To the Graduate Council:

I am submitting herewith a thesis written by Melvin Lee Warren, Jr., entitled "A Comparison of Food Conversion, Growth, and Weight Loss Due to Deprivation of Two Subspecies of Largemouth Bass." I 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:

Accepted for the Council:

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Graduate Studies and Research

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A COMPARISON OF FOOD CONVERSION, GROWTH, AND WEIGHT LOSS DUE TO DEPRIVATION OF TWO SUBSPECIES OF LARGEMOUTH BASS

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

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ABSTRACT

Over a 217-day period 32 specimens each of two subspecies of largemouth bass (Micropterus salmoides salmoides and M. s. floridanus) were evaluated in terms of food conversion, growth, weight loss due to deprivation, and weight gained subsequent to deprivation. Bass were placed in individual compartments in plastic wading pools in the laboratory. It was shown that salmoides converted forage to flesh more efficiently, whereas, floridanus grew at a faster rate. Differences were also noted in rates of weight loss due to deprivation; however, this was attributed to the dissimilar initial sizes of the subspecies. No differences were noted in total weight gained subsequent to deprivation; however, dissection revealed that eight of 15 salmoides females were ripe, whereas only one of 15 floridanus females showed signs of ovarian development at the reported maturation age.

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CHAPTER I

INTRODUCTION

The popularity of the largemouth bass Micropterus salmoides (Lacépède) as a gamefish, and its importance ecologically as predator and fish management tool, has made it the subject of numerous scientific investigations. Along with the creation of artificial impoundments in recent years, emphasis has been placed on improvement of fisheries through intensive management for optimum growth conditions. This approach is especially important with today's increased fishing pressures and the multiple use concept of water resource management.

The larger maximum growth of the largemouth bass, in relation to the other members of the genus Micropterus, has resulted in many growth investigations over the years. Upon comparing total lengths of largemouth bass at the end of their second year, several researchers reported an upward cline in length from northern to southern waters (Bennett 1937; Eshmeyer 1939; Viosca 1942). Variation in growth among same age bass in different bodies of water has been generally attributed to length of the growing season, temperature, water chemistry, presence of parasites, and size and availability of forage (Bennett 1937, 1962; Viosca 1942; Stroud 1939; Carlander 1950; Kramer and Smith 1960; Applegate and Mullan 1967; Pasch 1974).

Two subspecies of largemouth bass are known to exist. The Florida subspecies, Micropterus salmoides floridanus (Lesueur),

hereafter referred to as floridanus, whose native range is restricted to peninsular Florida and northward to the St. Johns and Suwannee Rivers, differs from the widely distributed northern subspecies, M. s. salmoides (Lacépède), hereafter referred to as salmoides, in coloration, size and number of scales, number of pyloric caeca, jaw and snout length, ratio of abdominal to caudal vertebrae, and in maximum size (Bailey and Hubbs 1949; Buchanan 1968; Bryan 1969; Thrasher 1974). Other differences noted between the northern and Florida subspecies concern longevity, age of maturation, spawning time, and catachability (Sasaki 1961; Clugston 1964; Bottroff 1967, 1971; Stevenson 1972; Graham 1973; Thrasher 1974; Zolczynski and Davies 1976).

The larger maximum size attained by floridanus has gained the attention of fisheries biologists and fishermen in past years. Carr and Goin (1955) state that 14 lb (5.4 kg) individuals in Florida are not rare. In California, trophy bass in excess of 9 lb (4.1 kg) are more commonly caught in waters containing floridanus (McCammon pers. comm.). According to Thrasher (1974), salmoides rarely exceeds 12 lb (5.4 kg). Since salmoides can be differentiated from floridanus morphologically, it seems probable that the large growth potential has, at least in part, a genetic basis (Bailey and Hubbs 1949). Several states interested in improving the genetic potential for growth in the large-mouth bass have initiated stocking and evaluation programs of floridanus with varying degrees of success. In California, state records were broken six times in 15 years after the introduction of floridanus. According to Thrasher (1974), the state record now stands at 20.9 lb

(9.4 kg). The apparent success of the California introductions led other states to initiate their own evaluation programs. However, McCammon (pers. comm.) stated that improved bass angling following introduction of floridanus into California waters may be transitory. He also stated that evidence is available that the Florida subspecies may have a depressing impact on other popular segments of reservoir fisheries. Further evidence has shown the Florida bass to suffer higher winter mortality rates than the northern subspecies at northern latitudes (Graham 1973; Stevenson 1973; McCammon pers. comm.). Findings in California (Sasaki 1961; Miller 1965), Ohio (Stevenson 1973, pers. comm.), Missouri (Graham 1973), Alabama (Addison and Spencer 1972; Zolczynski and Davies 1976), Florida (Clugston 1964), and Tennessee (Smith 1976) have raised questions concerning the relative contribution of genetic versus environmental factors in the larger maximum size attained by floridanus.

In order to achieve a better understanding of the factors governing the observed differences between floridanus and salmoides, basic research into the biology of the animals is required. The primary objectives of this study were to compare food conversion rates, growth rates, weight loss due to deprivation, and weight gained subsequent to deprivation of salmoides and floridanus under laboratory conditions. It is assumed that under the controlled conditions of the laboratory the influences of the environment may be more easily differentiated from genetic differences.

CHAPTER II

LITERATURE REVIEW

Research dealing with the largemouth bass is quite extensive and covers most aspects of the fishes' biology. Therefore, comments in this paper will be confined to growth, food conversion, and deprivation. Where possible emphasis will be placed on comparisons of floridanus and salmoides in these areas.

