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Growth of adult Florida largemouth bass in two small impoundments in Tennessee

Roy Brian Card

To the Graduate Council:

I am submitting herewith a thesis written by Roy Brian Card entitled "Growth of adult Florida largemouth bass in two small impoundments in Tennessee." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.

J. Larry Wilson, Major Professor

We have read this thesis and recommend its acceptance:

Richard J. Strange, Dewey Bunting

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Accepted for the Council:

Vice Chancellor
Graduate Studies and Research

A

GROWTH OF ADULT FLORIDA LARGEMOUTH BASS IN

TWO SMALL IMPOUNDMENTS IN TENNESSEE

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Roy Brian Card

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ABSTRACT

During an 18 month study, population and growth data were taken from 485 captures of Florida largemouth bass in two small Tennessee impoundments. Population densities of bass greater than 15.0 cm were estimated at 15 per ha in York Lake and 74 per ha in Lake Dickerson. Age analysis revealed the year-classes 1975 through 1980 in York Lake and 1976 through 1980 in Lake Dickerson. The mean back-calculated lengths achieved by York Lake bass (48 fish) at annuli 1 through 4 were 15.6 cm, 30.2 cm, 38.2 cm, and 42.6 cm, respectively. Mean back-calculated size at annuli and annual increments in both length and weight were greater for York Lake bass than Lake Dickerson bass (145 fish) at each age. Annual instantaneous growth rates, the von Bertalanffy growth coefficient (K), and the coefficient of condition (C) were all greater for York Lake bass than Lake Dickerson bass.

The growth of the Florida largemouth was compared to published reports of northern largemouth bass growth in Tennessee and surrounding states. Apparently, population density in relation to available forage was the major limiting factor on the Florida largemouth growth, rather than the shorter growing seasons and colder temperatures of Tennessee.

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CHAPTER I

INTRODUCTION

The largemouth bass, *Micropterus salmoides* (Lacepede), is the most widespread and abundant predator in the United States (Heidinger 1975). Its native range was originally restricted to the eastern United States from the Gulf of Mexico north to the Great Lakes and west into the Great Plains region. However, with the advent of private and government bass hatcheries in the early 1900's, naturalized populations of largemouth bass have gradually been established in waters throughout the continental United States and other regions of the world. The extensive construction of reservoirs and ponds has created suitable habitat for the largemouth bass in areas with previously ecologically unfavorable natural waters and therefore greatly enhanced the extension of its range. The largemouth bass, being so widespread and abundant a predator, plays a major ecological role in the balance of warmwater fish communities including other game fish populations.

In addition to its ecological importance, the largemouth bass is one of the most popular freshwater sportfish in the country. Our bass stocks are receiving increasingly heavy fishing pressure and concern has been mounting over the abilities of our resources to sustain quality fishing

(Anderson 1975). Although the quality of fishing is quite subjective, it has traditionally been measured in catch per angling hour. However, the author agrees with Anderson (1975) that large fish contribute more to quality fishing than an equal weight of smaller fish, because of more personal gratifications and memories. A relatively large potential size of largemouth bass is a principal attraction to many sport fisherman. Therefore density, size distributions, and maximum sizes of bass populations are important aspects of a quality bass fisheries.

Florida is world-renowned for its trophy largemouth which often grow to a size of 10 lb (4.5 kg) and larger. This large size was historically attributed to the longer growing season in peninsular Florida (Hubbs and Bailey 1940). However, with the recognition of a largemouth subspecies (*M. s. floridanus*, hereafter termed Florida bass) distinct from the common northern largemouth (*M. s. salmoides*, hereafter termed northern bass), fishery scientists have looked toward the Florida bass genotype as a management tool.

In 1959, California began introducing Florida bass into some of its southern reservoirs, many with existing populations of northern bass. The early investigations in California (Sasaki 1961; Miller 1965) and Florida (Clugston 1964) indicated superior growth of northern bass or no

significant size differences between the two subspecies during their early years of life. However, lakes in California stocked with Florida bass began producing a new state record every year. The state record was broken in 1968 with a 15 lb 5 oz (6492 g) fish and in 1973 the record topped 20 lb (at 9480 g) (Chew 1975). Lake Casitas, California, which was stocked with Florida Bass in 1968 and 1970, yielded the present state record of 21 lb 3-1/5 oz (9616 g) in March 1980 (Garrison 1980). The total length of the California record catch was measured at 27-5/8 in (70.1 cm) and meristic determinations indicated that it was a Florida bass (Garrison 1980). Apparent selection for the Florida genotype in most California test reservoirs was reported by Botroff and Lembeck (1978). They evaluated the Florida bass introductions as successful because of increased bass production and yield as well as high incidence of trophy-sized fish. Botroff and Lembeck concluded that a genetic difference between the Florida bass and the originally-stocked northern bass from Illinois resulted in these desirable changes in the bass fisheries of California.

The success of California's Florida bass plantings has prompted many state conservation agencies and researchers to introduce Florida bass into more northern waters or to study the feasibility of such a release (Childers 1975).

Although the introduction of Florida bass into warm waters outside their native range may benefit the largemouth populations, Childers warns that the introduction of the southern genotype into more northern waters may result in incorporation of maladaptive genes into the endemic northern bass populations. The genetic differences between the largemouth subspecies should be investigated exhaustively before further introduction of Florida bass in more northern waters are considered.

This research was designed to evaluate the growth of age 1 through age 5 Florida bass in two small Tennessee lakes. Growth information included observed and back-calculated growth histories in both length and weight as well as instantaneous growth rates, potential maximum size and condition of the two Florida bass populations. In addition, information concerning reproduction, survival, and populations densities was documented. Hopefully, this research adds to the understanding of the genetic influence on growth of Florida bass in more northern waters.

CHAPTER II

LITERATURE REVIEW

Initial observations on the growth of Florida bass in southern California ponds and reservoirs were summarized by Sasaki (1961). He reported no significant difference between the growth of Florida and northern bass during the first years of life (ages 0 and 1). Miller (1965) compared the growth rates of the two subspecies in Red Mountain Reservoir a 4.0 hectare (ha) impoundment in San Diego County, California. No significant difference in growth rates was observed for age 1 bass, although low numbers of recaptures, widely different initial sizes, and different stocking dates for the two subspecies resulted in inconclusive findings. Both authors concluded that the larger size of Florida bass in their native range was probably due to environmental influence and not genetic differences.

Clugston (1964) imported fingerling northern bass from Iowa and stocked them in hatchery ponds near Fort Lauderdale, Florida. In nearby ponds he stocked native Florida bass fingerlings of comparable size, and monitored the growth for 16 months. The northern bass obtained a larger size, although the difference was statistically insignificant. Clugston attributed the differences in

growth to variable water quality, temperature, and forage abundance between ponds.

These early investigators found no evidence of a superior growth rate in Florida bass at the early ages and the research interest in growth of the subspecies lagged. However, the previously mentioned success of Florida bass in California reservoirs indicated that the subspecies had inherent differences from northern bass, resulting in a larger maximum size, at least in areas where temperatures and the growing seasons were similar to those in Florida. As a result, research into the growth rate of the Florida bass outside its native range was renewed.

The growth differences of the two subspecies and their F_1 hybrid were evaluated in Alabama by Addison and Spencer (1971). They compared the growth of the three strains in 21 southern Alabama ponds, which ranged in size from 0.2 to 4.2 ha. There was little difference in the mean observed weights of age 1 fish, but the F_1 hybrids were somewhat larger. However, the Florida and hybrid bass grew both larger and faster than the northern bass at the ages of 22 and 27 months, with the hybrid bass achieving the greatest growth. The hybrid bass had observed mean weights of 858 g and 1292 g at 22 and 27 months, respectively, and the Florida bass had mean weights of 848 and 1073 g at the same ages. The significantly slower growing northern bass reached mean weights of 728 g (at 22

months) and 896 g (at 27 months). A hybrid bass attained the largest observed weight of 3420 g at 27 months, while the largest Florida bass weighed 2549 g and the largest northern bass weighed only 2132 g. The authors also emphasized that the hybrid and Florida bass exhibited a larger size variance in samples than did the northern bass. They suggested that the results indicated genetic differences in growth potential after the first year of life, although too preliminary to be conclusive because of pond differences.

In another study, both subspecies and the F_1 hybrid were stocked separately in three 0.04 ha ponds on the Alabama Agriculture Experiment Station and growth of the first summer was compared (Zolczynski and Davies 1976). The mean weight gains for 120 days were 225, 175 and 158 g for northern, Florida, and hybrid bass, respectively. The northern bass grew significantly faster than both the other strains, but growth rates of the Florida and hybrid bass did not differ significantly, further documenting no inherent growth advantage for the Florida genotype through age 1.

