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Growth, Survival, and Reproductive Success of Largemouth Bass Stocked with Selected Forage Fishes in South Dakota Ponds

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GROWTH, SURVIVAL, AND REPRODUCTIVE SUCCESS OF LARGEMOUTH BASS STOCKED WITH SELECTED FORAGE FISHES IN SOUTH DAKOTA PONDS

BY

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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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Abstract

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Five fish stocking combinations were evaluated to determine effects of forage availability and geographic location on largemouth bass (Micropterus salmoides) growth, survival, and reproductive success two and three years following stocking. Four forage species stocked with largemouth bass included bluegills (Lepomis macrochirus), black bullheads (Ictalurus melas), golden shiners (Notemigonus crysoleucas), and fathead minnows (Pimephales promelas). A largemouth bass only stocking strategy was also evaluated. Largemouth bass survival two years after stocking in eastern South Dakota ponds averaged 26.5%. Largemouth bass only and largemouth bass-bluegill combinations exhibited the greatest survival rates (31.6% and 28.8%, respectively), while the largemouth bass-black bullhead combination showed the poorest largemouth bass survival (8.4%). Mean annual survival of age-I largemouth bass in all stocking combinations was 58.6%. Mean total lengths after two growing seasons ranged from 270 mm for largemouth bass-golden shiner combinations to 324 mm for a largemouth bass-fathead minnow combination, with a grand total length for all stocking combinations of 286 mm. Largemouth bass averaged 317 mm in length and 500 g in weight at the end of the third growing season. Largemouth bass condition was good with Relative Weight values averaging 102 after three growing seasons. Largemouth bass-bluegill ponds supported the greatest biomass of largemouth bass after two growing seasons (77.0 kg/hectare). Largemouth bass-black bullhead ponds supported only 8.0 kg/hectare. Analysis of

variance indicated no significant differences ($P > 0.05$) in second and third year largemouth bass total lengths, survival, and condition due to forage species stocked or geographic region of South Dakota. Minimum pond depth explained 43.0% of the variation in second year growth in length. Largemouth bass did not spawn until the third growing season, and even then only 53.0% of 32 study ponds surveyed contained young largemouth bass. Relative abundance of young-of-the-year largemouth bass was highly variable ranging from 0.0 - 71.0 largemouth bass/seine haul. Angler harvest of largemouth bass from 12 South Dakota stock-ponds indicated greatest catch per effort values (2.8 fish/hr) in largemouth bass only ponds, while largemouth bass-bluegill ponds produced the most poundage of largemouth bass (1.1 kg/hr).

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ACKNOWLEDGEMENTS

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INTRODUCTION

Farm ponds are a major fishery resource throughout the United States. Estimates from the 1980 National Survey of Fishing and Hunting indicated 8.4 million anglers fished 167 million recreation days in lakes and ponds less than 4.0 hectares (10 acres) in size (U.S. Fish and Wildlife Service 1982). South Dakota ranks within the top 10 states in the continental United States with over 100,000 ponds constructed by the Soil Conservation Service (Modde 1980), representing well over 96,795 hectares (239,000 acres) of water (Anderson et al. 1978). Approximately 38,000 of these ponds have fishable populations (Peeters 1978).

Largemouth bass (*Micropterus salmoides*) and bluegills (*Lepomis macrochirus*) are commonly stocked together in ponds throughout the United States. This combination is recommended in South Dakota at a stocking rate of 247 largemouth bass/hectare (100/acre) and 741 bluegills/hectare (300/acre) with both species introduced simultaneously (Modde 1980). However, the largemouth bass-bluegill stocking combination developed by Swingle (1949) has not proven highly successful in the northern United States due to the tendency of bluegills to overpopulate (Krumholz 1950, Ball1952, Regier 1963a, Bennett 1970). In northern states this combination has often resulted in stunted bluegill populations, less efficient utilization of bluegills by largemouth bass, and poor largemouth bass recruitment. Peeters (1978) concluded that largemouth bass-bluegill populations in 27 of 30 previously stocked southeastern South Dakota ponds were unbalanced according to the definition of balanced populations suggested by Swingler (1950).