I. GROWTH

Considerable variation in growth and growth rates have been reported for largemouth bass within a single body of water and among different bodies of water. Variability in growth within a bass population has been correlated with density, timing of reproduction with respect to forage spawning activity, sex, and individual genetic variation in morphology, physiology, behavior, and growth potential (Hubbs and Cooper 1934; Bennett 1937; Padfield 1951; Pardue and Hester 1966; Dineen 1968; Pasch 1974). Variability in growth among same age bass in different bodies of water has been attributed to length of the growing season, temperature, water chemistry, presence of parasites, and size and availability of forage (Bennett 1937, 1962; Viosca 1942; Stroud 1949; Carlander 1950; Kramer and Smith 1960). Generally, fisheries workers have attributed the larger size of floridanus to environmental influences such as the longer growing season in its native range (Bailey

and Hubbs 1949). Bennett (1962) stated that an abundant and available food source is more important than the length of the growing season in the production of fish of above average size. Bailey and Hubbs (1949) felt that it was probable the large growth potential of floridanus had, in part, a genetic basis since this form was distinguishable morphologically from salmoides. Sasaki (1961) and Miller (1965) stated that the observed differences in salmoides and floridanus in growth and maximum size appear to be related to favorable environment and growing season rather than intrinsic factors. Neither investigator found significant differences in rate of growth between the subspecies during the first two years of life in California waters. On the basis of immunogenetic studies, Miller (1965) concluded that the separation of the subspecies in fish management was a questionable practice. Thus, there is some disagreement as to the relative contribution of genetic versus environmental influences in explaining the growth differences between salmoides and floridanus.

In a five year Ohio pond study, floridanus did not differ significantly in growth from native salmoides (Stevenson 1973). High winter mortality of floridanus was noted in the original stock; however, this was not a problem in later generations. This led Stevenson to conclude that some sort of environmental acclimation had taken place in later generations. Continuing investigation on original stock progeny has shown that growth of floridanus continues to parallel that of native Ohio largemouth (Stevenson pers. comm.).

In Missouri ponds, salmoides showed the best growth when stocked with equal numbers of floridanus. However, due to the high winter mortality of floridanus the reliability of this growth data was questionable (Graham 1973).

Addison and Spencer (1972) compared growth rates among floridanus, salmoides, and their hybrids in southern Alabama ponds for the first two years of life. They found that rapid growth occurred in both subspecies, but the hybrids grew the fastest initially. Differences in observed growth rates were attributed to differences in water quality and forage availability among the experimental ponds. Comparative first year growth studies in Alabama utilizing replicate ponds under controlled water quality and forage conditions were conducted by Zolczynski and Davies (1976). They reported that salmoides outgrew floridanus during the first summer of life. The F_1 hybrids exhibited an intermediate rate of growth. They considered the observed differences in growth rate to be genetic in origin since the environment was reasonably constant. Hence, the first year's growth was not the factor contributing to the larger adult size of floridanus. Smith (1976) reached similar conclusions in a study conducted in Tennessee ponds which were divided into equal areas by mesh barriers. During the five month study salmoides fingerlings showed significantly higher rates of growth and mean coefficients of condition.

Clugston (1964) conducted a 15-month growth comparison in subtropical Florida where conditions were suitable for growth year round. There was no marked decline in growth of salmoides during the winter

months as in northern waters, indicating salmoides has the capability for year round growth under suitable conditions. Both subspecies had high initial growth rates with a rapid decrease as the fish increased in size. During the early life history, salmoides grew faster; however, the northern subspecies were stocked four months later than floridanus when water temperatures were higher. He also noted that the maturation of floridanus during the study may have had a depressing effect on its growth. Due to the reported effect of temperatures determining certain meristic characters during the early embryonic development of fishes (Bailey and Gosline 1955; Brown 1957), Clubston (1964) stated that the major factor responsible for the observed differences between these forms may be environmental in nature. He concluded that there is little evidence to indicate that floridanus is genetically superior to salmoides as far as growth is concerned.

II. FOOD CONVERSION

Food conversion of largemouth bass under experimental conditions is a parameter of interest not only to the hatchery manager, but also to the systems ecologist concerned with defining the bioenergetic relationships of aquatic ecosystems. Brett et al. (1969) defined gross conversion efficiency (Eg) by the general formula $Eg = G/I \times 100$, where G is growth and I is food intake. Generally, however, simple conversion indices are calculated by dividing the weight of food consumed by the gain in weight of the consumer during a corresponding interval of time (Thompson 1941; Lagler 1952). There are limitations to this index due

to important sources of variation. These variations include conditioning of fish for the experiment; relation of the experimental period to natural growing seasons and environmental factors of growth; differences among individuals, species, and diets in assimilation into fats, carbohydrates, and protein; differences in tissue water content of the experimental fish; and genetic heterogeneity of experimental animals (Lagler 1952).

The efficiency of food conversion has been shown to depend on type of diet (quality), feeding frequency, feeding level, temperature, and size or age of the fish (Prather 1951; Williams 1959; Snow 1961; Blackburn 1966; Paloheimo and Dickie 1965; Brett et al. 1969). For fingerling largemouth, Snow (1961) reported the fathead minnow (Pimephales promelas) to be a more efficient food item in terms of conversion than the goldfish (Carrasius auratus). Blackburn (1966) reported that largemouth fed all they would eat at three day intervals exhibited higher gross conversion efficiencies (gain in weight of consumer/amount consumed x 100) thanbass fed under the same conditions at one or five day intervals. Many conversion studies have shown that efficiency declines with increasing amount of food eaten (Brown 1957; Paloheimo and Dickie 1965). The work of Thompson (1941) supports this conclusion for salmoides. Brett et al. (1969) found that conversion efficiency at a fixed level of feeding decreased both above and below the optimum conversion temperature of 11.5°C in young sock-eye salmon (Oncorhynchus nerka). He stated that temperature may have as much effect on conversion efficiency as feeding level when the full ranges

of both are examined. The effect of size of the fish on conversion efficiencies were noted by Prather (1951) and Williams (1959) in their work with salmoides. Both researchers cited evidence that smaller salmoides converted more efficiently than larger salmoides, although this relationship was not consistent enough to allow statistical verification.

