STUDY FINAL REPORT

State: Michigan **Project No.:** F-81-R-16

Study No.: 230550 **Title:** Energetics approach to predicting growth, maturation, and fecundity of Largemouth Bass, Bluegill, and Walleye

Period Covered: October 1, 2006 to September 30, 2015

Study Objectives (Summary): The overall objective of this study is to enhance our ability to evaluate fish population responses to alternative management actions, including alternative fishing regulations. The specific objectives are to: 1) conduct laboratory and pond experiments to better understand the strongly density-dependent processes of growth and reproduction; and 2) use the resulting information to improve the ability of simulation models to predict fish population responses.

Summary: Work on this study was stopped due to the retirement of the principal investigator and a lack of replacement staff.

Findings: Progress is reported below for all objectives and jobs from 2006 until 2012. Work stopped on this study in 2012 due to the retirement of the principal investigator and lack of replacement.

Objective 1: To conduct laboratory experiments on juvenile fish to better understand and predict the allocation of new mass to growth in length versus growth in condition.

Job 1. Title: Lab experiment on growth in length and weight.–A series of laboratory experiments were conducted to quantify growth in length and weight. In summer 2008, an experiment determined the influence of previous feeding level on allocation of energy to growth in length versus relative weight for juvenile largemouth bass. The 2x2 experimental design compared fish growth for two levels of feeding (5% or 10% of body weight per day) using fish from two previous feeding levels (5% or 10% BW/d).

Because the bioenergetics model for largemouth bass seems to overpredict weight loss during winter, a series of lab experiments were conducted to quantify fish weight loss during winter and allow estimation of the adjustments necessary to bioenergetics models to correctly predict weight loss during winter. In the winter of 2009-2010, 7 age-2 largemouth bass and 13 pumpkinseed were held in individual aquaria for 12 weeks under simulated winter conditions without food and periodically measured for length and weight. In the winter of 2010-2011, age-0 and age-1 largemouth bass were held in aquaria for 8–12 weeks under simulated winter conditions without food and periodically measured for length and weight. In the winter of 2011-2012, age-0 largemouth bass were again held in laboratory aquaria for 10 weeks under simulated winter conditions.

Objective 2: To conduct pond experiments on pre-adult and adult fish to better understand and predict the allocation of energy to gonads versus somatic tissue, and to quantify the reaction norm for maturation – the combinations of size and age that result in maturation under different growing conditions.

Job 2. Title: Pond experiment on maturation and fecundity of walleye.–In May 2007, four ponds at the Saline Fisheries Research Station were stocked with juvenile walleye. Two ponds were given a low ration of minnows, and two were given a high ration of minnows, with the intent of producing groups of walleye of the same age but different in body size. The ponds were drained in spring 2008 to determine how body size affects the probability of maturation and fecundity of female walleye under these conditions.

Job 3. Title: Prepare for pond experiment with bluegill.–In spring 2007 several ponds were drained at the Saline Fisheries Research Station, and yearling bass were stocked into a separate pond. This will enable the bass to be used in a pond experiment during the next reporting period. In 2008-2009, four ponds (ponds 3, 10, 17, and 18) were drained at the Saline Fisheries Research Station. Bluegill, largemouth bass, and other fish were distributed among several ponds to prepare for pond experiments.