Lopinot (1978) and Regier (1963a) attributed unbalanced pondfish populations to underfishing and lack of proper pond management. Most ponds in South Dakota are constructed for livestock watering; and therefore, management of fish populations is minimal or nonexistant (Farley unpublished[1]). A stocking strategy including largemouth bass and a forage species which compliments predator growth but does not tend to overpopulate is needed for South Dakota stock ponds. Alternative fish species which may compliment largemouth bass growth in the northern United States include the golden shiner (*Notemigonus crysoleucas*) (Regier 1963b), fathead minnow (*Pimephales promelas*) (Ball and Ford 1953), and black bullhead (*Ictalurus melas*) (Rickett 1976). Bennett (1970) recommended stocking largemouth bass only in Illinois ponds.

This study was designed to evaluate growth, survival, and reproductive success of largemouth bass stocked in combination with select forage species, including largemouth bass-bluegill and largemouth only stocking options, and determine factors influencing growth, survival, and reproduction of largemouth bass in South Dakota stock ponds. This investigation will provide needed information on

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[1]Personal communication, John Farley, Soil Conservation Service Biologist. Federal Building, 200 Fourth Street S.W., Huron South Dakota, USA

predator-prey relationships in South Dakota ponds for use in implementation of alternative stocking and management strategies based on individual pond characteristics and pond owner or angler preferences.

MATERIALS AND METHODS

Experimental Design

Eighty ponds located throughout South Dakota were selected for stocking from South Dakota Department of Game, Fish and Parks stocking applications, personal solicitation, and field surveys. Stock ponds selected for study met the following requirements: 1) 0.4 - 2.0 hectares (1.0 - 5.0 acres) in surface area, 2) 3.0 - 3.6 m (10.0 - 12.0 ft) minimum depth, and 3) an absence of fishes.

Initial study design established four geographical blocks within South Dakota to analyze regional differences in largemouth bass growth. Quadrat boundaries were defined by latitude 44° 21' and longitudinally by the Missouri River (Stone 1981). Twenty ponds were stocked in each quadrat (Figure 1). Each pond was randomly assigned one of five stocking combinations with four replications of each stocking combination per quadrat.

Because first year growth studies indicated no significant differences ($P > 0.05$) in largemouth bass growth among ponds in northern quadrats or among ponds in southern quadrats (Stone 1981), ponds in both northern quadrats were pooled and ponds in both southern

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A hybrid bluegill-fathead minnow-largemouth bass combination was originally stocked instead of the largemouth bass-bluegill combination in five ponds in Quadrat four. Investigations indicated a successful hybrid cross had not been established, therefore, those ponds actually contained largemouth bass, bluegills, and fathead minnows.