Two Tennessee studies also reported on growth differences between the subspecies in the first year of life. Smith (1976) conducted a split-pond study in Blount County, Tennessee, with one of the subspecies in each side of two ponds. The northern bass grew at a significantly faster rate through the first 5 months of the study. Warren (1977) reported that age 0 Florida bass grew significantly faster

in laboratory studies than same age northern bass in only one of five pools, with no difference between subspecies in the remaining pools.

The reports on test introductions of Florida bass in Texas and Oklahoma yielded some of the first information, which included older fish, on the observed growth potential of the subspecies in more northern latitudes. Inman et al. (1977) reported on the growth of the two largemouth subspecies and their F_1 hybrid after stocking age 1 fish in a 3.64 ha lake in north-central Texas. Strain differences in annual length and weight increments, condition as measured by the weight on length regressions, and parameters of the von Bertalanffy growth curves were compared. Similar absolute length gains were achieved by the strains during age 1, although the northern bass were in better condition during this interval. Differences in growth rates of the strains became apparent during age 2, with the average length increment for the hybrid (5.7 cm) almost twice the size of the Florida bass increment (3.2 cm) and three times as large as the northern bass age 2 increment (1.7 cm). The Florida and hybrid strains also surpassed the northern bass in condition during age 2, with the hybrid showing a significantly better condition than Florida bass. The growth rates of the hybrid bass slowed considerably during age 3, gaining only 0.6 cm; however, the Florida bass continued

rapid growth, gaining 4.3 cm, while the northern bass gained 2.3 cm in length. Best overall length gain was achieved by Florida bass although the hybrids gained more weight over the 3 year period. The northern bass grew significantly slower than the other two strains and also were less variable in length and weight. The heaviest Florida and hybrid bass both weighed 1861 g and the heaviest northern weighed 1771 g. Illustrating growth trends for the three years, the von Bertalanffy growth curves of the hybrid and Florida bass were almost identical except for initial size, and their curves showed significantly faster growth than that for the northern bass. Since the strains were raised in the same lake, Inmann (1977) concluded that "the superior growth of the Florida genotype . . . . appeared genetically controlled."

The first Oklahoma report documented initial attempts to stock marked Florida and northern bass in Boomer Lake and observe their growth and biology (Regier and Summerfelt 1976). Boomer Lake has a surface area of 40.8 ha and receives a thermal effluent from a gas-powered steam plant. The authors suggested that Florida bass may better utilize thermally enriched areas of more northern climates than the native bass. Due to low over-winter survival and poor mark retention, only observations to age 1 were collected. The daily instantaneous growth rate (G_d) was calculated from mean sample weights and compared among the subspecies.

Of the 1974 year-class, the Florida bass (G_d=0.0097) grew slightly faster than the stocked northern bass (G_d=0.0086) from the July stocking to February. June to May growth rates of the 1975 year-class showed that the Florida bass (G_d=0.0063) grew significantly faster than the northern bass (G_d=0.0038). The growth difference for the 1975 year-class occurred almost totally in the July to October interval when the Florida bass had a growth rate of 2.58 compared to the northern rate of 1.03. The results from these two year-classes indicated, for the first time, a growth advantage for Florida bass before age 1.

Further investigations of additional Boomer Lake introductions were conducted by Nieman (1978). The Florida bass were smaller than the northern bass at stocking and this initial size difference affected the first year's growth comparisons. However, the Florida bass did grow significantly faster over the first summer and at twice the northern rate the first winter, but the winter difference was statistically insignificant. The northerns grew faster (G_d=0.0047 for northern and 0.0037 for Florida bass) in the second year (age 1). Nieman (1978) evaluated the Florida bass introductions as unsuccessful because of their low over-winter survival, failure to reproduce, apparent competition with northern bass for food and habitat, and failure to obtain as large an average size as the northern

bass. However, observations in Boomer Lake were the first to document greater growth of Florida than northern bass during age 0.

A similar experiment in Dripping Springs Lake, a nearby Oklahoma reservoir, provided somewhat contradictory results (Wright and Wigtil 1980). Dripping Springs Lake, a new 402 ha reservoir, was originally stocked with marked individuals of both subspecies and their F_1 hybrid. Mean lengths and weights were obtained every fall and spring over a 4 year period (ages 0 to 3). The fall sample at age 0 showed no length or weight differences between the two subspecies, but both were significantly longer and heavier than the hybrids. However, during the summer of age 1 the Florida bass became significantly longer and heavier than the northern bass and remained so throughout the next 2 years. The mean lengths and weights of hybrids were either similar to or significantly greater than those of northern bass from spring of age 2 until the end of the study (fall of age 3). Lengths and weights of the Florida bass varied the most within most samples and hybrids varied the least. The heaviest Florida bass collected weighed 2778 g compared to weights of only 1701 g and 1588 g for the heaviest hybrid and northern bass, respectively. Relative weights, as an index of condition, were also compared and the only significant difference between the two subspecies was a better fall condition for Florida bass at ages 2

and 3. Examining the results of superior Florida bass growth after 18 months of life and no difference in over-winter survival between the strains, the authors concluded, contradictory to Nieman (1978), that Florida bass introductions into Oklahoma reservoirs could increase the quality of the native fisheries through larger average and maximum sizes of largemouth bass.

In summary, the evidence for superior growth potential of the Florida genotype has varied in results. No significant advantage in growth at early ages of Florida over northern bass was observed in California (Sasaki 1961; Miller 1965; Botroff and Lembeck 1978), Florida (Clugston 1964), Alabama (Addison and Spencer 1971; Zolczynski and Davies 1976), Texas (Inmann et al. 1977), or Tennessee (Smith 1976). Contradictory results, finding a significantly more rapid growth of Florida over northern bass at age 0, were reported in Boomer Lake, Oklahoma (Regier and Summerfelt 1976; Nieman 1978).

The majority of studies with observations of fish age 2 and over have indicated superior growth rates and larger size variance of older aged Florida bass, accounting for larger average and maximum sizes. Superior growth expressed by the Florida or hybrid bass was reported in the southern waters of California (Botroff and Lembeck 1978) and southern Alabama (Addison and Spencer 1971) as well as Texas (Inmann et al. 1977), and as far north as

north-central Oklahoma (Wright and Wigtil 1980). Growth studies in the more northern states of Missouri (Graham 1973), Oklahoma (Nieman 1978), Ohio (Stevenson 1973)and other midwestern states (Johnson 1975) have been hampered by low over-winter survival of young-of-year Florida bass.

CHAPTER III

DESCRIPTION OF STUDY AREAS

This study was conducted on two small impoundments in meteorologically and geologically diverse areas of eastern Tennessee. York Lake is a 2.4 ha impoundment on the Clyde York 4-H Camp in Cumberland County, Tennessee. This lake is in the upper Caney Fork watershed on the eastern rim of the Cumberland Plateau, at an elevation of 573 m. The watershed, for both York Lake and an additional 0.8 ha pond, is primarily planted pines and grass pasture.

York Lake has an average depth of 1.8 m and a 5.1 m maximum depth at full pool. The lake is devoid of permanent submerged structure except for a small dock and widely scattered stumps. *Chara spp.*, an anchored macroalgae, covered at least one third of the lake bottom during the summer months of the study period. An attempt to control the *Chara* in June of 1980, with a 1.2 ha treatment of Hydout (at a rate of 55 kg per ha), had little apparent effect on the alga growth.

Baseline water quality parameters were measured to insure that these factors were not limiting bass growth. Total alkalinity of York Lake was 30 mg/l and the pH was 7. Secchi disk visibility ranged from 1.3 m (September) to 4.6 m (July). The maximum recorded surface water

temperature was 33°C in June. Summer stratification did develop in summer months but the oxygen concentration of the top 2 meters was always near saturation.

The other study impoundment, Lake Dickerson, is located on the property of C. F. Industries (CFI) in south Hamilton County, Tennessee. The lake is in the Big Valley of the Tennessee River approximately 4.8 km east of Chickamauga Dam, at an elevation of 218 m above sea level. The lake-basin was excavated in the summer of 1975, for the purpose of CFI employee recreation and was filled initially in the fall of the same year. The watershed is mostly planted pines, with additional water inputs from the CFI reserve water tank (originally drawn from Chickamauga Lake).