Job 5. Title: Pond experiment on maturation and fecundity of largemouth bass.–A pond study conducted in spring 2008 attempted to determine the timing of reproduction of largemouth bass according to the size of mature males and water temperature. Experimental ponds at the Saline Fisheries Research Station contain largemouth bass of a range of sizes. Temperature loggers recorded hourly water temperature in several ponds. Beginning on April 16, 2008, ponds with bass were observed almost every day for nests during the reproductive period. The first largemouth bass nest was discovered on May 9 in Pond 13. As nests were discovered, the males were captured by hook and line, measured for length (nearest 1 mm) and weight (nearest 1 g), and marked by inserting a PIT tag just below the skin on the ventral side just ahead of the pelvic fins. Dorsal spines were collected for age determination and a small piece of caudal fin tissue was taken for potential use in genetic analysis. A total of 16 nesting male bass were captured and tagged. Length of these males ranged from 314 to 436 mm. It turned out to be more difficult than anticipated to discover bass nests. To assist in determining the timing of reproduction, bass fry were sampled by seining or netting once or twice per week and a subset of these fry were aged by counting daily otolith rings in order to determine the date of hatch. Processing and analysis of the samples are continuing. Because of the need to obtain more information on the timing of bass spawning in relation to fish size, it was felt necessary to delay the planned measurement of fecundity to insure that sufficient females would be present in the ponds next year to provide eggs for all the males that were inclined to nest.

In spring 2011, we drained four ponds at the Saline Fisheries Research Station to obtain mature female largemouth bass. From each pond, we selected a subsample of about 10 females over the likely adult length range of bass in that pond. Those fish were measured for length (nearest 1 mm) and weight (nearest 1 g), and sacrificed. Ovaries were removed from 40 females and weighed (nearest 0.01 g). Subsamples of mature eggs from three locations in the ovary were weighed (nearest 0.01 g) and counted, and used to compute total number of mature eggs per female. Females ranged from 264 to 495 mm TL; average length was 370 mm. Estimated fecundity ranged from 7,885 to 99,991 mature eggs per female; average was 35,583 mature eggs per female.

Job 6. Title: Pond experiment on maturation and fecundity of bluegill.–A pond study conducted in this reporting period (2008-2009) attempted to determine the timing of reproduction of largemouth bass according to the size of mature males and water temperature, continuing the pond study reported last year (2007-2008). As noted in the amendment submitted during this reporting period, additional information on largemouth bass is needed soon to prepare an evaluation of bass regulations, and the pond experiments on bluegill were deferred. Because of the need to obtain more information on the timing of bass spawning in relation to fish size, it was

necessary to delay the planned measurement of fecundity to insure that sufficient females would be present in the ponds next year to provide eggs for all the males that are inclined to nest.

Job 11. Title: Pond experiment on timing of nesting of largemouth bass.–Ponds containing adult largemouth bass at the Saline Fisheries Research Station were monitored in spring 2010 to watch for nesting males. Although water clarity made it difficult to find all nests, several male largemouth bass were observed guarding nests. Nesting males were captured by hook and line, measured for length and weight. A PIT tag was inserted if scanning indicated that the fish was not already tagged. Digital temperature loggers present in the ponds recorded water temperature at hourly intervals. This data will be used to determine the cumulative degree-days of thermal exposure at which each male was observed to begin nesting. This information for largemouth bass will be compared with published information for smallmouth bass (Ridgway et al. 1991; Suski and Ridgway 2007) and used to estimate the timing of reproduction in relation to both the catch-and-immediate-release season and the harvest season for black bass in Michigan lakes.

Objective 3: To conduct pond experiments to evaluate the hypothesis that forage availability the previous fall influences the fecundity of walleye.

Job 2. Title: Pond experiment on maturation and fecundity of walleye.–In May 2007, four ponds at the Saline Fisheries Research Station were stocked with juvenile walleye. Two ponds were given a low ration of minnows, and two were given a high ration of minnows, with the intent of producing groups of walleye of the same age but different in body size. The ponds were drained in spring 2008 to determine how body size affects the probability of maturation and fecundity of female walleye under these conditions.

Objective 4: To further develop an existing model of interacting fish populations to include new information on growth, condition, energy density, fecundity, and size and age at maturation, and to incorporate simulated responses to alternative fishing regulations in order to compare management scenarios.

Job 4. Title: Develop and apply energetics-based population model.–I continued development and application of an energetics-based population model, modifying the preliminary model developed in earlier studies (Breck 1993, 1998) to include dynamic changes in body composition and energy density (Breck 2008). I have implemented the new model in the R language (R Development Core Team 2006) and used it to simulate individual fish in two previous lab experiments involving growth in length as well as weight of juvenile largemouth bass. Preliminary analyses involving model simulations of these experiments appear to confirm the recent evidence that largemouth bass respiration rate changes with ration level (Ranney 2008).

