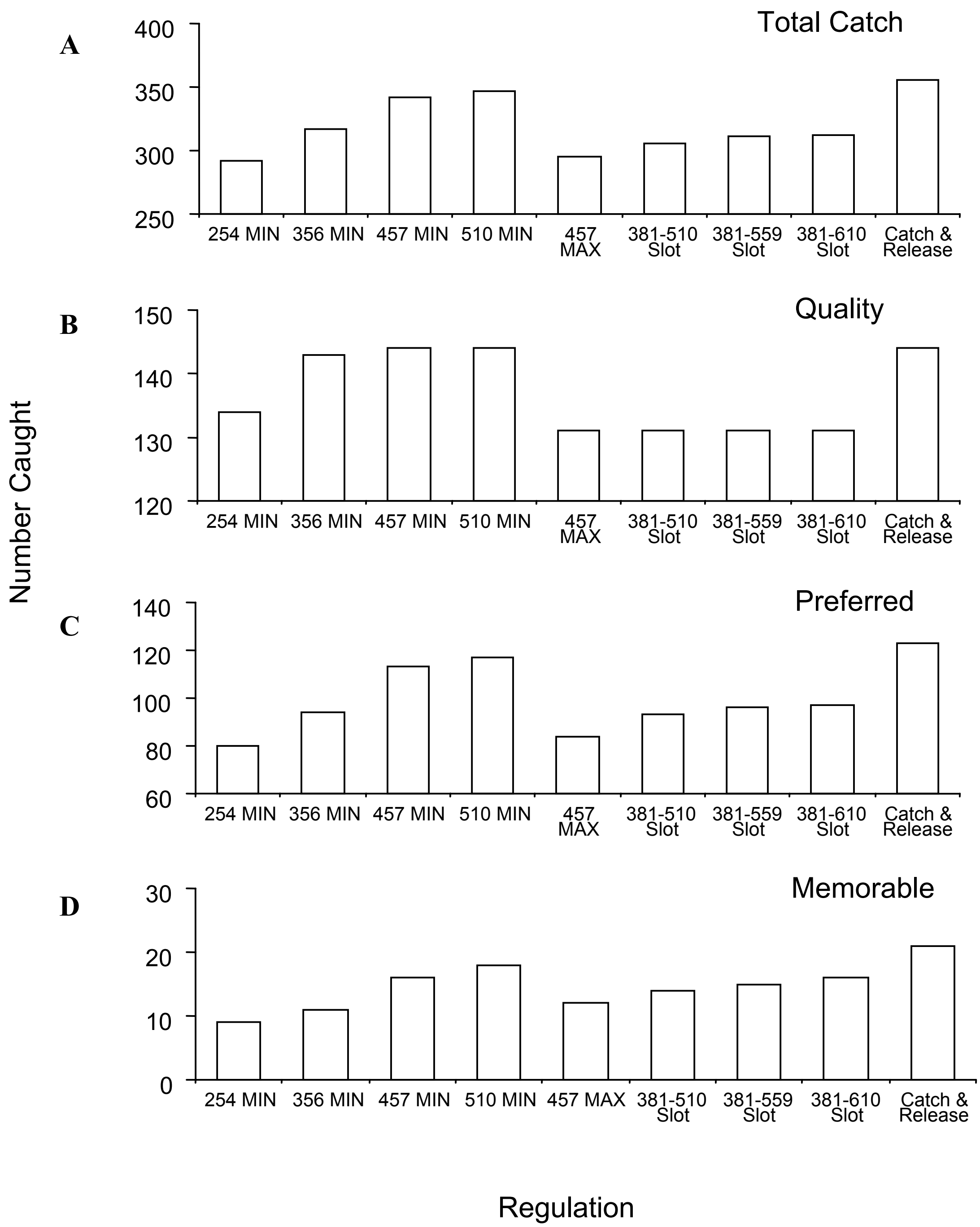


Figure 5. Estimated annual catch of all fish ≥ 254-mm (A) and quality (300-379-mm) (B), preferred (380-509-mm) (C), and memorable (≥ 510-mm) (D) sized fish based on 50-year simulations run in IFREGS. All estimates are based on 1,000 fish recruiting to age-1.