Mean food conversion ratios (weight of forage consumed/gain in weight of bass) have been calculated for salmoides by several investigators (Thompson 1941; Prather 1951; Lagler and Kruse 1952; Williams 1959; Snow 1961, 1963). Data in this area is unavailable for floridanus. Average values reported range from 1.8 - 8.2. Individual variation of bass has ranged from 1.1 - 24.2

III. DEPRIVATION

The ability of poikilotherms such as fishes to withstand the rigors of food deprivation through physiological, biochemical, and behavioral adaptations is a fact long known to the scientific community. Several species of fishes including cod (Gadus sp.), herring (Clupea sp.), brook trout (Salvelinus fontinalis), carp (Cyprinus carpio), American eels (Anguilla rostrata) and largemouth bass (M. s. salmoides) have been subjected to varying periods of food deprivation (28 - 360 days) with little or no mortality observed (James 1939; Wilkins 1967). Evidence available from studies on rainbow trout (Salmo gairdneri) and carp (C. carpio) indicate that deprivation or partial deprivation adversely effects the gonads and reproductive capacity of these fishes.

Adverse effects include suppression of maturation, decreased maturation rate, and reduction in number of eggs brought to maturity through the mechanism of follicular atresia (Wilkins 1967). Changes in body composition with food deprivation have been reported for bluegill sunfish (Lepomis macrochirus), as well as herring, brook trout, and largemouth bass (James 1939; Wilkins 1967; Savitz 1971; Niimi 1972; Niimi and Beamish 1974). James (1939) reported scale erosion, extreme thinness, digestive system atrophy, and poor general appearance of salmoides deprived of food for 126 days at 24°C. Weight loss in salmoides showed a curvilinear decrease as deprivation progressed, with the greatest average weight losses occurring during the first few weeks of starvation (James 1939; Niimi and Beamish 1974). Oxygen consumption studies revealed general physiological decreases and a gradual subsidence of spontaneous activity in deprived bass (Beamish 1964; Glass 1968). Metabolic maintenance levels expressed as a percent of body weight/day decreased with temperature and increasing weight of bass (Niimi and Beamish 1974). Formulas to calculate routine metabolic requirements of 20 - 50 gm salmoides for any food deprivation time period were calculated by Glass (1968). Beamish (1964) found that bass metabolism reaches a constant low after a short period of deprivation. Glass (1968) estimated this period to be 5 - 6 days after the last meal for 20 - 50 gm salmoides at 20°C.

CHAPTER III

MATERIALS AND METHODS

The largemouth bass used in this study were collected by seining with an 18 m bag seine with 1.3 cm bar mesh and a 30 m straight seine with 1.6 cm bar mesh. Bass measuring from 150 to 225 mm total length were selected to insure that they were yearlings (i.e., fish with one summer's growth).

Forty specimens of salmoides were collected on 24 September, 1975, from fall drawdown potholes in Cherokee Reservoie with the cooperation of the Tennessee Wildlife Resources Agency. The collection site was located off State Highway 25E near Holston River mile 74. Water temperature at the site was 21°C. Forty-four specimens of floridanus were collected on 16 September, 1975, from a 2 ha pond located on The University of Tennessee 4-H Camp in Crossville, Tennessee. This pond had been stocked in May with appropriate numbers of floridanus fry obtained from the Richloam Fish Hatchery in Webster, Florida. Water temperature at the site was 20°C.

All experimental fish were transported to laboratory facilities in a 1121 ℓ fish transport tank. Upon arrival the fish were slowly acclimated to laboratory water temperature and individually placed in pool compartments.

The study was conducted in four plastic wading pools measuring 2.4 m in diameter and 50 cm in depth with a maximum water capacity of

2394 ℓ. Each pool was divided into 16 compartments with netting mounted on rectangular wooden frames. Each compartment had an approximate volume of 140 ℓ. Additional wire screening was stapled to the outer edges of the dividers to prevent forage fish movement between compartments. A hardware cloth cylinder was placed in the center of each pool to screen bass and forage from the agitators. Heavy nylon netting was used to cover the pools and thus prevent jumping during feeding.

Laboratory lighting was provided by florescent and 100-watt incandescent bulbs. The florescent bulbs were set on a 12-hr photoperiod by means of electric timers. The incandescent bulbs were turned on only during observation, feeding, or weighing periods. Additional lighting reached the pools from eight windows equally spaced above the pools.

Heating in the laboratory was provided by several 220 v portable stack heaters and one ceiling mounted 220 v heater. Water temperatures were recorded daily. Some changes in water temperature did occur due to changes in ambient temperature; however, changes were slight and did not seem to affect feeding behavior.

All pools were filled to an approximate depth of 45 cm with aged tap water. During the study, the pool bottoms were cleaned at least once per week and the aged water exchanged at least once every two weeks. Pools A and D developed slow leaks during the study and as a consequence it was necessary to periodically top these pools with aged water.

As mentioned above, each pool was equipped with a centrally located 110 v agitator to insure that all compartments received adequate

circulation. Agitators were left running at all times except during feeding, weighing, cleaning, and observation periods.

After acclimation to laboratory temperatures, 32 largemouth bass of each subspecies were placed one bass per compartment into the four pools. Fish were randomly selected from holding tanks and alternately placed among the 16 compartments of each pool; therefore, a total of eight salmoides and eight floridanus occupied each pool.

