Working title: Long-term trends in largemouth bass population responses to length limits

Output controls are the most frequently applied approach to regulate catch, prevent biological overfishing, and conserve inland freshwater fisheries. Length limit restrictions are a common output control for sport fish, providing managers a way to limit catch. Restricting catch by length is relatively easy to implement and enforce, relative to input controls (e.g., effort restrictions). In theory, length limit restrictions may be used to influence population size structure and potentially achieve management objectives. For example, increasing a minimum length limit (MLL) to a higher value should increase the abundance of fish below the MLL by protecting those fish from harvest. Similarly, a protected slot limit should increase the number of fish in a population by restricting harvest to fish below are above the protected slot limit values—commonly used to protect spawning sized portion of the population. Using length restrictions to meet management objectives about fish population (e.g., size structure changes, spawner protection) assumes anglers abide regulations and harvest fish.

Length limit regulations are also enacted to meet another fundamental agency objective of angler satisfaction. Varying angler types (i.e., subsistence, recreational, trophy, tournament) present a challenge to using a system-level length limit. For example, subsistence anglers may be satisfied by high catch rates and catch comprised of stock and quality-sized fish. Alternatively, trophy and tournament anglers may be satisfied with lower catch rates, but catch is dominated by memorable and trophy sized fish. Well organized angler groups can exert pressure on fisheries management agencies to modify length limits based on perceived changes in catch or size structure. Organizational pressure may extend to lobbying state fish and wildlife commissioners to vote in a particular way on proposed length limit changes [cite Miranda’s and Allen’s bad ass model?].

Regardless of whether length limits are enacted to meet biological or angler satisfaction objectives or a combination of both, a population response should be expected if harvest occurs. Changes over time of angler’s preferences for harvest or catch and release may interact with population responses to length limits. Additionally, decreases in overall effort on a system over time due to changing angler demographics through reduced angler recruitment and retention, may limit expected population responses. Never the less, length limits continue to be used to meet fishery and angler satisfaction objectives and therefore understanding how sport fish populations respond to length limit changes is needed, especially given changes in angler effort, harvest rates over time. For example, the effect the same length limit on a size structure or abundance of a fish population may not be the same today as it was 30 years ago.

Length limit regulation can potentially influence many aspects of a fish population. This includes, but is not limited to changes in population size structure, relative abundance, relationship of length and weight, and condition. Evaluating these potential changes represents a challenge because changes in population metrics may take several years to respond to length limit changes. Therefore, long time series of population metrics over time are needed to evaluate the influence of length limit changes. The objective of this study was to evaluate the effect of length limits on the largemouth bass population over a 30 year period. We hypothesized that population status would differ among regulations, but that after a regulation was applied there would be a gradual shift toward a new state over several years.

Methods

Study site

Ross Barnett Reservoir is a 31,000 acre impoundment of the Pearl River northeast of Jackson, Mississippi. The reservoir is managed by the Pearl River Valley Water Supply District as a water supply source for the Jackson metropolitan area and for recreation. Filling began in 1962 and by January 1965 the reservoir impounded water 35 miles upstream. Mean depth is xx and water level fluctuations range <1.5 ft. Centrarchidae, Ictaluridae, and Moronidae provide most of the fisheries; Clupeidae provide an essential prey for the fish assemblage.

Harvest regulations

Length-limit regulations have been used to manage harvest of largemouth bass in Ross Barnett Reservoir since 1988. Before then a bag limit was the only harvest restriction. In early 1988 a 13-16-in protected slot length limit was implemented. The slot was continued for 10 years through 1997. Beginning in 1998 the slot was replaced with a 15-in minimum length limit, which lasted 11 year until it was replaced with a 12-in minimum length limit in February 2009. The 12-in limit was in place through 2015. A bag limit of seven fish lasted throughout the 27 year period between 1988 and 2015. Annual fish population surveys, and desires from angler groups and tournament organizers have been catalysts for regulation changes.

Fish collections

The Mississippi Department of Wildlife, Fisheries, and Parks has been conducting standardized electrofishing monitoring in Ross Barnett Reservoir since 1989. TRY TO FIND OLDER DATA. Electrofishing surveys were conducted in fall following methods described in Miranda (2005) and similar to those described by Miranda and Boxrucker (2009). Over the study period there have been changes in electrofishing equipment and personnel, but electrofishing protocols and sampling design have remained steady. Samples lasting 0.25-0.5 h each were taken in fall along shorelines at randomly selected sites systematically selected throughout the reservoir. All largemouth bass collected were measured individually for total length and total weight.