Table 1. Estimated catch of 2,638 largemouth bass tagged and released at Rodman Reservoir, Florida. The adjusted numbers of tagged fish were corrected for tag loss (p & p^2) and tagging mortality (0%). Period-1 adjusted tagged fish in 2002 were also corrected for natural mortality and angler removal of tags during 2001. Tag returns were adjusted for non-reporting to obtain estimated catch.

Tagging Period (P)	Recapture Year (y)	Value ($)	Tagged (N)	Tag Loss (p, p^2)	Adjusted Tagged (T)	Number Returned (R)	Percent Returned (%)	Reporting Rate (λ)	Estimated Catch (C)
1	2001	5	739	0.0557	698	113	16	0.3893	290
1	2001	10*	400	0.0031	399	82	21	0.4944	166
1	2001	50	223	0.0557	210	63	30	0.7192	88
1	2001	55*	6	0.0031	6	2	33	0.7379	3
Total:			**1,368**		**1,313**	**260**	**20%**		**547**
Percent:									**42%**
1	2002	5	739	0.2576	188	23	12	0.3893	59
1	2002	10*	400	0.0663	135	23	17	0.4944	46
1	2002	50	223	0.2576	57	18	32	0.7192	25
1	2002	55*	6	0.0663	2	0	0	0.7379	0
Total:			**1,368**		**382**	**64**			**130**
Percent:									**34%**

Table 1. Continued

Tagging Period (P)	Recapture Year (y)	Value ($)	Tagged (N)	Tag Loss (p, p^2)	Adjusted Tagged (T)	Returned (R)	Percent Returned (%)	Reporting Rate (λ)	Estimated Catch (C)
2	2002	5	686	0.0438	656	76	12	0.3893	195
2	2002	10*	400	0.0019	399	50	13	0.4944	101
2	2002	50	104	0.0438	99	23	23	0.7192	32
2	2002	55*	50	0.0019	50	10	20	0.7379	14
2	2002	100*	30	0.0019	30	8	27	0.8650	9
Total:			**1,270**		**1,234**	**167**			**351**
Percent:									**28%**

* Indicates that the fish were tagged with two tags (double-tagged).

Table 2. Tag loss rates for single-tagged (p) and double-tagged (p^2) largemouth bass at Rodman Reservoir. Tag loss was estimated based on electrofishing and angler recaptures of double-tagged fish. Proc LOGISTIC (SAS 1996) was used to obtain intercept (a) and parameter (p) estimates for tag loss models: $\text{logit}(l) = a + b_1(time)$.

Tagging Period (P)	Recapture Year (y)	Intercept (a)	Parameter Estimate (b_1)	Average Time (tij)	Tag Loss Single Tag (p)	Tag Loss Double Tag (p^2)
1	2001	-3.2904	0.0053	86.93	0.0557	0.0031
1	2002	-3.2904	0.0053	421.09	0.2576	0.0663
2	2002	-3.7512	0.0101	66.08	0.0438	0.0019

Table 3. Quarterly catch rates of tagged fish caught from Rodman Reservoir during the first 3 quarters of 2001 and 2002. Adjusted tagged fish were corrected for tag loss (p & p^2), tagging mortality (0%), and angler removal of tags (C). Fish tagged in period-1 and recaptured in 2002 were adjusted for natural mortality (v = 38%). Returns were adjusted for non-reporting to estimate catches (C).

Quarter (q)	Recapture Year (y)	Value ($)	Adjusted Tagged (T)	Number Returned (R)	Percent Returned (%)	Estimated Catch (C)	Percent Caught (%)
1	2001	5	698	42	6	108	15
1	2001	10	399	31	8	63	16
1	2001	50	210	30	14	42	20
1	2001	55	6	1	17	1	23
Total			**1,313**	**104**		**214**	
Percent					**8%**		**16%**
2	2001	5	590	48	8	123	21
2	2001	10	336	41	12	83	25
2	2001	50	168	28	17	39	23
2	2001	55	5	0	0	0	0
Total			**1,099**	**117**		**245**	
Percent					**11%**		**22%**
3	2001	5	467	17	4	44	9
3	2001	10	253	7	3	14	6
3	2001	50	129	1	1	1	1
3	2001	55	5	1	22	1	29
Total			**854**	**26**		**60**	
Percent					**3%**		**7%**