Prior to data collection fish were allowed time to become accustomed to their new environment. After several days without food each fish was offered one forage fish; if taken promptly, another was released into the compartment. This was repeated until forage was refused. Fish used were Pimephales promelas, Gambusia affinis, and Carcassius auratus. Throughout the study, forage fish were of a size which could be utilized by all experimental fish. During this acclimation period several bass of each subspecies died presumably due to injury sustained during capture, transport, or handling. These were replaced with bass which were fed in the manner described above. In addition, several bass developed lesions on the tip of the dentary and/or the tips of the caudal and dorsal fins, probably as a result of swimming and feeding activities in a new and restricted environment. To prevent infection all pools were treated with a 2 ppm solution of potassium permanganate on 9 October.

The majority of the bass were readily accepting at least two forage fish per day after 10 days of the acclimation feeding period. This feeding regimen was continued for another eight days; at this

point, all fish appeared healthy and fed voraciously on the forage offered them.

On 17 October each pool was drained to within 20 cm of the bottom to facilitate capture of the fish. Individual bass were weighed and as a prophylactic measure, held for approximately 60 sec in a 100 ppm formalin solution before being returned to their respective compartments. All fish were placed in a water filled container and weighed to the nearest eighth of an ounce. Weights were subsequently converted to grams. All bass were handled using surgical gloves and fine mesh (fry) dip nets to minimize trauma and stress from the weighing procedure. As each fish was weighed, all forage fish and fecal material was removed from the compartment in which it was held.

On 20 October the growth and food conversion portion of this study was initiated. As a beginning ration each bass was offered live forage fish (Carassius auratus and Pimephales promelas) at an approximate rate of 7% of its body weight in food per day. This rate was chosen to assure availability of food to even the fastest growing bass. Forage was weighed to the nearest 0.1 gm. After this initial ration enough forage was released into each compartment to insure access to food at all times. Compartments were checked at least every other day and any dead minnows or remnants were removed and weighed before additional fish were added.

This feeding regimen was continued for 94 days with all forage being removed and weighed and all bass weighed on days 27, 55, and 94. Due to a loss of records, only data from the first 27 days were analyzed

to determine rates of food conversion; however, growth data was analyzed for the entire period based on three weighings, i.e., 1, 27, and 94.

Upon completion of the growth and food conversion portion of this study, all bass were deprived of food for 102 days (20 January thru 30 April). During this period all bass were weighed 14 times (as described above) at intervals of 7 - 9 days.

The final phase of this study was initiated on 30 April and continued for 21 more days. Forage (Pimephales promelas) was offered to each bass as in the acclimation period described above. All bass were weighed on days 1, 10, 18, and 21; however, only the total gains in weight for this period were compared.

All experimental fish were dissected for sexual determination and a gross examination of viscera. Females were classified as immature or ripe (Lagler 1952). Counts were conducted to determine numbers of pyloric caecae, lateral line scales, and caudal peduncle scales to insure that fish were not accidentally mixed during weighing procedures.

Growth and deprivation weighings were analyzed by means of an analysis of covariance (Snedecor 1956) after scatter diagrams indicated linearity of the data. The final weight (Y) was regressed on initial weight (X) for both the growth and deprivation data. T-tests were performed on regression coefficients of each subspecies in each pool to determine if final weight was dependent on initial weight. In addition t-tests were performed to determine if there were differences in

regression coefficients between the subspecies in each pool. Conversion ratios were computed as unit weight of forage consumed per unit weight gained. Ratios were analyzed by means of a two-way analysis of variance with unequal sample sizes (Steel and Torrie 1960). This analysis was also performed on the total weight gained by each bass in the final portion of the study. All hypothesis testing was performed at the .05 level of significance.

Data on bass which died during a portion of the study were eliminated from the analysis of that portion. Any fish for which no gain in weight was detected or a loss in weight was detected during the food conversion portion of the study was eliminated from that analysis, but not subsequent analyses.

During weighing and observation periods subsequent to the studies initiation, one fish in pool C was sight identified as Micropterus punctulatus; closer examination revealed this to be the case. Data on this specimen was not included in any of the analyses.

CHAPTER IV

RESULTS AND DISCUSSION

Although the specific effects of temperature and its variation on food conversion, growth rates, and deprivation weight loss were not analyzed in this study, experimental fish were exposed to fluctuations in water temperature in response to ambient temperature. However, water temperatures did not vary more than ± 2°C/day during any phase of the study, and no differences in temperature were found among any of the four pools. Average temperatures and ranges are given with the results of each phase of the study later in the text. In addition, growth history of each subspecies is presented in Figure 1.

Although temperature effects were not included, it is recognized that certain of these effects are documented for salmoides. Decreasing temperatures retard growth rate in salmoides fry, decrease satiation feeding levels (expressed as percent of body weight in food/day), decrease maintenance levels in 8 - 150 gm salmoides, and decrease oxygen consumption at a given swimming speed (Strawn 1961; Beamish 1970; Niimi and Beamish 1974). Kramer and Smith (1960) correlated first year's growth of salmoides in Minnesota with water temperature. The preferred temperature of salmoides was reported by Bennett (1966) as 26.6 - 27.7°C. Thus, water temperature and its variations in this study probably resulted in less than optimum conversion efficiencies, growth rates, and deprivation weight loss for both subspecies.