Fish population metrics

Fish length, weight, and count data were organized into 18 metrics descriptive of largemouth bass population status including population density, size structure, and body condition. Population density metrics included catch per hour of all fish, and catch per hour of fish < 8 in, 8-11.9 in, 12-14.9 in, and >15 in. Size structure metrics included median length of all fish, median length of fish < 12 in, median length of fish > 12 in, and percentage of fish < 8 in, 8-11.9 in, 12-14.9 in, and >15 in. Body condition metrics included a condition index of all fish combined, of fish < 8 in, 8-11.9 in, 12-14.0 in, >15 in, and the slope (*b*) of the logarithmic weight-length regression. The condition index (*K*) was computed as the observed individual weight divided by the expected weight estimated with a weight-length equation fitted to all of the fish collected during the 27-year period. Separation of population density, size structure, and body condition into classes within the largemouth bass length range were expected to enhance our ability to discriminate among years by providing a more meticulous description of the population

Data analysis

Data analysis focused on testing our expectations that population status would differ among regulations, but that after a regulation was applied there would be a gradual change towards a new state. Because of the large number of metrics involved, we employed multivariate procedures. These procedures facilitate the compression of numerous metrics that are often correlated, into a few factors that represent the main aspects of the full set of metrics. To test if population state differed among regulations, we conducted a multivariate analysis of variance that considered in unison all 18 metrics relative to the length-limit regulations. To examine how the population shifted after a regulation was applied, we plotted factor scores against year.

The multivariate analysis of variance was conducted with a permutation procedure (perMANOVA). With years as replicates, the perMANOVA relied on 9,999 permutations to assess statistical significance with a pseudo-F test and P < 0.10. This distance-based procedure is analogous to conventional parametric multivariate analysis of variance, but does not make assumptions about data distribution, although it does assume independence of samples and homogeneity of dispersion among variables (Anderson, 2001). If the perMANOVA detected differences in population structure among length limits, pairwise comparisons were performed to identify where the differences occurred. A Bonferroni adjustment for multiple comparisons was included. Factor scores were the axes scores generated by a Principal Coordinate Ordination (PCO) of the 18 metrics (PCO is equivalent to principal components analysis when applied to a matrix constructed with a Euclidean similarity coefficient).

The perMANOVA and PCO were applied to a similarity matrix constructed with the Euclidean similarity coefficient applied to normalized (z-scores) metrics. Prior to normalizing, all fish catch rates were log (x + 1) transformed to reduce skewness, thereby satisfying the assumption of homogeneity of dispersion. No other transformations were necessary. Analyses were conducted with the PERMANOVA+ add-on package for PRIMER-E v7 software (Clarke and Gorley, 2015; Anderson et al., 2008).

Results

Over the 27 year period 848 samples were taken. In terms of number of samples effort varied from 8 to 38 samples and averaged 31.4 samples per year. In terms of electrofishing hours effort varied from 4 to 19 hours and averaged 11.9 hours per year. This effort produced a total of 19, 274 largemouth bass, averaging 714 per collection, and ranging in number from 359 to 1,222 per collection. In general, catch rates and size structure metrics were the most variable among years and condition estimates the least variable (Table 1).

The perMANOVA detected that a significant difference existed in the population metrics among length-limit periods (pseudo-*F* = 3.2, *P* = 0.001). A follow up analysis with Bonferroni adjusted pairwise tests indicated the population characteristics differed between the 13-16-in slot and the 12-in minimum (*t* = 2.5, *P* < 0.001), the 15-in minimum and the 12-in minimum (*t* = 1.6, *P* = 0.024), and not different between the 15-in minimum and the 13-16-in slot (*t* =1.4, *P* = 0.077).