Table 3. Continued

Quarter (*q*)	Recapture Year (y)	Value ($)	Adjusted Tagged (T)	Number Returned (R)	Percent Returned (%)	Estimated Catch (C)	Percent Caught (%)
1	2002	5	844	67	8	172	20
1	2002	10	534	49	9	99	19
1	2002	50	156	23	15	32	20
1	2002	55	52	5	10	7	13
1	2002	100	30	7	23	8	27
Total			**1,616**	**151**		**318**	
Percent					**9%**		**20%**
2	2002	5	672	27	4	69	10
2	2002	10	435	18	4	36	8
2	2002	50	124	15	12	21	17
2	2002	55	45	5	11	7	15
2	2002	100	22	0	0	0	0
Total			**1,298**	**65**		**133**	
Percent					**5%**		**10%**
3	2002	5	603	5	1	13	2
3	2002	10	399	6	2	12	3
3	2002	50	103	3	3	4	4
3	2002	55	38	0	0	0	0
3	2002	100	22	1	5	1	5
Total			**1,165**	**15**		**30**	
Percent					**1%**		**3%**

DISCUSSION

The optimal harvest restriction for the reservoir should provide the best combination of overall total catch and total catch of large fish, while catering to angler preferences. The top three regulations for improving overall total catch and total catch of memorable-sized fish were (1) the catch and release regulation, (2) the 510-mm minimum length limit, and (3) the 457-mm minimum length limit. In 2001, anglers harvested memorable-sized largemouth bass at a much higher rate than smaller fish, thus eliminating harvest with a catch and release regulation may interfere with preferences of some angler groups. A catch and release regulation would also prevent tournaments from taking place at the reservoir because tournament exemptions are prohibited under a catch and release regulation (FFWCC). During the 2001 fiscal-year, the FFWCC granted tournament exemptions at Rodman Reservoir to 37 tournament groups which involved 1,018 tournament anglers (W. Chamberlain, FFWCC, unpublished data). Eliminating the ability to hold future tournaments by instating a catch and release regulation, would therefore conflict with a substantial number of tournament anglers. Due to the potential conflicts with angler groups, managers should consider alternatives to the catch and release regulation.

The 510-mm minimum length limit and the 457-mm minimum length limit were the next best regulations for maximizing overall total catch and the total catch of memorable-sized fish. In addition, the 510-mm and 457-mm minimum length limits were the most effective regulations for maximizing harvest of memorable-sized fish.

Both regulations had a similar effect on the total catch of largemouth bass, however the total harvest of memorable-sized fish under the 510-mm minimum length limit was 22% (range: 20% to 50%) higher than total harvest of memorable-sized fish under the 457-mm minimum length limit. Therefore, the 510-mm minimum length limit would at least be equivalent to if not better than the 457-mm minimum length limit. I suggest that managers should consider implementing a 510-mm minimum length limit at Rodman Reservoir. However, should managers have difficulty instating the 510-mm minimum length limit because the regulation has not been previously approved for use by the FFWCC, the 457-mm minimum length limit would serve as a suitable alternative. This length limit has been previously used by the FFWCC to regulate largemouth bass fisheries within Florida, and it is the next most effective regulation for maximizing overall total catch and total catch and harvest of memorable-sized fish.

Estimates of annual exploitation used in the simulation models were based on 2001 tag returns and ranged from 8% (quality fish) to 20% (memorable fish). A review of mortality rates associated with 30 largemouth bass populations in the United States showed annual exploitation rates to range from 9-72% (average u = 36%) (Allen et al. 1998). Based on these findings the exploitation rates of largemouth bass at Rodman Reservoir appear to be low compared to historical data in the United States. Despite the low rates of exploitation, exploitation rates were positively related to fish length, indicating a preference among angler to harvest large fish.

The total annual mortality rate used in the simulations was 49%. Allen et al. (1998) reviewed mortality estimates for 30 largemouth bass populations in the United States and found total annual mortality rates to range from 24-92% (average A = 64%). Allen et al.

(2002) calculated a 51% average total annual mortality rate for largemouth bass in 45 Florida water bodies. The total annual mortality rate of largemouth bass at Rodman Reservoir was slightly lower than the national average but similar to the average total annual mortality of largemouth bass in Florida waters.