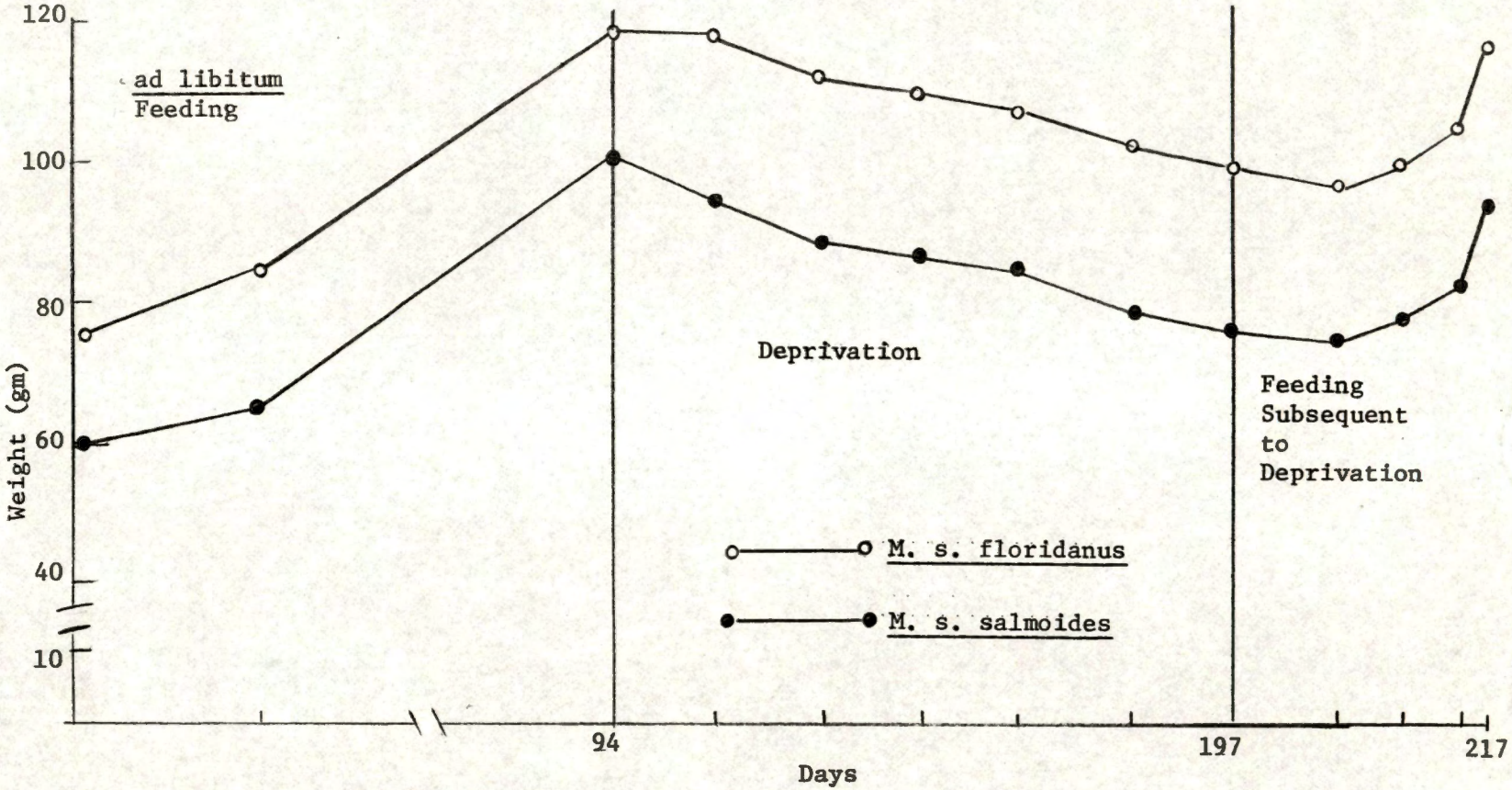

Figure 1. Growth history of Micropterus salmoides floridanus and M. s. salmoides: ad libitum feeding, deprivation, and feeding subsequent to deprivation.

Temperatures experienced by the bass during the food conversion and growth phases of the study were not unlike the fall season temperatures encountered in East Tennessee lakes and ponds although temperatures during the deprivation phases were higher than area winter temperatures. The fact that growth did occur in both subspecies at well below the reported temperature optimum for largemouth bass coincides well with the findings of Brett et al. (1969) on sockeye salmon (Oncorhynchus nerka) acclimated to various temperatures.

In any comparison of salmoides and floridanus it must be recognized that there may be subspecific differences in reaction to temperature variation although there have been no studies to confirm this conjecture. It is suggested that improvements in experimental design would include precise and accurate control of water temperature. Inclusion of this variable in the analysis would facilitate separation of temperature effects from other subspecific differences.

I. CONVERSION

The analysis of variance of food conversion efficiency (gm of forage consumed/gm gained by bass) given unequal sample sizes indicated a significant difference ($F_{.05[1,34]} = 5.07$) between salmoides and floridanus. The northern subspecies of largemouth converted at an average rate of 5.4 with a range of 1.9 - 9.4. The Florida subspecies converted forage to flesh at an average rate of 6.7 with a range of 2.7 - 12.0. Interaction between subspecies and pools was not significant ($F_{.05[3,34]} = 2.60$). During the 27 day period no weight gains were

detected for nine salmoides and six floridanus; weight losses were recorded for three salmoides and one floridanus. Mortalities during this time consisted of three floridanus. Mean water temperature was 16.6°C with a range of 13 - 20°C.

The variation in rate of conversion of forage to flesh observed is not unlike that found in previous work with salmoides (Thompson 1941; Prather 1951; Lagler and Kruse 1952; Williams 1959; Snow 1961, 1963). Conversion information on floridanus is unavailable at present. Conversion efficiency has been shown to depend on temperature, the type of diet, the feeding interval, feeding level, and size or age of the fish (Prather 1951; Williams 1959; Snow 1961; Blackburn 1966; Paloheimo and Dickie 1965; Brett et al. 1969). Although the conversion indices observed in this study were within the ranges reported by past investigators, the average values were higher for both the subspecies groups. This may be due to the ad libitum feeding regimen maintained. Upon reviewing numerous fish conversion studies Paloheimo and Dickie (1966) concluded that, at a given temperature, increasing the amount of food decreased conversion efficiency. Evidence presented in the works of Thompson (1941) and Blackburn (1966) supports this conclusion for salmoides.