Lake Dickerson's surface area of 2.2 ha at full pool is divided approximately in half by an east-west levee. Two 0.5 m metal culverts through the levee, connect the two sides of the lake, 1.0 m below full pool. The north side (hereafter termed shallow side) of the lake has an average depth of 2.1 m, with a maximum depth of 4.8 m. The south side (hereafter termed deep side) has an average and maximum depth of 3.4 m and 7.6 m, respectively. Large stumps provide most of the submerged structure, along with a few brush piles.

The total alkalinity and pH of Lake Dickerson waters was measured at 138 mg/l and 7.4, respectively. The Secchi

disk visibility varied from 0.4 m (March) to 3.0 m (January). The maximum recorded temperature of surface waters was 30°C in June. Oxygen concentrations were always adequate for growth in Lake Dickerson, except in the bottom meter during summer months.

CHAPTER IV

MATERIALS AND METHODS

Fish Stocks

York Lake, being an older impoundment with an established fish population, was renovated in preparation for the study, in the fall of 1973. Later that fall, bluegill and redear (3:1 ratio) were stocked at a rate of 1850 per ha. On 23 May 1974, Florida bass fingerlings were stocked at 350 per ha. The average length and weight of bass at stocking were 4.4 cm and 1.2 g.

Although some poaching of bass occurred, the fishing pressure on York Lake bass was low due to limited accessibility. No information regarding angler harvest of bass was collected. However, radical thinning of the Florida bass population was observed in September 1976. The excessive growth of *Chara* that summer precipitated the untimely use of an aquatic herbicide, which resulted in the death of substantial numbers of fingerlings and larger bass. The fish-kill probably resulted from a large oxygen deficit in the lake, created from rapid decomposition of the *Chara*. The impact of this die-off on the bass population was not quantitatively assessed.

Lake Dickerson was initially stocked in early March 1976, with bluegill and redear (3:1 ratio) at a rate of

1230 per ha, as well as channel catfish fingerlings at 135 per ha. A month later, Florida bass fingerlings were stocked at a rate of 250 per ha. All fish species stocked in Lake Dickerson were distributed equally to each side of the lake.

Since Lake Dickerson is inside a fenced reservation with access only through a manned gate, fishing pressure was easily controlled and monitored. Harvesting of the Florida bass was prohibited the first two years after stocking. Beginning in the spring of 1978, removal of bass by angling was allowed. CFI personnel collected the creel information, including the numbers and types of fish removed and associated lengths and weights.

Data Collection

Florida bass samples obtained from each lake were as follows: an initial sample in the summer of 1979, monthly samples from September 1979 to September 1980, and a final sample in late fall 1980. Samples were collected with a boat electroshocker. The unit included a 110v AC generator with a rheostat and 4X step-up transformer mounted on a flat-bottom boat. Electrofishing with 250v AC current was conducted from dusk of each sampling date until early the next morning. At least two circuits of the lake shore were electrofished, with additional circuits made if the sample size was insufficient (less than 10 fish from York Lake and

less than 20 fish from Lake Dickerson). Collections by angling were also made at various sample dates, using artificial lures only. Additional samples were collected during the summer months with a minnow seine in order to document reproduction of the Florida bass.

Prior to the final collection in October, York Lake was drained to a size of approximately 0.6 ha and 2 m maximum depth. In addition to electrofishing, an attempt was made to seine most of the body of water. Three seines (two seines 30.5 x 1.8 x 0.03 m, and one 17.1 x 1.8 x 0.01 m) tied end to end were hauled through the main water body, while persons seined the shallow water with small mesh minnow seines.

After capture, the bass were anaesthetized in a concentration of 0.075 g/l MS-222 (tricaine methanosulfate). Upon immobilization, the fish were measured in total length (to the nearest tenth of a centimeter) and weighed to the nearest gram on a triple beam balance. The larger fish (over 1500 g) were weighed to the nearest 10 g, using a Chatillion hanging spring scale (6 kg maximum).

The left pelvic fin of each bass was clipped above its base at first capture. Scales were taken from all "first-capture" fish for subsequent age and growth analyses. A sample of at least 10 scales was removed with a dull knife from a place posterior to the tip of the depressed

left pectoral fin and either above the lateral line (if collected before February 1980) or below the lateral line (if captured after February 1980). These scale samples were stored in envelopes on which the date of capture, length, weight, mark, and lake were recorded.

After data collection and marking, the fish were placed in a live basket (1.0 m in diameter and 1.2 m deep) in the lake. The bass were released into the lake following the sampling effort and recovery of the fish from the anaesthesia.

Population Estimates

The multiple census method was employed to obtain mark-recapture data, which was analyzed for estimates of bass population numbers in each lake. Direct sampling, with sample size dictated by fishing success, was performed over a 10-month period (September to April) as described in Data Collection (p. 18). The basic population data collected at each sampling were n_i = total number of fish captured in sample i, m_i = total number of marked fish in sample i, d_i = total number of fish removed during sample i, and M_i = total number of marked fish in the population just before sample i.

Adherence to the assumptions of the multiple census method were discussed. The assumptions included the basic mark-recapture assumptions of a permanent mark, random

mixing of marked and unmarked fish, as well as the assumption of a closed population.

Two analysis techniques, the modified Petersen and modified Schumacher methods, were employed to calculate population estimates. A modified Petersen estimate (N^*) was calculated after each sample, by the formula:

$$N^* = \frac{(M_i+1) \cdot (n_i+1)}{m_i+1} \quad \text{(Ricker 1975).}$$

The mean of the sample estimates (N^*'s) was considered the best estimate of population size of a lake from the Petersen method. The confidence interval of the mean estimate was derived from the variance of the sample estimates about the mean (Ricker 1975).

The modified Schumacher estimate was derived from the simple linear regression, through the origin, of the proportions of recaptures in each sample (m_i/n_i) on the number of marked fish in the population at the time of sampling (M_i), and weighted by sample size. The inverse of the regression slope provided the Schumacher estimate ($\hat{N}$) (Ricker 1975):

$$\hat{N} = \frac{\Sigma(n_i \cdot M_i)^2}{\Sigma(m_i \cdot M_i)}$$

The confidence intervals of Schumacher estimates were computed following the procedures of Ricker (1975).

Age Analysis

Each sample of scales was removed from the envelope and placed into a petri dish to rehydrate and soften the scales. Upon examination with a dissecting microscope, all scales with regenerated centers or abnormal shape were discarded and up to eight normal scales were cleaned of excess mucous and skin tissue. The cleaned scales were mounted between two standard glass slides and the ends of the slides were tightly wrapped with tape. Lake, mark, identifying number, and date of capture were transferred from each scale envelope to the corresponding slide.

The establishment of criteria for interpretation of scale features has increased the accuracy and validity of aging by scales (Carlander 1956; Regier 1962). Therefore, criteria for distinguishing annuli from "accessory" marks were established, following those outlined by Prentice and Whiteside (1974). The scale features considered most useful in identification of a scale mark as an annulus were: (1) the mark was preceded by narrowly spaced circuli and followed distally by wider spaced circuli, (2) anastomoses or "cutting off" of circuli in the lateral field, (3) extension of the mark into all fields of the scale, and (4) the mark being equally well-defined in all scales of a fish. However, some subjectivity remained in the interpretation of scale features.

Negligible or no growth in the late winter months was assumed; thus, in aging a fish collected during the interval from January to annulus appearance in the spring, an annulus was read at the scale margin.

Mounted scales were examined at 48X magnification in a modified Microfiche reader. Using the criteria, two independent readings of each scale sample were made by the author without any knowledge of fish size. This procedure was an attempt to eliminate prejudgement of a fish's age by its size. The duplicate readings were then compared, and if the ages differed, a third reading was conducted and the fish was assigned an age using all available information. Carlander (1956) believed that more serious errors occur if difficult scales are eliminated, than if the fish are included and assigned the most probable age.

The validity of the scale method for age and growth analysis of the Florida bass populations was examined by the fulfillment of the following criteria (Prentice and Whiteside 1974): (1) annulus formation occurs regularly over a short interval, (2) empirical lengths increase with the number of annuli read, and (3) back-calculated lengths of older fish at younger ages agree with empirical lengths of fish captured at the ages.

Upon determination of the annuli positions, four scales from each individual were measured along the mid-line

of the anterior field, from the focus to each annulus and to the scale margin. The mean annuli and scale radius measurements of each fish were used in the back-calculation of growth.

Back-Calculated Growth

Several representations of growth were calculated to attempt a full description of the Florida bass growth. Growth analyses were calculated separately for each lake. Analysis of growth by the scale method was conducted only on samples from fish at "first capture," to avoid a bias in regression analyses stemming from repeated samples from the same individuals.