Gender-specific mean total-length-at-age estimates used in the simulations predicted that male largemouth bass would not exceed a mean total length of 443-mm, thus precluding males from contributing to the memorable-size portion of the population. Only one male largemouth bass was collected in excess of 510-mm TL during age-and-growth sampling, therefore males did not contribute greatly to the memorable-size portion of the population. Regulations that restrict harvest of fish < 510-mm TL will therefore focus the majority of the harvest on the female portion of the population. Managers should be aware that focusing the majority of harvest on one gender could eventually skew the sex ratio of the population.

Female largemouth bass at Rodman Reservoir reached memorable size between ages 6 and 7 and reached an average weight of 2.2-kg by age-11. A previous study by Allen et al. (2002) examined gender-specific growth rates for 35 largemouth bass populations in Florida lakes and found that female largemouth bass with average growth reached memorable size between ages 6 and 7. Therefore, female growth rates at Rodman Reservoir were about average in comparison to other Florida water bodies. According to the FFWCC 'Big Catch' program a largemouth bass must be ≥ 610-mm TL or ≥ 3.6-kg to be considered a trophy catch. Average growth rates at Rodman Reservoir do not produce trophy fish, thus memorable-sized fish were used as a gauge to measure each regulation's effectiveness at increasing the number of large fish (≥ 510-mm TL) within the reservoir.

Results of the tagging study showed that tag retention rates declined with increasing time at large. Retention rates ranged from 96% (66 days at large) to 74% (421 days at large), based on the average number of days fish were at large. Renfro et al. (1995) found 100% tag retention in largemouth bass that were tagged and held in hatchery ponds for 3-months, and 98% average retention (range: 93% to 100%) for largemouth bass that were tagged and held in sample ponds for 15-months, using the same tags used in this study. Renfro et al. (1995) did not find retention rates to decrease with increasing time at large. Retention rates calculated in this study were lower than those calculated by Renfro et al. (1995). The individual error associated with fish tagging was compounded by the high number of individuals (N = 25) that participated in tagging efforts and may have contributed to the high level of tag loss observed in this study. Additionally, anglers may have intentionally or inadvertently misreported the presence of two tags in follow-up phone interviews. Conversations with anglers revealed a common belief that both tags should not be removed from double-tagged fish. Some anglers believed that it was wrong to remove both tags, while others believed they were contributing to the success of the study by not removing all tags. In either case, misreporting a tag loss from a double-tagged fish would have inflated my estimate of tag loss. In response to this apparent confusion among anglers, signs were posted at boat ramps in January 2002, indicating that all tags should be removed from double-tagged fish (Appendix 3). Tag retention rates may have been more comparable to those found by Renfro et al. (1995) had the angling community clearly understood how to treat double-tagged fish.

Cage trials conducted during the fall and winter showed a 100% survival rate for tagged fish. This survival rate was comparable to the survival rates calculated in previous tagging studies (Tranquilli and Childers 1982; Renfro et al. 1995). Renfro et al. (1995) showed that over the course of a three-month pond study mortality rates of fish tagged with Halprint® dart-style tags did not differ significantly from mortality rates of untagged fish. Tranquilli and Childers (1982) also showed 100% survival rate for tagged fish in a 191-day pond experiment.

Tag returns may have suffered from a lack of independence. Pollock et al. (2001) suggested that anglers may have a tendency to collect low-reward tags until they gather enough tags to make them worth mailing. Anglers participating in this study commonly returned several tags at once indicating a possible lack of independence. The tag return envelopes used in this study may have also contributed to the lack of independence in tag returns. Tag return envelopes were not postage-paid therefore the cost and effort associated with mailing a single tag may have outweighed the reward, possibly leading anglers to accumulate tags until they had collected enough reward money to justify mailing in the tags. This possible lack of independence in tag returns may have inflated my reporting rate estimates.