I continued development of an energetics-based population model, focusing on dynamic changes in body composition and energy density, working to include a reduction in respiration rate during winter, using lab data from Job 1. The model in the R language (R Development Core Team 2006) is being used to simulate individual fish in the lab experiments conducted under Job 1. It is clear that largemouth bass reduce their respiration rate during winter beyond the reduction that would be expected based only on the lower water temperatures.

I continued development and application of an energetics-based population model, focusing on dynamic changes in body composition and energy density (Breck 2008). The model in the R language (R Development Core Team 2006) is being used to simulate individual fish in my previous lab experiments as well as other published experiments and modeling studies involving changes in fish body composition (Huisman et al. 1979; Machiels and Henken 1986, 1987; Machiels and Van Dam 1987; Cacho 1990; Conceição et al. 1998). A talk on the development of

this model was presented at the December 2009 Midwest Fish and Wildlife Conference, in a talk titled "An enhanced bioenergetics model to predict growth in length and weight in juvenile largemouth bass."

An energetics-based growth model in R was used to estimate the relative growth of largemouth bass in all Michigan lakes larger than five acres. First, seasonal water temperatures were estimated for all 10,000 lakes in Michigan, using landscape variables and the method of Shuter et al. (1983). Second, seasonal water temperatures were estimated for a reference lake, constructed as the average of the daily values across all lakes. Third, the energetics model was used to simulate growth of largemouth bass in that reference lake, with the proportionate ration size of each age class adjusted so that bass length at age matched the average values for Michigan (Schneider et al. 2000). Fourth, using these constant values for proportionate ration size of each age class and changing only water temperature, simulations were run for all 10,000 lakes to estimate the expected change in bass size at age if water temperature were the only difference among lakes. This procedure results in an index value (relative bass size at age) for each lake that translates the predicted seasonal water temperatures into a relevant biological response.

Progress was also made in developing a second method of estimating water temperature, which uses a statistical approach modified from Matuszek and Shuter (1996). This new method finds a statistical relationship between 10-day running-average air temperature and the average daily water temperature as estimated from Shuter et al. (1983). In other words, this new method uses daily air temperature to estimate deviations from the long-term average daily water temperature. It is expected that this method can be used to make predictions about annual and daily variations in water temperature in previous years and thus help to explain observed temporal variations in fish growth rate in historic data.

Job 12. Title: <u>Evaluate catch-immediate-release season for black bass.</u>–A draft report evaluating Michigan's catch-and-immediate-release season for black bass was prepared by the Bass Regulation Evaluation Task Group: Breck, J. E., Chair, M. T. Bremigan, T. Galarowicz, T. Grischke, S. Hanshue, M. Thomas, G. Towns, B. Utrup, and T. Wills. The draft report, titled "Evaluation of the 2006 black bass fishing regulations," was submitted June 8, 2011 to Fisheries Division's Management Team. The report analyzed several sources of information and found no catastrophic effects on Michigan black bass populations that could be reasonably attributed to this fishing regulation. The report included several recommendations for additional research and monitoring of black bass populations. No changes to black bass regulations were recommended at this time. However, the task group recommended looking at black bass populations again in about five years, because it will take more information and time to detect small or moderate effects of this catch-and-immediate-release fishing regulation.

Job 7. Title: <u>Write annual performance report.</u>–This final performance report has been prepared in lieu of an annual report.