The relationships of body length-scale radius were used in back-calculating lengths at annuli. Absolute growth in length was then described by average lengths attained at annuli and also the average annual length increments (absolute growth rate). The absolute growth in length was then converted to the weight dimension, using the general length-weight relationships.

Annual instantaneous growth rates in weight were computed and von Bertalanffy curve parameters were estimated, using the back-calculated length data.

Absolute growth in length. The body length-scale radius relationship has routinely been described by the

least squares estimate of the linear regression of length on radius for use in back-calculating lengths at annuli. However, body-scale measurement data do not conform to the assumptions of the least squares method and the geometric mean estimate of the functional regression (G. M. regression) provides less biased regressions (Ricker 1973). Therefore, the length on radius regressions used in back-calculating of length were fitted by the G. M. method. However, no procedures for statistical testing (such as covariance analysis, testing of regressions slope differences, testing of the difference in a slope and a constant, etc.) have been developed for the G. M. regressions. Ricker (1973) suggested that standard least squares regressions and least squares test procedures be performed in addition to computation of the G. M. regressions. Ricker also suggested that the results of least squares statistical tests be assumed indicative of the G. M. regression differences, although this assumption is not necessarily valid. Therefore, least squares analyses were performed and they were considered indicative of G. M. regression differences. However, only the length on radius regressions calculated by the G. M. method were used in the back-calculations of lengths.

The bass were grouped within lakes by the place of scale procurement (above or below the lateral line) for

investigation of the length on radius regressions. Statistical analyses using the least squares method were conducted to determine whether a separate regression for the above-line and below-line groups within each lake provided a better explanation of the length-radius relationship than did a common regression for each lake.

Total lengths at each annulus and at capture were predicted from each fish's mean annuli and scale radius measurements, respectively, using the appropriate G. M. length on radius regression. The predicted lengths at annuli were then corrected for the variance of an individual's scale size from the mean, multiplying by the ratio of observed to expected lengths at capture (Carlander 1980). Therefore, back-calculated lengths at annuli were computed for each fish, from the formula:

$$L_n = [a + (b \cdot S_n)] \cdot (L / L_c)$$

where,

L_n = back-calculated length at annulus n,

a, b = the Y-intercept and slope of the appropriate G. M. length on radius regression,

S_n = distance (mm) to annulus n on the magnified scale image,

L = empirical length at capture, and

L_c = predicted length at capture = a + (b x S_r) where S_r = scale radius.

Absolute growth histories were reported as average lengths at annuli for each year-class within each lake.

Annual absolute growth rates (annual length increments) for each completed year of life of each individual were computed by the formula: $IL_n = L_n - L_{n-1}$, where IL_n was defined as the annual length increment for the year n of life (demarcated by annulus n-1 and annulus n on the scale). For example, an increment for the fourth year of a fish's life was computed as the length at annulus 3 subtracted from the length at annulus 4.

Absolute growth in weight. The general relationship between the growth dimensions of weight and length was described by fitting the observed data to the linear regression of the logarithm of weight (logW) on the logarithm of total length (logL), for each lake separately. As with the length-radius data, the logW-logL data does not conform to the least squares basic assumptions; thus, the G. M. regression method should be employed to predict weight from length (Ricker 1973). Therefore, following the procedures outlined in discussion of length on radius regressions (p. 24), each logW on logL regression was estimated by the least squares method for use in statistical analyses and the G. M. regression was used for prediction of weight.

Absolute growth expressed as weights at annuli were computed by substituting the back-calculated lengths at annuli for each individual into the appropriate length-weight relationship:

$$\log W_n = a + (b \cdot \log L_n)$$

where,

W_n = back-calculated weight at annulus n, and

a, b = the Y-intercept and slope of the lake's G. M. regression of logW on logL.

Annual weight increments (IW_n) were then computed for each year of life of each individual by the formula:

$$IW_n = W_n - W_{n-1}.$$

Growth models. The growth coefficients (instantaneous rates of increase) in the model of exponential growth in weight were calculated following the procedures outlined in Ricker (1975). First, the annual instantaneous growth rate in length (g_n) was computed for each completed year's growth of each fish, by the formula:

$$g_n = \log_e L_n - \log_e L_{n-1}.$$

The individual rates in length were then averaged by year within each year-class. These mean instantaneous rates in length ($\bar{g}_n$) were multiplied by the slope of the general logW on logL regression to obtain the mean instantaneous rates of weight increase ($\bar{G}_n$) for each completed year of life of each year-class.

A generalized description of the growth pattern throughout life in each lake was described by the von Bertalanffy equation:

$$L_n = L_\infty \cdot [1 - e^{-K(n-t_o)}]$$

where,

L_n = mean length at annulus n (or age n),

L_∞ = theoretical maximum length,

K = a measure of the rate at which length approaches the asymptote L_∞, and

t_o = time at length 0, if growth had always followed the described pattern.

The Beverton method as outlined in Ricker (1975) was used in estimating the von Bertalanffy parameters. The data used in fitting the equations were mean lengths at annuli (1 to 4), for each year-class, age group (aged 2 and older). First, the G. M. regression of $\bar{L}_{n+1}$ on $\bar{L}_n$ was used to determine the Ford equation and provide preliminary estimates of L_∞ and K. The estimate for L_∞ was then used in the least squares regression of $\log_e(L_\infty - \bar{L}_n)$ on age n, which should be straight. The straightness of the line is sensitive to the L_∞ used; and the L_∞ producing the best fit (highest R^2 value) was determined along with the corresponding K and t_o values.

Condition

The length-weight relationship for isometric growth was used to study the condition or well-being of the bass populations. The coefficient of condition (C) was calculated for individual fish by the formula (Ricker 1975):

$$C = \frac{100 \cdot (\text{weight in grams})}{(\text{length in centimeters})^3}$$

CHAPTER V

RESULTS AND DISCUSSION

Population Estimation

The mark-recapture data collected during the census period included a total of 75 capture observations from York Lake and 161 from Lake Dickerson. In York Lake, the nine samples collected in the census averaged 8 fish (2 to 11). In Lake Dickerson, the sample sizes ranged from 11 to 50 and averaged 18. The first recaptures were obtained in the third sample in both lakes. The number of recaptures in individual samples ranged from 3 to 7 in York Lake and from 5 to 28 in Lake Dickerson. The total numbers of marked fish in the populations just before the last sample (M_i) were 30 in York Lake and 101 in Lake Dickerson.

The size of the population of bass over 15.0 cm in length was estimated for each lake. The mean Petersen ($\overline{N}$*) and Schumacher ($\hat{N}$) estimates and their 95% confidence intervals are as follows:

Lake	Mean Petersen	Confidence Interval	Schumacher	Confidence Interval
York Lake	35	29-40	37	32-43
Lake Dickerson	153	100-170	163	133-192

The Petersen was less than the Schumacher estimate in both lakes. Ricker (1975) reported that the Schumacher method

produces the most reliable estimates; therefore, that estimate was used in comparisons.

The basic mark-recapture assumptions were adequately satisfied in the census. The mark (fin clip) was considered permanently identifiable over the entire census period. Although some regeneration of clipped fins occurred, the marks could still be identified by the waviness of the regenerated tissue. The month or more between sample times was considered adequate for random mixing of marked and unmarked fish. Although the sampling gear was undoubtedly selective, low selectivity of smaller fish was not considered a problem due to the establishment of minimum lengths for the population to be estimated.

The multiple census method also requires a closed population (no recruitment or mortality). The establishment of a minimum length at rather distinct gaps in the length ranges should have minimized recruitment into the population through growth when combined with a restricted census period. No evidence of unknown mortality or recruitment was expressed as a general trend (increase or decrease) in the series of sample Petersen estimates (Appendix A). Therefore, the assumption of a relatively constant population for the census period was considered valid.

The Schumacher estimates for the described bass population, reported as number per ha, were 15 for York

Lake and 74 for Lake Dickerson. The low density in York Lake may have resulted from the 1976 die-off and low subsequent reproduction and survival in competition with a dense sunfish population.

Age Determination

Scale samples collected from individuals at first capture were interpreted for age analysis. The assigned age-group number represented the number of annuli read on the fish's scales. For example, an age 3 individual had three annuli on its scales and was in its fourth year of life. Since the study period extended through January 1980, each year-class (except the 1980 year-class) may have contained fish of two different ages.