The exploitation rate of largemouth bass calculated for the first three quarters of 2002 was low (u_{2002} = 3%) in comparison to the 2001 annual exploitation rate (u_{2001} = 11%). Although the 2002 exploitation rate will increase as tags are returned from fish caught in the fourth quarter of 2002, I do not expect the exploitation rate to increase dramatically nor do I expect it to match or exceed the 2001 annual exploitation rate. The low exploitation rate in 2002 was probably due to (1) the 610-mm minimum length limit implemented during the 2001-2002 reservoir drawdown and (2) a possible decline in the return rate of tags from 2001 to 2002. The temporary 610-mm minimum length limit placed on the largemouth bass fishery during the drawdown period coincided with the first quarter of 2002 and protected the majority of the fish caught during that quarter from harvest. Because 66% of all the fish caught in the first three quarters of 2002 were caught during the first quarter of the year, the temporary length limit contributed to the lower exploitation rate in 2002. In addition, using 2001 reporting rate estimates to estimate total catch in 2002 may not have been appropriate since reporting rates have been shown to decline from the first year of the study to subsequent years (Dequine and Hall 1949; Moody 1960). If reporting rates declined from the first to second year of my study, the use of first year reporting rates would result in underestimates of exploitation and total catch in 2002. Reward-specific reporting rates were not calculated for 2002 because a complete year of tag return data was not available. Although 2002 reporting rates were not available, comparing the percent return of tags in the second (11%) and third (3%) quarters of 2001 to the second (5%) and third (1%) quarters of 2002 revealed a decline in the return rate of tags (Table 3). However, the percent return of tags in the first quarter of the year increased from 2001 (8%) to 2002 (9%) (Table 3). This increase may be an indication that tag return rates did not decline with increasing study length. Nevertheless, it is more likely that a decline in reporting rates occurred and was masked by an increase in angler catch rates associate with the reservoir drawdown. Therefore, angler catch rates calculated for the first three quarters of 2002 were probably underestimated, leading to an underestimate of exploitation and total catch for 2002.

Harvest restrictions are often more effective at altering the age structure of populations that have additive mortality rates as opposed to compensatory (Allen et al. 1998). Changing exploitation rates in populations with additive mortality has a direct effect on total annual mortality. However, changing exploitation rates in populations with compensatory mortality may not effectively reduce total annual mortality. Growth and natural mortality of a population may also dictate the effectiveness of a regulation. Beamesderfer and North (1995) found that angler catch rates and the occurrence of large fish were likely to increase when harvest restrictions were applied to average (average growth, average v) or productive (fast growth, low v) populations. Conversely, they found that limiting exploitation of unproductive populations (slow growth, high v) may not be beneficial because many fish would die before they reached quality size. Compared to the populations studied by Beamesderfer and North (1995), growth rates and natural mortality of largemouth bass at Rodman Reservoir were average. Based on these findings and the assumption that mortality rates of largemouth bass were additive, harvest restrictions should serve as an effective means for manipulating the age structure of the largemouth bass population at Rodman Reservoir.

Miranda et al. (2002) questioned the effectiveness of tagging studies as a means for accurately assessing exploitation rates. They reported that the variability associated with estimating reporting rates is so large that it precludes a manager’s ability to accurately assess exploitation, thus Miranda et al. (2002) recommended that managers seek an alternate means for estimating exploitation. Because my exploitation rates were derived from a tagging study, I introduced high error into my reporting rate estimates and used the associated exploitation and natural mortality rates in simulation models to verify that trends in the simulation results would remain constant regardless of the possible variability associated with my reporting rate estimates. Simulations using exploitation and natural mortality rates associated with ± 50% variability in reporting rate showed that trends in total catch remained constant. Trends in total harvest were moderately affected by the extreme variation in reporting rates. Overall, variability in exploitation due to reporting rate error did not significantly impact the relative value of each harvest restriction.

The purpose of the simulation model was to identify trends in the population's response to various harvest restrictions. Simulation models have error associated with their estimates just as field data have associated error (Johnson 1995). Therefore, error associated with specific predictions of the simulation model my recommendation to implement a 510-mm minimum length limit at Rodman Reservoir was based primarily on the trends reveled by the simulations, not the specific values.

FURTHER STUDY

Several factors could interfere with the success of the proposed 510-mm minimum length limit. These factors include (1) a potential for reduced growth due to the proposed high minimum length limit, (2) a potential for increased fish removal during tournaments due to the re-opening of Buckman Lock, and (3) the potential elimination of the reservoir due an ongoing debate to remove of the Senator George Kirkpatrick Dam.