The first three axes of the PCO ordination accounted for 32.7, 21.9, and 17.4% of the multivariate variability in the 18 metrics, for a total of 72% of the total variability. The correlation between each metric and the scores of the first three axes suggested the population characteristics indexed by each axis (Table 1). Axis 1 contrasted small fish versus large fish as the percentage and catch per hour of fish < 8 in were inversely correlated with axis 1 and percentage of fish 12-14.9 in, percentage of fish >15 in, median length of all fish, and median length of fish <12 in were directly correlated with axis 1 scores. Axis 2 was directly correlated with the all the condition metrics. Axis 3 was positively correlated with most of the catch rate metrics. Thus, axis 1 reflected size, axis 2 reflected condition, and axis 3 reflected abundance.

Plots of axes 1-3 scores against year were variable from year to year and did not show distinct gradual shifts. Instead, values fluctuated along discernible gradients. Axes 1 scores (size) exhibited a positive relationship with year, suggesting an overall positive trend in size as length limits shifted from the 13-16-in slot, to the 15-in minimum length limit, and to the 12-in minimum length limit. Axes 2 scores showed a concave pattern with values decreasing after implementation of the slot, remaining at a low level during the 15-inch minimum, and increasing after implementation of the 12-inch minimum. Axes 3 (abundance) scores showed a convex pattern with scores increasing after implementation of the slot, peaking with the 15-in minimum, and dropping slightly with the 12-in minimum length limit.

Discussion

Table 1. Summary statistics of 18 population density, size structure, and body condition metrics used to describe the largemouth bass population at Ross Barnett Reservoir, Mississippi, 1989-2015 (N = 27 years). Median total length values are given in inches. The axis 1-3 values represent the correlation between a metric and the axis score. Arbitrarily, correlation > 0.7 are bolded to highlight the metrics best represented by each axis. I added in this table the summary stats and the correlation with axes 1-3. The summary stats are used at the beginning of the results, and the correlations later. I could have made two separate tables but for conciseness I put everything in one table. Should they be two tables for clarity?

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Metric | Mean | CV | Min | Max | Axis 1 | Axis 2 | Axis 3 |
| Density | | | | | | | |
| Catch per hour all | 55.5 | 25 | 30.8 | 79.5 | -0.41 | -0.02 | **0.89** |
| Catch per hour <8 in | 13.6 | 55 | 3.6 | 26.2 | **-0.86** | -0.13 | 0.37 |
| Catch per hour 8-11.9 in | 16.2 | 29 | 7.1 | 24.8 | -0.20 | -0.12 | **0.89** |
| Catch per hour 12-14.9 in | 15.5 | 27 | 8.1 | 23.0 | 0.36 | 0.13 | **0.83** |
| Catch per hour >15 in | 10.1 | 28 | 5.1 | 15.7 | 0.23 | 0.27 | **0.74** |
| Size structure | | | | | | | |
| Median TL all | 279.7 | 10 | 211 | 316 | **0.81** | -0.10 | 0.05 |
| Median TL <12 in | 202.3 | 7 | 165 | 227 | **0.83** | -0.05 | 0.07 |
| Median TL >12 in | 363.6 | 2 | 350 | 379 | -0.43 | -0.13 | -0.18 |
| Percentage <8 in | 23.8 | 44 | 9.6 | 39.1 | **-0.91** | -0.10 | -0.09 |
| Percentage 8-11.9 in | 29.2 | 15 | 21.4 | 36.4 | 0.27 | -0.14 | 0.32 |
| Percentage 12-14.9 in | 28.5 | 24 | 18.4 | 40.9 | **0.87** | 0.11 | -0.03 |
| Percentage >15 in | 18.5 | 24 | 11.2 | 27.9 | **0.71** | 0.26 | 0.00 |
| Condition | | | | | | | |
| *b* | 3.217 | 2 | 3.134 | 3.267 | 0.14 | **0.91** | 0.05 |
| *K* all | 1 | 3 | 0.93 | 1.09 | -0.01 | **0.93** | 0.13 |
| *K* <8 in | 1 | 5 | 0.91 | 1.17 | -0.20 | **0.70** | -0.01 |
| *K* 8-11.9 in | 1 | 4 | 0.93 | 1.10 | 0.07 | **0.93** | 0.04 |
| *K* 12-14.9 in | 1 | 4 | 0.92 | 1.07 | 0.25 | **0.88** | 0.06 |
| *K* >15 in | 1 | 4 | 0.95 | 1.09 | 0.25 | **0.76** | -0.20 |

Figure 1.