Age comparison of the first two independent scale readings on each sample resulted in agreement for 81% of the 244 bass in both lakes combined. The final year-class distribution of the 79 "first captures" from York Lake was as follows: 1980--28, 1979--5, 1978--23, 1977--4, 1976--12, and 1975--7. Twelve (15%) of the scale samples required a third reading for age assignment. Lake Dickerson age analysis was conducted on 165 of 180 "first captures," of which 34 (21%) of the individuals disagreed on the first two age assignments and required additional analysis. The age analysis resulted in the following year-class distribution: 1980--20, 1979--9, 1978--55, 1977--69, and 1976--12.

The validity of the scale method for age and growth analysis of largemouth bass populations has been supported as far south as Alabama (Prather 1966) and central Texas (Prentice and Whiteside 1974). In York Lake, annuli first appeared at the edge of the scales in the May sample. All fish in samples collected after June exhibited the current year's annulus; however, only two first capture bass were collected in July and August. Lake Dickerson bass began forming annuli by the end of April and all fish collected after July had formed the current year's annulus. These observations indicated relative compliance with the criteria of regular annulus formation over a short time interval (2 to 3 months). Upon investigation of mean empirical lengths, an increase in the lengths with increasing age of the fish further supported the validity of the scale method (Appendix B). A final criterion comparing back-calculated and empirical lengths was discussed with the growth analysis.

Back-Calculated Growth

Absolute growth in length. The G. M. and least squares estimates of the body length on scale radius linear regressions were computed for each place of scale procurement (above or below the lateral line) within each lake and for each lake (Appendix C). Using the least squares

estimates, statistical analysis indicated that fitting a separate line for each place-group within each lake significantly ($p < 0.0001$) reduced the unexplained variation of one common regression for each lake. Therefore, two different regressions (G. M. method) were used in the back-calculation of lengths for each lake.

The York Lake regressions for above (N=38) and below (N=41) the lateral line were $L = 5.87 + (0.1495 \cdot S)$ and $L = 2.07 + (0.1433 \cdot S)$, respectively. Lake Dickerson length on radius regressions (G. M.) were $L = 2.13 + (0.1879 \cdot S)$ and $L = 3.19 + (0.1471 \cdot S)$ for above (N=86) and below (N=79) the line samples, respectively (Figure 1).

Steeper regression slopes were calculated for scale samples from above the lateral line as compared to below in both lakes. The York Lake regressions were similar in slope with the larger Y-intercept for the above-line sample accounting for much of the difference. However, in Lake Dickerson, the above-line sample exhibited a slope evidently steeper than the below-line sample. The difference in length-radius relationships for samples acquired above and below the lateral line were expected because of the variability in scale development on a fish's body. The below-line samples in both lakes included smaller fish than the above-line samples and the range differences probably accentuated the place of procurement effect. Collecting

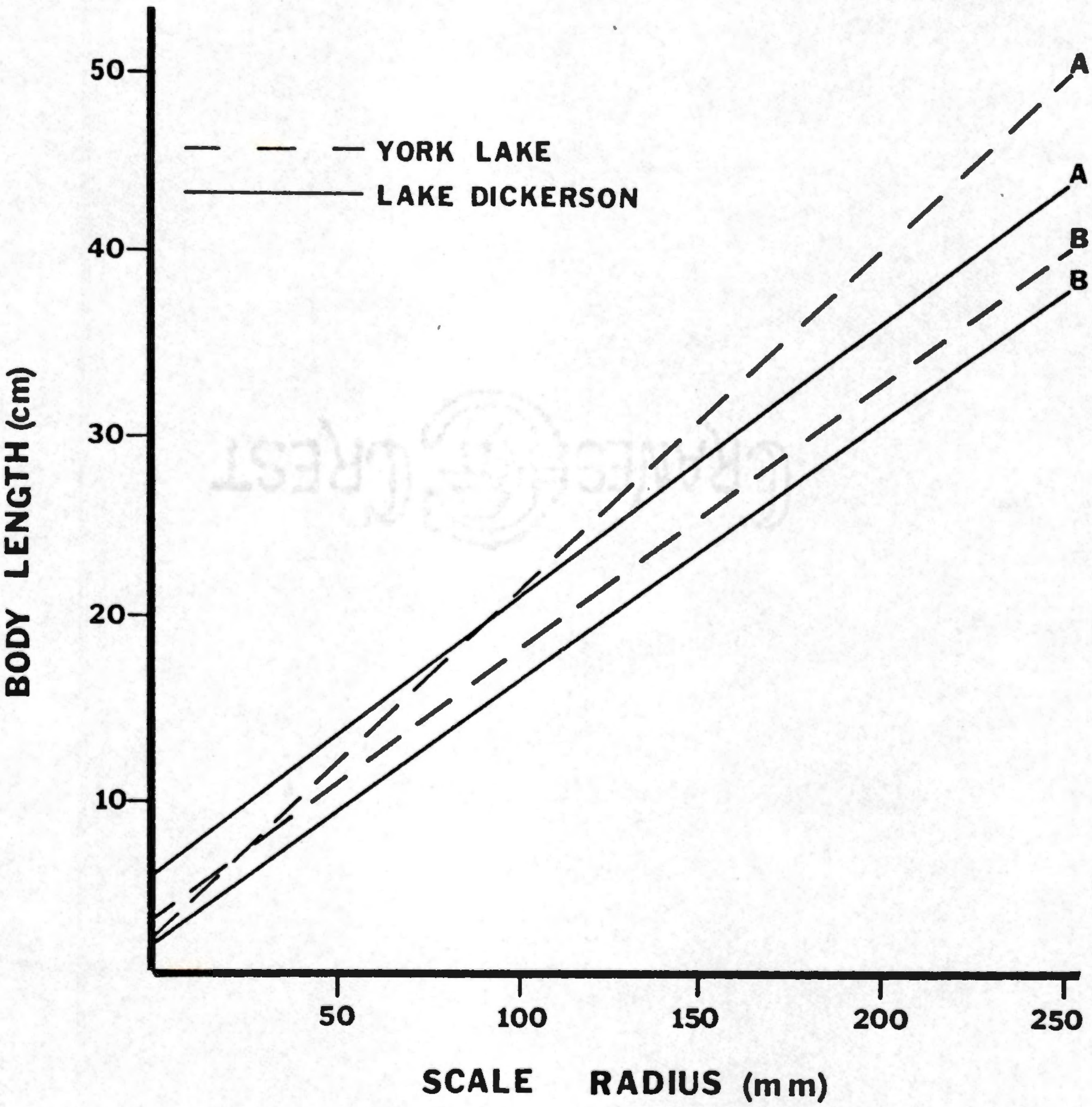

Figure 1. The G. M. regressions of body length on scale radius for the above the above the lateral line and below the lateral line groups of Florida largemouth bass in each lake. A indicates above-line equations and B indicates below-line equations.

all scale samples from one place on the fish's body would have increased the accuracy of back-calculation.

Absolute growth, expressed as lengths at annuli, was calculated for 48 Florida bass from York Lake and 145 from Lake Dickerson. In addition, average annual length increments were calculated for the fish. The results for York Lake and Lake Dickerson were summarized in Tables 1 and 2, respectively. The mean lengths at annuli and sample size, as well as mean length increments were computed for each year-class and for all year-classes combined within each lake.

The grand means (means of all year-classes combined within a lake) of lengths at annuli were larger for York Lake bass than Lake Dickerson bass at annuli 1, 2, and 3. The grand mean lengths at annulus 4 differed by only 0.1 cm, resulting in an apparently large growth for the fourth year (annulus 3 to 4) of fish from Lake Dickerson. However, the grand mean increments were greater for York Lake than Lake Dickerson for all years of life, including the fourth year. Ricker (1969) stated that growth rates calculated from mean lengths of different aged fish would be biased if differential growth was expressed by the ages. Increments calculated individually and then averaged do not reflect such a bias. Therefore, the grand mean annual increments were smaller in Lake Dickerson for years 3 and 4

Table 1. Mean back-calculated lengths (cm) and annual length increments (cm) for Florida largemouth bass in York Lake, by year-class.[a]

Year-Class	N	Annulus 1	2	3	4
1979	2	9.9			
		9.9			
1978	23	16.1	29.6 (6)		
		16.1	14.9		
1977	4	17.8	32.8	35.6 (2)	
		17.8	15.0	5.3	
1976	12	15.1	31.3	39.0	40.9 (3)
		15.1	16.1	7.7	4.1
1975	7	15.1	27.5	37.7	43.3
		15.1	12.4	10.2	5.6
Total N		48	29	21	10
Grand means					
Length		15.6	30.2	38.2	42.6
Increment		15.6	14.7	8.3	5.1

[a]Parentheses indicate the subset of the designated year-class sample captured at the oldest age.