The inclusion of the goldfish in the diet of the experimental fish may have also contributed to the reduced conversion efficiencies. Snow (1961) reported in a study on food conversion of salmoides that goldfish were a less efficient food item than fathead minnows.

It was realized that any comparison of feeding experiments must be approached with caution due to the many factors which may affect them. Initial size of the experimental fish was one of these factors. Prior work on food conversion in salmoides has been confined largely to bass less than 29 gm in weight (Lagler and Kruse 1952; Williams 1959; Snow 1961, 1963). Prather (1951) did use fingerling salmoides ranging up to 257 gm; however, the majority of his data was collected on bass less than 85 gm. Thus, the larger size of the bass utilized in this study may account for the lower conversion efficiencies observed.

The effect of size on conversion efficiency must also be considered in interpreting the comparison of conversion ratios between salmoides and floridanus. Both Prather (1951) and Williams (1959) cited evidence that smaller salmoides converted more efficiently than larger salmoides, although the relationship was not consistent enough to allow statistical verification. The average initial weight of salmoides in this study was 60.6 gm (range = 42.5 - 92.1 gm); the average initial weight of floridanus was 71.9 gm (range = 56.7 - 120.5 gm). Thus, the difference in efficiency of food conversion between the subspecies may have been due, in part, to the initial size differences of the experimental groups.

It should be noted that 19 of 63 study fish either failed to gain weight or lost weight during this 27 day period. This may indicate that the fish were not yet conditioned to their laboratory environment for after this period of the study all bass showed gains for the

remaining 67 days. It is suggested that improvements in experimental design include a longer acclimation period to laboratory conditions and the selection of similar size and subspecies groups for comparison.

In light of the above considerations, it is felt that salmoides has the ability to convert forage to flesh more efficiently than floridanus under the experimental conditions maintained in this study. Differences in initial size alone could not have produced the differences noted in rate of conversion between the subspecies.

II. GROWTH

Results of the analysis of covariance based on the weighings at days 1, 27, and 94 indicated significant differences in growth rates (gm gained/day) between salmoides and floridanus ($F_{.05[2,6]} = 23.72$) and among the bass of the four pools ($F_{.05[6,161]} = 4.35$). An average growth rate of 0.52 gm/day with a range of 0.32 - 1.00 gm/day was noted for floridanus, while salmoides grew at an average rate of 0.46 gm/day with a range of 0.06 - 0.87 gm/day. Interaction of subspecies with pools was not significant ($F_{.05[6,161]} = 0.98$). All bass exhibited positive overall growth, even though, as mentioned above, several fish did not show gains during the first 27 days. Mortalities other than those reported in the conversion results consisted of one floridanus. Mean water temperature was 16.7°C with a range of 13 - 20°C.

The weighings at days 1 and 94 of the growth study revealed that the average weight of floridanus was greater than salmoides both initially and finally in all pools (Figure 1, page 18). Mean weights

and ranges for each of the growth weighings are presented in Table 1. T-tests on regression coefficients calculated by regressing final on initial weight for each subspecies group in each pool indicated that final weight was generally dependent on the initial weight of the bass. The exception was the floridanus group in pool B; the rate of dependence of final on initial weight for these bass was not significantly different from zero. T-tests comparing the differences in regression coefficients (final weight in gm/initial weight in gm) between the subspecies in each pool revealed no significant differences in pools A, B, or D. However, there were significant differences in dependence of final on initial weight between floridanus and salmoides in pool C. In this pool, the regression coefficients calculated for floridanus were significantly higher than those for salmoides.

Even though the bass were collected near the end of the East Tennessee growing season, it is not surprising that both subspecies continued to grow in the laboratory since Clugston (1964) found salmoides, like floridanus, has the capability for year round growth under appropriate conditions. Analysis of the weight data for the 94-day growth study revealed significant differences in growth rates between the subspecies with floridanus growing faster than salmoides. These findings were in contrast to those of Saski (1976), Stevenson (1973, pers. comm.), Zolczynski and Davies (1976), and Smith (1976). Both Saski (1961) in California investigations and Stevenson (1973, pers. comm.) in Ohio found no significant differences in growth rates between the subspecies in lake and pond studies in the first two years

TABLE 1

MEAN WEIGHTS AND RANGES FOR M. S. SALMOIDES AND M. S. FLORIDANUS AT DAYS 1, 27, AND 94 OF THE GROWTH STUDY

Day	Mean Weights and Ranges (gm)	
	M. s. salmoides	M. s. floridanus
1	60.6 (35.4 - 92.1)	74.4 (56.7 - 120.5)
27	65.8 (35.4 - 99.2)	84.3 (56.7 - 141.8)
94	102.0 (49.6 - 141.8)	118.9 (92.1 - 198.5)

of life. Smith (1976) found that salmoides outgrew floridanus in Tennessee ponds during the first five months of life. Zolczynski and Davies (1976) reached similar conclusions in a year long study conducted in Alabama ponds where water quality and quantity of forage was under control. Other evaluations have been at best inconclusive due to lack of control over growth-affecting variables such as water quality, forage availability, high winter mortality of floridanus, low returns of marked fishes for growth analysis, competition between the subspecies, unknown effects of angling mortality on growth, and differential water temperatures at time of stocking (Saski 1961; Clugston 1964; Miller 1965; Addison and Spencer 1972; Graham 1973; McCammon pers. comm.). Environmental influences have been cited by various authors as the factor responsible for the observed differences between salmoides and floridanus (Bailey and Hubbs 1949; Saski 1961; Clugston 1964; Miller 1965; Addison and Spencer 1972). In this study, many potentially growth-affecting variables of previous investigations were controlled; those not monitored were the same for the subspecies groups compared. Placement of both subspecies in each pool assured like exposure to temperature regimes, water quality, and photoperiod. Individual compartments for each bass eliminated competition for forage, space, and cover, and also, allowed monitoring of each individual throughout the study. There was no bias introduced from potentially non-randum sampling procedures as might be encountered in lake and pond studies. Thus, variation due to genetic heterogeneity within a subspecies was not masked as might be the case in group sampling or mark-recapture studies.