The proposed high minimum length limit could potentially reduce the growth rates of largemouth bass at Rodman Reservoir, thus interfering with the success of the proposed regulation. Seidensticker (1994) found evidence that slow growth of largemouth bass began 5-years after a 406-mm minimum length limit was implemented at a Texas reservoir. I suggest conducting semi-annual age-and-growth surveys at the reservoir to assess the potential effects of the regulation on fish growth rates. Age-and-growth assessments would allow managers to identify potential problems as well as track the success of the regulation as a means for altering the age structure of the population. According to Allen and Pine (2000) the probability of detecting differences in the age structure of a population due to an altered harvest restriction was higher under 5-year evaluations than 3-year evaluations. Wilde (1997) concluded that data should be collected for a minimum of three years following the implementation of a regulation in order to detect differences. In either case, duration of evaluation was the key to determining the effects of a regulation on a population. Based on these finding, I suggest monitoring age-and-growth of the population periodically for 5-7 years.

The re-opening of Buckman Lock could lead to an increase in the number of largemouth bass removed from the reservoir due to tournaments and potentially lead to an increase in total annual mortality. Buckman Lock connects Rodman Reservoir to the St. Johns River allowing boater access between the two water bodies. The lock is commonly used by tournament anglers participating in fishing tournaments held outside of the reservoir. Tournament anglers that lock through to fish the reservoir remove largemouth bass from the reservoir when they return to the St. Johns River for weigh-ins. Tournament anglers participating in tournaments outside of the reservoir do not release fish back into the reservoir, thus tournament anglers could potentially contribute to the total annual mortality of largemouth bass at Rodman Reservoir. Buckman Lock was closed for the duration of this study except for a brief period in December of 2001 when the lock was opened to allow anglers participating in the Citgo Bassmasters Eastern Open to fish the reservoir. Buckman lock re-opened for regular operation in October of 2002. Due to the re-opening of the lock, I recommend that managers assess effects of outside tournament anglers on the abundance of largemouth bass at Rodman Reservoir. If tournaments remove a significant number of fish, I suggest re-evaluating the harvest restriction to ensure that the 510-mm minimum length limit is still the optimal regulation for the reservoir.

Finally, the potential elimination of the reservoir due to an ongoing debate to remove the Senator George Kirkpatrick Dam and restore the free flowing Ocklawaha River could completely negate the findings of this study. The US Forest Service has voiced its intention to initiate action by 2006 to restore the federal land which is currently submerged beneath the reservoir and abuts the Senator George Kirkpatrick Dam. The intentions of the US Forest Service would effectively result in the removal of the reservoir. However, in response to the US Forest Service's intentions, the 'Save Rodman Reservoir' advocacy group has voiced their plan to file suit against the US Forest Service, should the US Forest Service take action to remove the dam. Managers should consider the potential for dam removal when deciding whether to implement a new harvest restriction. As previously stated, the effects of the regulation may not be visible for five or more years, thus the removal of the dam could prevent the regulation from ever taking full effect and if the dam was removed, a re-assessment of the fishery would need to take place before a new optimal harvest restriction could be chosen. Managers should take caution and consider all of these potential problems prior to implementing a new harvest restriction.

APPENDIX A
REWARD SIGN-1

Reward sign posted at fishing access points around Rodman Reservoir and at local tackle shops.

R E W A R D

$5 AND $50

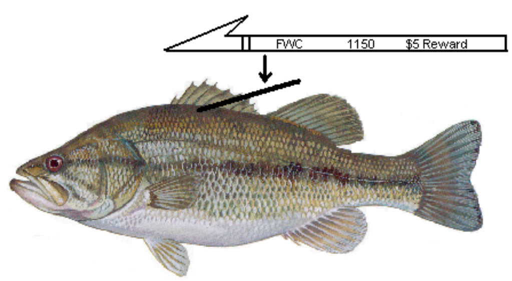
Fishery biologists have tagged Largemouth bass in the Rodman Reservoir. To receive a reward of $5 or $50, you must cut the tag from the fish and mail the tag and the following information to the address listed below.

Send the following information with each tag:

NAME	**DATE CAUGHT**
ADDRESS	**APPROXIMATE CATCH LOCATION**
PHONE NUMBER	**APPROXIMATE FISH LENGTH**
SOCIAL SECURITY NUMBER*	**COMMENTS**
SIGNATURE	

***Needed to receive reward.**

Address information is also provided on the tag, and tag mailers are provided at local tackle shops for your convenience.