Table 2. Mean back-calculated lengths (cm) and annual length increments (cm) for Florida largemouth bass in Lake Dickerson, by year-class.[a]

Year-Class	N	Annulus 1	2	3	4
1979	9	9.8			
		9.8			
1978	55	12.6	23.1 (34)		
		12.6	9.8		
1977	69	15.2	25.3	30.0 (20)	
		15.2	10.0	3.5	
1976	12	19.1	30.0	37.2	42.5 (4)
		19.1	10.9	7.1	4.1
Total N		145	115	32	4
Grand means					
Length		14.2	25.1	32.7	42.5
Increment		14.2	10.1	4.8	4.1

[a]Parentheses indicate the subset of the designated year-class sample captured at the oldest age.

(4.8 and 4.1 cm, respectively) than mean length differences for the same years (7.6 and 9.8 cm, respectively). The difference indicated a trend in year-class growth in Lake Dickerson that was not evident in York Lake.

The York Lake bass population contained year-classes with relatively similar lengths at annuli (Table 1), considering the large natural variation in individual growth and the small sample size of some year-classes. Year-classes may have consisted of fish caught at two ages, because the sampling was conducted through January. Therefore, even within individual year-classes, the final year's growth was best expressed by annual increments. The largest year-class mean increments for each year of life (except year 4) in York Lake was in the 1977 growing season and the next largest increment was in the 1978 growing season. These two years immediately followed the 1976 die-off. No other definitive trends were expressed in the year-class mean lengths and increments of York Lake; thus, the grand means were relatively representative of average growth patterns.

Lake Dickerson bass exhibited a trend of progressively smaller lengths at corresponding annuli for successive year-classes (Table 2). This trend is often found in new lakes, when originally stocked fish are the fastest growers and increasing bass densities with lake age result in slower growth of the later year-classes (Carlander 1977). The

stocked year-class (1976) attained lengths at annuli similar to York Lake grand means; however, the 1977, 1978, and 1979 year-classes attained progressively smaller lengths at corresponding annuli, largely due to a successive decrease in mean lengths at annulus 1. The second year increments (annuli 1 to 2) showed only a small difference in growth rates of year-classes 1978, 1977, and 1976. Only two year-classes (1976 and 1977) contained third year data and the 1976 mean increment (7.1 cm) was more than twice the 1977 mean (3.5 cm).

Absolute growth in weight. The general length-weight relationship, described by the regression of logW on logL, was calculated by both the G. M. and least squares methods (Appendix D). The G. M. equations for York Lake (N=79) and Lake Dickerson (N=145) were as follows: $\log W = -2.0948 + (3.1577 \cdot \log L)$ and $\log W = -2.2318 + (3.1914 \cdot \log L)$, respectively (Figure 2).

The least squares estimates of the regression slopes were smaller than the G. M. estimates (as always), but the differences between the two methods were less than the standard errors of the least squares slopes (Appendix D). The least squares slopes of both lakes were significantly greater ($p < 0.05$) than the coefficient of isometric growth (3.0). The difference between the least squares slopes of the lakes was not statistically significant

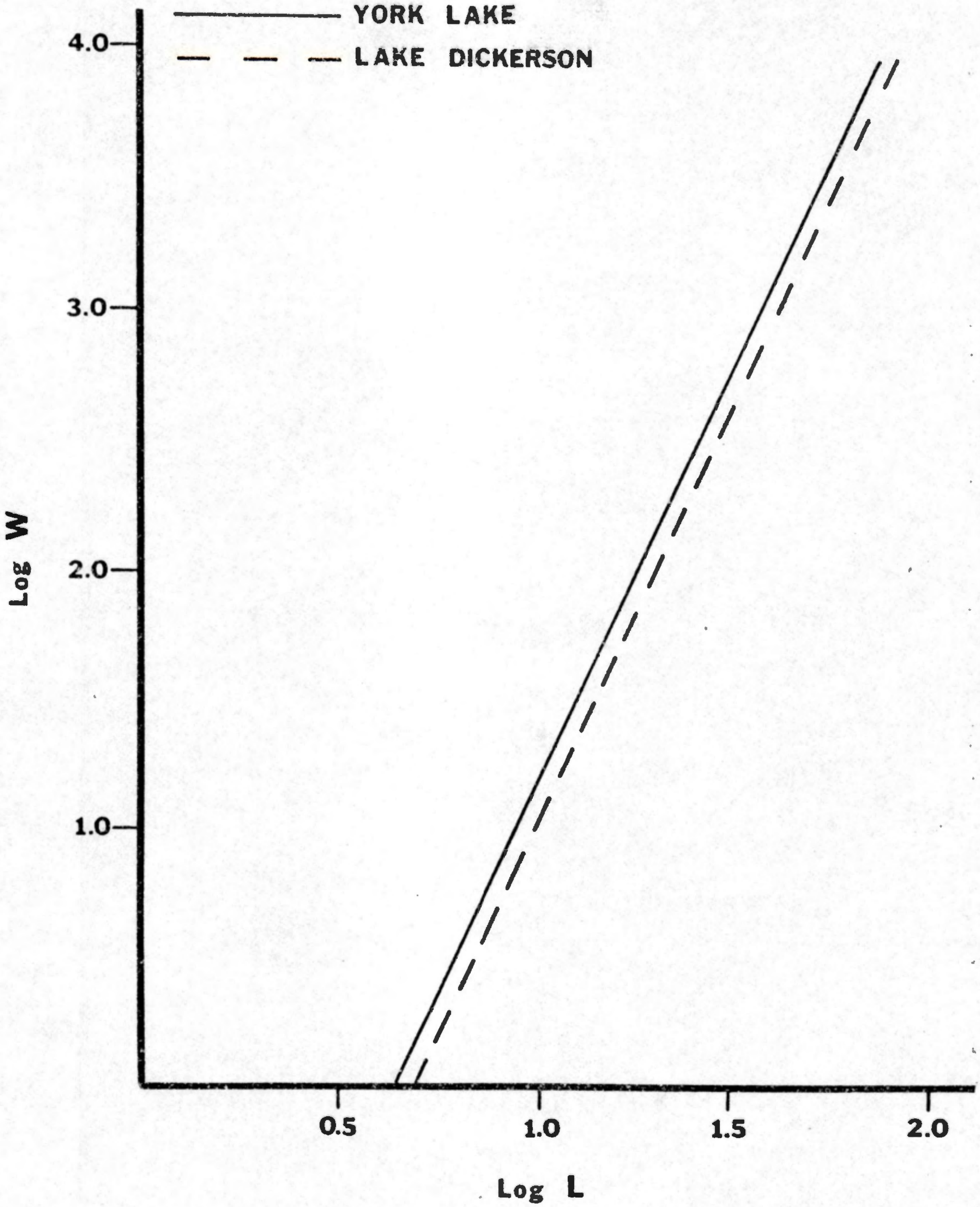

Figure 2. The G. M. regressions of the logarithm of weight in grams (logW) on the logarithm of length in centimeters (logL) for the Florida largemouth bass of each lake.

($p > 0.05$). However, the data from the lakes were treated separately, due to the difference in Y-intercepts.

The individual weights at annuli, converted from back-calculated lengths using the G. M. regression of each lake, are summarized in Tables 3 and 4 (York Lake and Lake Dickerson, respectively). Also, mean individual annual increments are presented. The grand mean weights attained at annuli 1-4 were larger for York Lake than Lake Dickerson, as were grand means of weight increments for each year. Since York Lake bass were heavier than Lake Dickerson bass at any given length (Figure 2), larger growth and growth rates of York Lake bass in length were further enhanced in the weight dimension.

York Lake's year-classes showed differential growth in weight for same age fish, but not consistently better growth of any year-class through all ages. The faster growth of same age fish for the 1977 and 1978 growing seasons compared to other growing seasons were shown in the weight dimension. However, the absolute growth rates (annual weight increments) for 1977 was not consistently higher than same age 1978 growth rates in weight, as it was in the length dimension.