Although the variables mentioned above were under the control of the investigator, prior growth history of the experimental fish was unavailable. An attempt was made on a pool by pool basis to analyze the dependence of final weight on initial weight both within and between the subspecies in order to determine if the initial size differential between the subspecies influenced the growth rate in favor of floridanus. Niimi and Beamish (1974) determined that growth at a given level of feeding was significantly higher in larger bass among successive weight classes of 8 - 150 gm. In this study, there were significant differences in the rate of dependence of final on initial weights between salmoides and floridanus in one of four pools. The regression coefficients calculated for floridanus in this pool were significantly higher than those for salmoides. Thus, in three of four pools there appeared to be no advantage in growth of floridanus due to its larger average initial size.

The analysis of covariance on the growth weighings revealed significant differences in bass growth rates among the four pools. Considerable variation in growth rate of same-age salmoides both within a body of water and among different bodies of water has been noted in the literature (Bennett 1937, 1962; Viosca 1942, 1953; Stroud 1949; Lambou 1958; Kramer and Smith 1960; Clugston 1964; Pardue and Hester 1966; Pasch 1974). Variability in growth rates among different bodies of water has been generally attributed to length of the growing season, temperature, water chemistry, presence of parasites, stocking density, and size and availability of forage (Bennett 1937, 1962; Viosca 1942;

Stroud 1949; Carlander 1950; Kramer and Smith 1960; Applegate and Mullan 1967; Pasch 1974). Even though there appeared to be no differences among the pools in length of the growing period, temperature, water quality, stocking density, and size and availability of forage, the microenvironments in some of the pools apparently created a more favorable medium for growth than the others.

Casual observation of the mean values for food conversion and growth rates of salmoides and floridanus may lead one to conclude that salmoides converts forage to flesh more efficiently than floridanus, while the latter grows at a faster rate. However, this conclusion may or may not be valid. The data from which conversion efficiencies were computed were collected for the first 27 days of the 94 day growth study. As mentioned before, all bass did not show gains during this period. If conversion rates had been computed for the entire 94 day period, then comparisons of the conversion and growth phases of the study would be more conclusive.

In light of the results presented above, it seems unlikely that the differences found in growth rates between floridanus and salmoides were affected by prior growth history as reflected in dependence of final on initial weights. In conclusion, it is probable that yearling floridanus have the potential for faster growth than salmoides under these laboratory conditions.

III. DEPRIVATION

The analysis of covariance performed on the data from the 102 day deprivation period indicated significant differences in weight loss

(gm/day) between *salmoides* and *floridanus* ($F_{.05[2,839]} = 57.84$) and among the bass of the four pools ($F_{.05[6,839]} = 24.32$). The average weight loss for *floridanus* was 0.26 gm/day with a range of 0.19 - 0.35 gm/day. Daily average weight loss for *salmoides* was 0.23 gm/day with a range of 0.12 - 0.32 gm/day. Interaction between subspecies and pools was nonsignificant ($F_{.05[6,839]} = 2.16$). Mortalities during this phase of the study consisted of two *salmoides*. Mean water temperature was 18.8°C with a range of 14 - 21°C.

T-tests performed on the regression of final on initial deprivation weight for each subspecies group in each pool indicated that final weight was significantly dependent on initial weight in every case. T-tests comparing differences in this relationship between *salmoides* and *floridanus* in each pool were nonsignificant. Mean initial and final deprivation weights were 118.9 gm and 97.4 gm for *floridanus* and 102.0 gm and 75.5 gm for *salmoides* (see Figure 1, page 18).

Size of the experimental fish must be considered once again in interpreting the results of the deprivation study. Niimi and Beamish (1974) reported that 100 gm *salmoides* held at 18°C and deprived of food for 14 days lost 0.26 gm/day, whereas 150 gm *salmoides* held under the same conditions lost 0.37 gm/day. This difference is due to the fact that larger bass require more energy for maintenance than smaller bass. The fact that *floridanus* lost an average of 0.26 gm/day and *salmoides* 0.23 gm/day over a 102 day period may indicate that in general the largemouth bass loses weight at a relatively constant rate even over prolonged periods of deprivation. The average initial weight of

floridanus was 16.9 gm greater than the average initial weight of salmoides. T-tests performed on regressions of final on initial weights indicated no differences in rate of dependence between the subspecies. This implies that neither subspecies was favored as far as weight loss was concerned due to its initial size. Even though the average weight difference between the subspecies was relatively slight, and the t-tests comparing rates of dependence of final on initial weight between the subspecies were nonsignificant, it is recognized that dissimilar initial weights may have been a factor in the differences observed between the subspeices in rate of weight loss. Data presented by Niimi and Beamish (1974) on maintenance levels of salmoides supports this argument. They found that as the weight of bass at a given temperature increased from 50 to 150 gm the maintenance level expressed as a percent of bodyweight/day decreased. Thus, even though a larger bass may lose weight at a faster rate (gm/day) than a smaller bass, the weight lost in proportion to body size is actually less for the larger bass. In future comparisons of weight loss between salmoides and floridanus, it is suggested that similar size groups be selected for comparison. Elimination of the size effect on weight loss would facilitate the analysis of inherent differences between salmoides and floridanus.

The analysis of the deprivation data revealed that among the pools there were significant differences in weight loss of bass. As noted previously, significant differences were found in bass growth rates among the pools. In both instances, efforts were made to maintain

conditions such that each pool was an identical experimental unit. Thus, the differences noted among the pools in rate of weight loss may have resulted from the creation of microenvironments which influenced the rates in some pools more than others.