Please mail tag and information to:
Florida Fish and Wildlife
Conservation Commission
7922 NW 71st St. Gainesville, FL 32653
(352) 392-9617 ext. 240

APPENDIX B
TAG-RETURN INVOICE

Tag- return invoice distributed to all anglers that returned largemouth bass tags.

Please mail tag and information to:
Florida Fish and Wildlife
Conservation Commission
7922 NW 71st St. Gainesville, FL 32653
(352) 392-9617 ext. 240

INVOICE

To: Florida Fish and Wildlife Conservation Commission
7922 NW 71st St.
Gainesville, FL 32653

TO BE FILLED OUT BY ANGLER

From: (Please Print)
Name:____
Social Security Number:____-___-____ (Needed for reward)
Address:____
____

Phone Number:(   ) _____-_____
Approximate Fish Length (inches):________________
Date Caught:___________________
Approximate Catch Location:___________________
Was Fish Kept_______ or Released______
Comments:____
____

Tournament : Yes/No **(Circle)**
Tournament Name:_____________________________
Weigh-in Location: ______________________________

APPENDIX C
REWARD SIGN-2

Informational sign posted at fishing access points around Rodman Reservoir beginning January 2002. The sign was intended to alleviate confusion among anglers regarding the number of tags that should be removed from double-tagged fish.

LARGEMOUTH BASS TAGS

Please Cut All Orange Tags from Fish Regardless of Whether the Fish is Kept or Released.

REWARDS: $5,$10,$50,$55,$100

Please mail Tags to:

Florida Fish and Wildlife Conservation Commission
7922 NW 71st Street. Gainesville, FL 32653
(352) 392-9617 ext. 240

LIST OF REFERENCES

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

Allen, M. S., L. E. Miranda, and R. E. Brock. 1998. Implications of compensatory and additive mortality to the management of selected sportfish populations. Lakes & 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.

Allen, M. S., W. Sheaffer, W. F. Porak, and S. Crawford. 2002. Growth and mortality of largemouth bass in Florida waters: implications for use of length limits. International Black Bass Symposium.

Anderson, R. O., and R. M. Neumann. 1996. Length, weight, and associated structural indices. Pages 447-482 *in* B. R. Murphy and D.W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Bayley, P. B., and D. J. Austen. 2002. Capture efficiency of a boat electrofisher. Transactions of the American Fisheries Society 131:435-451.

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.

Benton, J., and D. Douglas. 1994. Ocklawaha chain of lakes largemouth bass population studies. Pages 29-54 *in* Upper Ocklawaha River completion reports: 1991 to 1994. Florida game and freshwater fish commission fisheries research laboratory, Eustis, FL.

Canfield, D. E. Jr., E. J. Schulz, and M. V. Hoyer. 1993. "To be or not to be"--The Rodman Reservoir controversy. Final report, Department of Fisheries and Aquaculture, Center for Aquatic Plants. University of Florida, Gainesville.

Crawford, S., W. S. Coleman, and W. F. Porak. 1989. Time of annulus formation in otoliths of Florida largemouth bass. North American Journal of Fisheries Management 9:231-233.

Dequine, J. F., and C. E. Hall, Jr. 1949. Results of some tagging studies of the Florida largemouth bass *Micropterus salmoides floridanus* (LeSueur). Transactions of the American Fisheries Society 79:155-166.

DeVries, D. R., and R. V. Frie. 1996. Determination of age and growth. Pages 483-512 *in* B. R. Murphy and D.W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Hoyer, M. V., J. V. Shireman, and M. J. Maceina. 1985. Use of otoliths to determine age and growth of largemouth bass in Florida. Transactions of the American Fisheries Society 114:307-309.

Johnson, B. L. 1995. Applying computer simulation models as learning tools in fisheries management. North American Journal of Fisheries Management 15:736-747.

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., P.W. Bettolli, S. D. Finely, and V. J. DiCenzo. 1998. Analyses of the sauger fishery with simulated effects of a minimum size limit in the Tennessee River of Alabama. North American Journal of Fisheries Management 18:66-75.

Miranda, L. E., R. E. Brock, and B. S. Dorr. 1997. Growth, fishing, and natural mortality of crappies in Mississippi. Pages 56-70 *in* Miranda, L. E., M. S. Allen, R. E. Brock, K. M. Cash, B. S. Dorr, L. C. Issak, and M. S. Schorr. Evaluation of regulations restrictive of crappie harvest. Mississippi Cooperative Fish and Wildlife Research Unit. Mississippi State University, Starkville.