Lake Dickerson exhibited decreasing weights achieved at corresponding annuli for successive year-classes. The 1976 year-class achieved over twice the mean

Table 3. Mean back-calculated weights (g) and annual weight increments (g) for Florida largemouth bass in York Lake, by year-class.[a]

Year-Class	N	Annulus 1	2	3	4
1979	2	18 18			
1978	23	63 63	369 (6) 321		
1977	4	84 84	518 433	737 (2) 312	
1976	12	44 44	430 386	854 423	991 (3) 275
1975	7	44 44	302 258	820 519	1229 409
Total N		48	29	21	10
Grand means					
Weight		56	399	832	1157
Increment		56	359	444	396

[a]Parentheses indicate the subset of the designated year-class sample captured at the oldest age.

Table 4. Mean back-calculated weights (g) and annual weight increments (g) for Florida largemouth bass in Lake Dickerson, by year-class.[a]

Year-Class	N	Annulus 1	2	3	4
1979	9	9			
		9			
1978	55	24	140 (34)		
		24	111		
1977	69	43	181	308 (20)	
		43	138	97	
1976	12	75	324	648	961 (4)
		75	249	324	259
Total N		145	115	32	4
Grand means					
Weight		37	184	435	961
Increment		37	149	182	259

[a]Parentheses indicate the subset of the designated year-class sample captured at the oldest age.

weights of the 1977 and 1978 year-classes combined, at corresponding annuli. The decrease in growth rates in weight (annual increments) of same age fish for successive year-classes was more dramatic in weight than length because of their exponential relationship.

Growth models. Annual weight gains were also analyzed in terms of instantaneous growth rates, a measure of annual growth relative to weight at the beginning of the year (initial weight). The average annual instantaneous rates in weight ($\overline{G}$) for each completed year of life (except the first) were summarized in Table 5. As in analysis of absolute growth rates in weight, the grand mean instantaneous rates of York Lake bass were higher than those for Lake Dickerson bass at the same age.

Investigation of year-class mean instantaneous rates showed the fastest rates for York Lake bass in 1977 for the second and third years of life (1976 year-class and 1975 year-class, respectively) and in 1978 for the fourth year (1975 year-class). A reversal of the trend of decrease in absolute growth rates of successive year-classes in the second year of life was seen in Lake Dickerson when weight was analyzed by a relative measure. This reversal was largely due to a substantial decrease in initial weights (annulus 1) with successive year-classes. In all

Table 5. Mean instantaneous growth rates ($\overline{G}$) for each completed year of life (2 to 4) of Florida large-mouth bass in York Lake and Lake Dickerson, by year-class.[a]

Lake	Year-Class	N	Year of Life 2	3	4
York Lake	1978	6	2.2741		
	1977	4	2.0094	0.4777 (2)	
	1976	12	2.2923	0.7010	0.3358 (3)
	1975	7	1.8673	0.9911	0.4544
	Total N		29	21	10
	Grand mean		2.1469	0.7764	0.4188
Lake Dickerson	1978	34	1.8540		
	1977	69	1.7483	0.3952 (20)	
	1976	12	1.4316	0.6725	0.3314 (4)
	Total N		115	32	4
	Grand mean		1.7465	0.4992	0.3314

[a]Parentheses indicate the subset of the designated year-class captured at the oldest age.

year-classes of both lakes, the instantaneous rates were largest for the second year of life and decreased with increasing age.

The length data was fitted to the von Bertalanffy equation for each lake to obtain a single growth coefficient (K) describing the pattern of growth throughout life and a theoretical maximum average length (L_∞). The G. M. regression of $\bar{L}_{n+1}$ on $\bar{L}_n$ (Ford equation) gave the initial estimates of K = 0.5711 and L_∞ = 48.5 cm for York Lake. The trials of the von Bertalanffy equation (least squares regression of $\log_e(L_\infty - \bar{L}_n$ on age) resulted in the best fit (R^2 = 0.9403) where L_∞ = 49.0 cm, K = 0.5261, and t_o = 0.2049 yr. The Lake Dickerson G. M. regression of the Ford equation gave the estimates of L_∞ = 57.7 cm and K = 0.2684. However, trials of the von Bertalanffy equation resulted in the best fit (R^2 = 0.8935) with L_∞ = 68.0 cm, K = 0.2267, and t_o = -0.3811 yr.

These parameter estimates of the von Bertalanffy equation depend upon the range of ages used. The data available for these lakes did not go beyond the fourth year which seriously affected the values of the parameters. The York Lake data fit the model better than the Lake Dickerson data. Differential growth of year-classes may have biased the results, especially in Lake Dickerson. Qualitative comparison of the final estimate of K for each lake showed

a large difference in values, with York Lake's K more than twice that of Lake Dickerson. Since K and L_∞ are negatively correlated, the maximum length for Lake Dickerson was much larger than for York Lake.

Condition

The grand mean condition factors (C) for the Florida bass were 1.32 (0.74 to 1.78) for York Lake and 1.08 (0.72 to 1.54) for Lake Dickerson. A trend of increase in condition with length increase was expected because the logW on logL regression slopes were larger than 3.0 in both lakes. Length-classes below 30.0 cm showed no trend in mean condition for York Lake and only a small range of differences in Lake Dickerson, 0.98 to 1.06 over five length-classes (Table 6). However, above 30.0 cm there was a distinct trend of increasing mean condition with increasing length in both lakes.

Mean condition factors were higher for York Lake fish than Lake Dickerson fish in every length-class. This indicated a more robust population in York Lake, probably due to lower densities and a better forage base in York Lake. In comparison of monthly mean condition within length-classes, there was little evidence of a seasonal cycle in condition of the bass in either lake. With the small sample size of length-classes for many months, any seasonal variation could have been masked by individual variation.

Table 6. Mean condition factors (C) for Florida largemouth bass in York Lake and Lake Dickerson, by 5.0 cm length-class.

Length	N	York Lake	N	Lake Dickerson
≤ 5.0	8	1.24		
5.1-10.0	15	1.01	11	0.98
10.1-15.0	1	1.24	14	0.98
15.1-20.0	7	1.23	16	1.02
20.1-25.0	14	1.20	63	1.02
25.1-30.0	22	1.23	147	1.06
30.1-35.0	36	1.26	53	1.15
35.1-40.0	18	1.39	6	1.26
40.1-45.0	29	1.55	3	1.49
≥ 45.0	15	1.62	6	1.48

General Comparisons

Many factors affect the growth rates of fishes. Among these are population density, genetics, available forage, water characteristics, climate, and others (Bennett 1970). Many researchers have reported negative correlation between density of bass and growth rates (Cooper et al. 1963; Brown and Logan 1960; Elrod 1971; Pardue and Hester 1966). Involved in the relationship between growth rates and densities is the amount of vulnerable prey available. Available prey has been positively correlated with the growth rate of largemouth bass (LaFounce et al. 1964; Regier 1963; Bennett 1970; Carlander 1977). The influence of density and available forage was believed to be the major factors resulting in the wide variation of growth found in the Florida bass populations studied.

The York Lake Florida bass densities were relatively low and consisted mainly of larger bass. The qualitative observations of the sunfish populations revealed many intermediate-sized and few large individuals. This typical structure of fish populations, characterized by Smith et al. (1975) as a "crowded bream population," and the preceding rapid bass growth was believed to result from the 1976 die-off of bass. This was demonstrated by the fact that the fastest growth rates of the bass for each year of life, 1 to 3, was achieved in 1977 (no year 4 data was available

for 1977). Also, the second fastest rate for each year of life (except the fourth) was in 1978.

The Lake Dickerson bass population consisted of mainly small bass (1977 and 1978 year-classes) at a relatively high density. Also, qualitative observations of the bluegill-redear populations revealed a scarce forage base consisting of larger individuals and few intermediate bluegill. This combination of fish populations was a good example of the "typical crowded bass population" described by Smith et al. (1975). The slow growth rates of the smaller bass (1977, 1978 and 1979 year-classes) in Lake Dickerson resulted from the high bass density and low forage base combinations.

A general comparison of the growth of the Florida bass populations to northern bass growth in the literature was made below. However, it is evident from the preceding discussion that many factors affect the growth of bass. Thus, difference in growth of the two subspecies does not necessarily reflect genetic differences. Most of the northern bass growth studies have reported absolute growth as lengths at annuli and comparisons were restricted to this measure of growth.

In discussion of Florida bass growth in Lake Dickerson, mean lengths were reported for the 1976 year-class separately from the slower growth of the 1977 and 1978 year-classes which were averaged together. The grand means

for all York Lake bass were used without grouping because they were relatively representative of the average growth.

The similar growth of York Lake bass and the 1976 year-class of Lake Dickerson was somewhat higher than most of the northern bass growth reported in the literature for Tennessee and surrounding states (Table 7). The average lengths at annulus 1 of these Florida bass were similar to those reported for northern bass. The lengths attained at annuli 2, 3, and 4 were higher than most lengths at corresponding annuli for northern bass.