Job 8. Title: <u>Write manuscript for publication.</u>–Several manuscripts were prepared under this study. A draft manuscript was prepared for publication that describes the experiments conducted under this study that quantified over-winter weight loss for age-0, age-1, and age-2 largemouth bass. The manuscript also discusses modifications to previous bioenergetics models for largemouth bass that are required to make the model output consistent with data collected during this study. In particular, the metabolic rate of largemouth bass must be lower during winter than predicted by the bioenergetics model for this species reported in Rice et al. (1983). The bioenergetics model of Hewett and Johnson (1992) and Hanson et al. (1997) predicted lower metabolic rates at winter temperatures than the Rice model, but still overestimated winter weight loss, as did the largemouth bass model of Anett Trebitz (1991). The manuscript proposes an over-

winter depression of metabolic rate to reduce the model's predicted weight lost during winter and better match the observed weight losses by food-deprived age-0, age-1, and age-2 largemouth bass held for 10-12 weeks under winter temperatures.

Another manuscript prepared under this study was the draft report evaluating Michigan's catch-and-immediate-release season for black bass, prepared by the Bass Regulation Evaluation Task Group: Breck, J. E., Chair, M. T. Bremigan, T. Galarowicz, T. Grischke, S. Hanshue, M. Thomas, G. Towns, B. Utrup, and T. Wills. The draft report was submitted June 8, 2011 to the Fisheries Division Management Team.

Bass Regulation Evaluation Task Group: Breck, J. E., Chair, M. T. Bremigan, T. Galarowicz, T. Grischke, S. Hanshue, M. Thomas, G. Towns, B. Utrup, and T. Wills. Evaluation of the 2006 black bass fishing regulations. Submitted June 8, 2011 to Fisheries Division's Management Team.

Another manuscript prepared under this study describes a model for seasonal surface water temperatures in inland lakes. This model was used to help evaluate the black bass fishing regulations, including the timing of spawning in relation to the timing of the fishing regulations. The temperature model for surface water temperatures in inland lakes modifies the approach of Shuter et al. (1983). This manuscript is being revised, to allow application to a wider range of mean annual air temperatures, as currently occur in nearby states or as might occur in Michigan under climate change scenarios.

Job 9. Title: <u>Publish manuscript.</u>–The following three manuscripts were prepared and published. The first describes a new way to estimate body composition and energy density of fish, useful for enhanced versions of energetics-based growth models of fish. The acknowledgments section of the paper mentions support from the Federal Aid in Sport Fish Restoration Program, Project F-80-R, through the Michigan Department of Natural Resources Fisheries Division, and the Fish and Game Fund of the State of Michigan.

Breck, J. E. 2014. Body composition in fishes: body size matters. Aquaculture 433:40-49.

A second publication resulting (in part) from work under this study involved comments on proper ways to solve bioenergetic equations for modeling fish growth. This paper was prepared in collaboration with Raymond P. Canale. The acknowledgments section of this paper also mentions support from the Federal Aid in Sport Fish Restoration Program, Project F-80-R, through the Michigan Department of Natural Resources Fisheries Division, and the Fish and Game Fund of the State of Michigan.

Canale, R. P., and J. E. Breck. 2013. Comments on proper (and improper) solutions of bioenergetic equations for modeling fish growth. Aquaculture 404-405:41-46.

A third publication resulting (in part) from work under this study involved validation of a bioenergetic model for juvenile salmonids. This paper was prepared in collaboration with Raymond P. Canale, Karl D. Shearer, and Kathleen G. Neely. The acknowledgments section of this paper also mentions support from the Federal Aid in Sport Fish Restoration Program, Project F-80-R, through the Michigan Department of Natural Resources Fisheries Division, and the Fish and Game Fund of the State of Michigan.

Canale, R. P., J. E. Breck, K. D. Shearer, and K. G. Neely. 2013. Validation of a bioenergetic model for juvenile salmonid hatchery production using growth data from independent laboratory feeding studies. Aquaculture 416-417:228-237.

Job 10. Title: Write final report.–This final report was prepared.

Job 13. Title: Write study renewal to meet Fisheries Division needs for energetic-based approaches for evaluating fish population responses to alternative management actions and environmental change.–A study renewal was not completed due to a loss of personnel and shifts in division priorities.

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