Miranda, L. E., R. E. Brock, and B. S. Dorr. 2002. Uncertainty of exploitation estimates made from tag returns. North American Journal of Fisheries Management 22:1358-1363

Moody, H. L. 1960. Recaptures of adult largemouth bass from the St. Johns River, Florida. Transactions of the American Fisheries Society 89(3):295-300.

Nichols, J. D., R. J. Blohm, R. E. Reynolds, R. E. Trost, J. E. Hines, and J. P. Bladen. 1991. Band reporting rates for mallards with reward bands of different dollar values. Journal of Wildlife Management 55(1):119-126.

Noble, R. L., and T. W. Jones. 1993. Managing fisheries with regulations. Pages 383-402 *in* C. C. Kohler and W. A. Hubert, editors. Inland fisheries management. American Fisheries Society, Bethesda, MD.

Orth, D. J. 1979. Computer simulation model of the population dynamics of largemouth bass in Lake Carl Blackwell, Oklahoma. Transactions of the American Fisheries Society 108:229-240.

Pollock, K. H., J. M. Hoenig, W. S. Hearn, and B. Calingaert. 2001. Tag reporting rate estimation: 1. an evaluation of the high-reward tagging method. North American Journal of Fisheries Management 21:521-532.

Renfro, D. J., W. F. Porak, and S. Crawford. 1995. Tag retention of Hallprint dart tags and tag-induced mortality in largemouth bass. Proceedings of the Annual Conference of the Southeast Association of Fish and Wildlife Agencies 49:224-230.

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

SAS (Statistical Analysis Systems) 1996. SAS statistics user's guide. SAS Institute, Inc. Cary, North Carolina.

Seidensticker, E. P. 1994. Lake Nacogdoches, Texas: a case history of largemouth bass overharvest and recovery utilizing harvest regulations. Proceedings of the Annual Conference of the Southeast Association of Fish and Wildlife Agencies 48:453-463.

Schramm, H. L. Jr., and D. C. Smith. 1987. Differences in growth rates between sexes of Florida largemouth bass. Proceedings of the Annual Conference of the Southeast Association of Fish and Wildlife Agencies 41:76-84.

Tranquilli, J. A., and W. F. Childers. 1982. Growth and survival of largemouth bass tagged with Floy anchor tags. North American Journal of Fisheries Management 2:184-187.

U.S. Department of the Interior, Fish and Wildlife Service, and U.S. Department of Commerce, Bureau of the Census. 2002. 2001 National survey of fishing, hunting, and wildlife-associated recreation, Washington, D.C.

U.S. Department of the Interior, Fish and Wildlife Service, and U.S. Department of Commerce, Bureau of the Census. 1998. 1996 National survey of fishing, hunting, and wildlife-associated recreation, Washington, D.C.

U.S. Department of Labor. 2002. Bureau of Labor Statistics, Division of Consumer Prices and Price Indexes, Washington, D.C.

Wilde, G. R. 1997. Largemouth bass fishery responses to length limits. Fisheries 22(6):14-23.

Zagar, A. J. and D. J. Orth. 1986. Evaluation of harvest regulations for largemouth bass populations in reservoirs: a computer simulation model. Pages 218-226 *in* Hall, G. E. and M. J. Van Den Avyle, editors. Reservoir Fisheries Management Strategies for the 80's. Reservoir Committee, Southern Division American Fisheries Society, Bethesda, MD.

BIOGRAPHICAL SKETCH

Kristin Rene Henry was born on October 5, 1977, in Rochester, New York, the daughter of Robert and Jacquieline Henry. She was raised in the small town of Walworth, New York, with her brother Jason. She acquired a love for the ocean during annual family camping-trips to the Atlantic coast, and decided to purse a degree in marine science at Long Island University/Southampton College in the fall of 1995. She graduated with a B.S. in marine biology in May 1999. After graduation she pursued an interest in fisheries biology working with striped bass on the Roanoke River in North Carolina. In June 2000, she began work as a fisheries technician for the University of Florida and began her graduate work in the Department of Fisheries and Aquatic Sciences at the University of Florida in January 2001. She will graduate with a Master of Science degree in May 2003. Her future plans are to travel, spend time with her family, and pursue a career in marine fisheries management.