The slower growth of the 1977 and 1978 year-classes of Lake Dickerson Florida bass was below average when compared to the northern bass (Table 7). These Florida bass attained lengths similar to the northern bass at annulus 1, at the lower end of the northern bass lengths for annulus 2, and below most annulus 3 lengths reported for northern bass.

Therefore, the growth of Florida bass in Tennessee was comparable to northern bass growth for surrounding regions. Apparently, the Florida bass growth was not limited by the shorter growing season and lower temperatures of Tennessee than their native Florida, but rather by other factors (population density, available forage, etc.) affecting all bass populations.

In addition, reproduction of the Florida bass was documented, although not the focus of this study. The 1980

Table 7. Mean back-calculated total lengths (cm) at annuli for the Florida largemouth bass of the present study and northern largemouth bass reported in the literature.

Author	Study Location	No.	Annulus 1	2	3	4	5	6
Present study	Clyde York Lake	48	15.6	30.2	38.2	42.6		
	Lake Dickerson 1976	12	19.1	30.0	37.2	42.5		
	Lake Dickerson 1977-78	124	14.1	25.1	30.0			
Carlander 1977	Unweighted Mean Ala., Ga., La., Tex.		16.6	25.6	31.5	39.1	43.7	51.8
	Unweighted Mean Ky., Tenn.		15.3	26.8	35.2	40.4	44.6	48.4
	Unweighted Mean Okla.		14.2	24.9	32.5	38.6	43.7	48.4
	Unweighted Mean Del., Md., N.C., Va.		13.3	23.5	31.2	37.4	42.4	46.1
	Unweighted Mean Ark., Kan., Mo.		12.7	21.1	26.8	33.4	38.1	46.3
Brashier 1965	Old River, La.	164	20.3	30.5	36.3	41.4	45.5	48.3
	False River, La.	182	17.3	27.2	32.8	37.3	41.4	45.0
Shay & Ward 1969	Darborne Pit, La.	181	16.8	24.6	30.2	34.5	36.8	38.6
Webb & Reeves 1975	Lewis Smith Res., Ala.	224	14.7	27.5	35.8	40.2	44.2	48.5
TVA 1970	Chickamauga Res., Tenn.	65	9.1	20.3	27.9	36.3	49.8	

reproduction resulted in abundant young-of-year bass in York Lake. Ninety-four young-of-year were collected in the final October sample. Sampling in Lake Dickerson was less effective for young-of-year bass because steep banks and many stumps in the shallow area made seining difficult. However, 20 young-of-year were collected in 1980.

Also, the age structure of the populations documented past reproduction. The multiple year-classes within each lake indicated past reproduction and over-winter survival.

CHAPTER VI

SUMMARY

1. Two small Tennessee impoundments were stocked with Florida bass fingerlings. York Lake was renovated and stocked in 1974 and Lake Dickerson, a new impoundment, was stocked in 1976. During the study period (beginning in the summer of 1979) a total of 165 bass captures were made in York Lake, of which 79 were "first captures." In Lake Dickerson, 320 bass captures were made during the study period of which 180 were "first captures."

2. Population estimates for number of bass exceeding 15.0 cm in the winter of 1980 were 15 per ha in York Lake and 74 per ha in Lake Dickerson.

3. Age analysis by the scale method was conducted on 244 individual bass from both lakes combined and 81% of the samples agreed on two independent readings. The age analysis resulted in assignment of ages 1 through 4 for both lakes.

4. Back-calculation of growth attained at annuli was computed for 48 bass from York Lake and 145 bass from Lake Dickerson. Two body length on scale radius regressions (G. M.), one for samples collected above the lateral line and one for below-line samples, in each lake were used in the back-calculations of lengths. York Lake

bass achieved the best average absolute growth in length at each annulus and greater mean absolute growth rates in length than Lake Dickerson bass for each year of life.

5. Investigation of the absolute growth and growth rates in length of individual year-classes revealed several characteristics. York Lake bass achieved the fastest growth for each year of life in the calendar years 1977 and 1978, following the 1976 die-off. No year-class in York Lake achieved faster growth throughout all years of life. On the contrary, a substantial decrease in length achieved at corresponding annuli was exhibited by successive year-classes in Lake Dickerson. This was largely due to a successive decrease in length at annulus 1.

6. A general logW on logL regression (G. M.), for each lake separately, was used to convert back-calculated lengths to the weight dimension. York Lake bass were heavier than Lake Dickerson bass for corresponding lengths. Therefore, the greater average absolute growth in length of York Lake bass than Lake Dickerson bass was further enhanced in the weight dimension.

7. The instantaneous annual growth rates in weight, a measure of the growth rate of a year of life relative to the initial weight for the year, generally resulted in similar findings as the absolute growth rates in weight. The most notable difference in rates of weight increase

when measured on the absolute and instantaneous scales was in the second year of life for Lake Dickerson bass. Due to the large decrease in initial weights (weights at annulus 1) for successive year-classes, the trend of decreasing year 2 absolute growth rates was reversed in the instantaneous measure.

8. The description of the trend of growth in length over life by the von Bertalanffy model resulted in a coefficient of growth for York Lake bass over twice that of Lake Dickerson bass. Since the coefficient of growth and the maximum length parameter are inversely correlated, the maximum length of Lake Dickerson bass was almost 20.0 cm greater than the estimate for York Lake bass. The lack of fish above age 4 in both lakes and the differential year-class growth in Lake Dickerson were believed to have severely affected the validity of these estimates.

9. In conclusion, Florida bass annual growth in Tennessee was comparable to reports of northern bass growth in Tennessee and surrounding states. They did not appear limited in growth by low temperatures but rather by population densities in relation to amount of available forage. Further study will be required to determine the influence of genetic differences on the growth of the two subspecies in more northerly regions than California and Florida. The future studies should compare the growth of

the two subspecies in the same environment to determine the genetic influence on growth separately from the environmental influences.

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APPENDIXES

APPENDIX A

Table 8. Modified Petersen estimates (N*) of the population numbers of Florida largemouth bass greater than 15.0 cm in length, at consecutive samples, for York Lake and Lake Dickerson.

Lake	Sample						
	1	2	3	4	5	6	7
York Lake	26	36	38	28	35	34	46
Lake Dickerson	116	196	179	137	133	149	163

APPENDIX B

Table 9. Mean empirical lengths (cm) and weights (g) of Florida largemouth bass at first capture for each year-class within York Lake and Lake Dickerson.

Year-Class	York Lake N	York Lake Length	York Lake Weight	Lake Dickerson N	Lake Dickerson Length	Lake Dickerson Weight
1980	28	7.9	15	20	12.3	23
1979	5	20.9	115	9	16.3	56
1978	23	30.5	389	55	23.7	144
1977	4	36.8	818	69	29.1	279
1976	12	41.2	1081	12	40.7	1019
1975	7	45.7	1619			

APPENDIX C

Table 10. Statistics for body length on scale radius regression for the Florida largemouth bass of York Lake and Lake Dickerson, by place of scale procurement (above or below the lateral line) within each lake and for all samples combined within each lake.[a]

Lake	Place	N	Least Squares Slope	Least Squares Y-Intercept	G. M. Slope	G. M. Y-Intercept	Standard Error of Slope	R^2
Lake York	Above	38	0.1469	6.38	0.1495	5.87	0.0047	0.9652
	Below	41	0.1349	2.90	0.1433	2.07	0.0017	0.9942
	Combined	79	0.1522	3.19	0.1550	2.81	0.0033	0.9645
Lake Dickerson	Above	86	0.1809	3.10	0.1879	2.13	0.0055	0.9270
	Below	79	0.1449	3.47	0.1471	3.19	0.0029	0.9703
	Combined	165	0.1575	4.19	0.1691	2.64	0.0048	0.8681

[a]Each regression was estimated by both the least squares and G. M. methods.

APPENDIX D

Table 11. Statistics for the logarithm of weight (logW) on the logarithm of length (logL) regressions for the Florida largemouth bass of York Lake and Lake Dickerson, estimated by both the least squares and G. M. methods.

Lake	N	Least Squares		G. M.		Standard Error of L.S. Slope	R^2
		Slope	Y-Intercept	Slope	Y-Intercept		
York Lake	79	3.1541	-2.0901	3.1577	-2.0948	0.0173	0.9977
Lake Dickerson	165	3.1806	-2.2169	3.1914	-2.2318	0.0205	0.9933

VITA

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