Although significant differences were noted between salmoides and floridanus in rate of weight loss, and it was shown that salmoides lost less weight/day than floridanus, the size differences between the experimental groups precludes acceptance of the results as genetic differences between the subspecies. In order to determine the extent of the difference in rate of weight loss due to subspecies differences, further investigation is required utilizing groups of the subspecies similar in size.

IV. FEEDING SUBSEQUENT TO DEPRIVATION

The results of the analysis of variance given unequal sample sizes performed on the total weight gained during the 21 day feeding regimen subsequent to deprivation indicated no significant differences between the subspecies ($F_{.05[1,49]} = 0.5$). Interaction between subspecies and pools was not significant ($F_{.05[1,49]} = 1.51$). Gains in weight were recorded for all bass during this time (see Figure 1, page 18). There were no mortalities. Mean water temperature was 19.5°C with a range of 18 - 21°C.

Upon being offered forage fish for the first time in 102 days, all but 5 of 57 study fish immediately took the food. These five ate at subsequent feedings. James (1939) reported that two salmoides of

less than 35 gm refused food after 126 days of starvation at 24°C; he attributed this refusal to atrophy of the digestive system. By day 20 of this study, the majority of the bass readily accepted at least two forage fish per feeding. Gain in weight was rapid with the greatest gains realized in the last few days of the study. Weight gains were recorded for all bass with some reaching their initial weight before deprivation in this relatively short recovery period.

Although no significant difference in total weight gained between the subspecies were indicated during this period, dissection of the fish revealed that 8 of 15 salmoides females were ripe, whereas only one of 17 floridanus females showed signs of ovarian development. Apparently an increase in mean water temperature coupled with abundant forage induced sexual development in the females. Several authors reported that floridanus mature and spawn at age I, whereas most salmoides mature and spawn at age II (Saski 1961; Clugston 1964; Graham 1973). Emig (1966) states that maturity at age I occurs most often in fast growing largemouth populations. Evidence available from other fish species indicates that prolonged deprivation has pronounced effects on the gonads and the reproductive capacity in general. Lowered maturation rates and suppression of maturation have been noted in the literature (Wilkins 1967). Suppression of maturation due to deprivation may partially account for the relatively small number of floridanus females showing signs of development at the reported maturation age of floridanus. McCammon (pers. comm.) and Graham (1973) both cited evidence that floridanus suffers higher winter mortality at northern

latitudes than salmoides. Stevenson (pers. comm.) reported high winter mortality of original stock floridanus in Ohio was not a problem in successive generations. He also noted that the original stock floridanus matured at age I, whereas progeny matured at age II. He concludes that some sort of environmental acclimation has taken place in floridanus in Ohio. Although the evidence is scant, further examination of the adverse effects of the winter season in northern waters on the reproductive capacity and survival of floridanus would be helpful in the formulation of stocking policies. As suggested by McCammon (pers. comm.) and Graham (1973), the introduction of floridanus into northern waters could result in the introduction of maladaptive genes to the detriment of existing bass populations. Examination of the effects of additional parameters such as winter temperatures, partial deprivation, rate of maturation, enumeration of eggs brought to maturity, and changes in biochemical composition of study fish could be beneficial in determining differences between salmoides and floridanus.

V. POST-MORTEM EXAMINATION

Post-mortem examination of the bass revealed the presence of the nematode genus Contracaecum sp. (Petersen pers. comm.). Only one nematode was found in any one bass. The nematode was tightly coiled and embedded in fatty tissue around the viscera. Ten salmoides and two floridanus were infected. It is felt that the presence of this nematode had little, if any, effect on the infected bass as far as food conversion, growth rate, deprivation weight loss, or weight grained subsequent to deprivation was concerned.

Sex of the experimental fish was also determined during the post-morten examination. There were 14 male and 15 female salmoides. In the floridanus group, 11 males and 17 females were identified. Even though the total number of each sex was similar between salmoides and floridanus, the distribution of the sexes among the pools was uneven. It was felt that this had no significant effect on the data collected. Previous work comparing growth rates between male and female salmoides has not been consistent. Padfield (1951) determined that differential growth rates appeared to exist between the sexes with the females growing faster than the males; however, this occurred in environments where conditions for rapid growth were not present. Pardue and Hester (1966) found that male salmoides outgrew the females in pond studies. Both Kramer and Smith (1960) and Pasch (1974) found no significant differences in growth rates between the sexes. Dineen (1968) reported evidence of differential growth rates between the sexes of floridanus; however, differences were slight during the first two years of life. Thus, it is not possible to determine the specific effects sex may have had on the parameters examined in this study. In future comparisons of salmoides and floridanus, utilization of one sex would eliminate this variable from the analysis.

CHAPTER V

SUMMARY AND CONCLUSIONS

It was concluded from this study that floridanus converted forage to flesh less efficiently than salmoides over the period examined. In terms of growth, floridanus grew at a significantly faster rate than salmoides under the conditions maintained in the laboratory. Significant differences in rate of weight lost due to deprivation were also determined between the subspecies; however, this difference was attributed to initial size differences between salmoides and floridanus. Although no differences were noted between the subspecies in the total weight gained subsequent to deprivation, both subspecies showed rapid gains in a relatively short period of time. It is suggested that further research into the metabolism of salmoides and floridanus be undertaken. Information in this area would be helpful in formulating a rational policy regarding future introductions of floridanus at northern latitudes.

In the opinion of the author, introduction of the Florida subspecies of largemouth bass at northern latitudes will not improve the genetic potential for growth in existing bass populations. It is suggested that development of techniques to improve existing habitat would be more beneficial in producing largemouth bass of above average size.

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