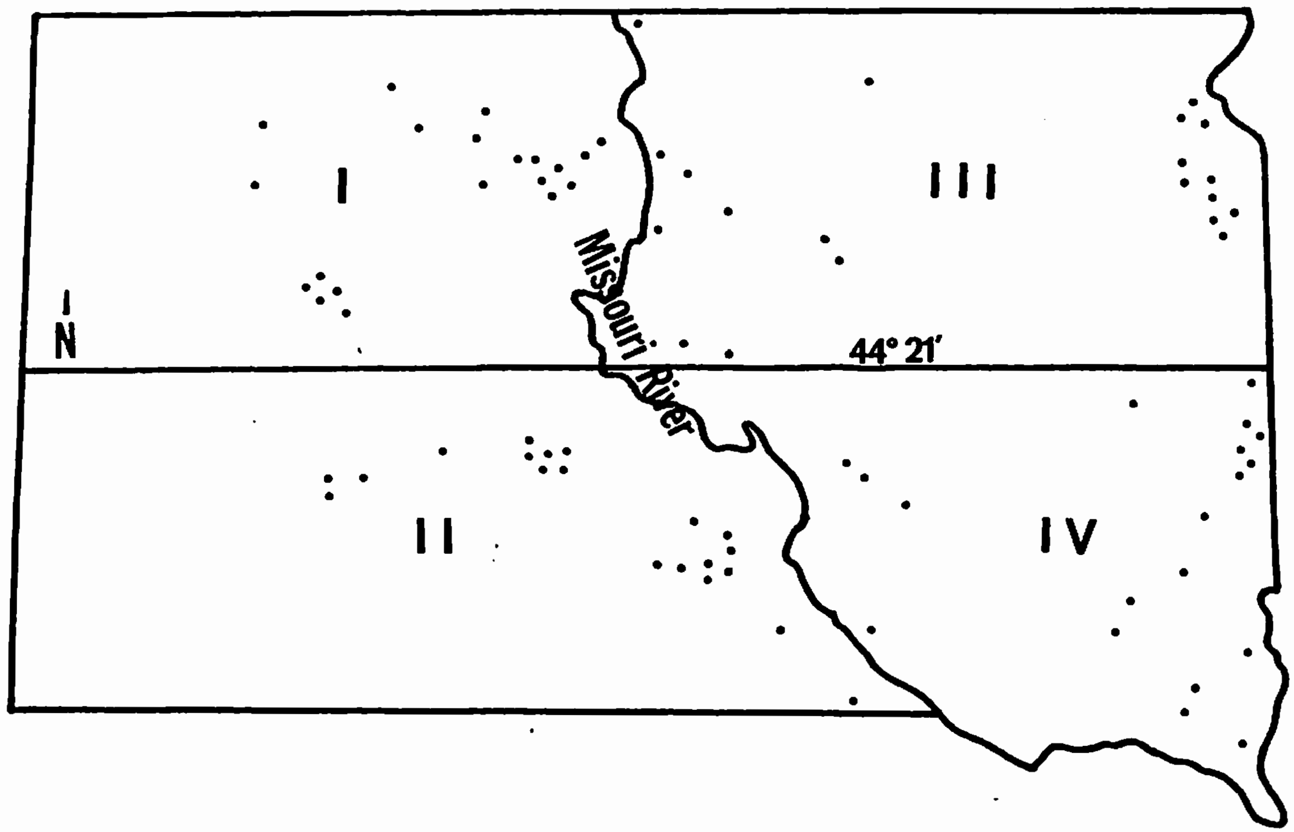

Figure 1. Initial study quadrats and locations of 80 ponds selected for largemouth bass (*Micropterus salmoides*) stocking combination investigations in South Dakota, 1979-1982.

quadrats were pooled to form north-south study regions divided by latitude 44° 21'. Original quadrat numbering was maintained for ease of pond identification.

Study ponds were stocked in 1979 to evaluate the following stocking combinations:

1) largemouth bass only,

2) largemouth bass - bluegills,

3) largemouth bass - black bullheads,

4) largemouth bass - golden shiners,

and 5) largemouth bass - fathead minnows.

Largemouth bass obtained from Gavins Point National Fish Hatchery were stocked 9 July - 19 July, at a mean length of 36.7 mm (1.4 in) and rate of 247/hectare (100/acres). Bluegills, also obtained from Gavins Point National Fish Hatchery, were stocked in August, at a mean length of 27.3 mm (1.1 in) and rate of 1,235/hectare (500/acre). Fingerling black bullheads were captured at Wall Lake, South Dakota, and stocked in late July, at a mean length of 34.1 mm (1.3 in) and rate of 988/hectare (400/acre). Juvenile and adult golden shiners and fathead minnows were supplied by commercial bait dealers and stocked in May and June, prior to largemouth bass stocking. Both forage species were stocked at 1,235/hectare (500/acre).

Field Methods

Largemouth bass were sampled from 3 northern ponds and 21 southern ponds 22 April - 28 June, 1981. All ponds known to hold original largemouth bass stocks were surveyed in 1982. Largemouth bass were captured by seining (45.4 m X 4.9 m, 19 mm mesh; and 23 m X 2.1 m, 19 mm mesh bag seines), electrofishing (230 volt, 3 cycle ac generator), and angling, when other methods failed. Scale samples were removed and total length and weight measurements recorded for each largemouth bass. Due to low numbers of largemouth bass captured from many study ponds in 1981 and 1982, minimum sample sizes were set at 10 largemouth bass per pond. Only ponds equal to or exceeding the minimum sample size were included in analyses, with exception of the Hinricher 2 pond which yielded only seven largemouth bass, an accurate estimate of the existing population.

Selected physical and water quality variables were determined at each pond prior to sampling in 1982. Hardness, alkalinity, and turbidity were measured with a Hach Kit, Model DR-EL/2. A Hach Model 17-G Cresol Red wheel or Hach Model 17-J Thymol Blue wheel was used to determine pH. Conductivity and salinity were measured with a Yellow Springs Model 33, S-C-T- meter. Maximum depth was determined with a Lowrance Fish LO-K-TOR, Model LFP-300D depth finder. Surface water temperatures were measured with a thermometer at a depth of 0.3 m. Only maximum pond depths and surface temperatures were recorded prior to sampling in 1982.

Largemouth bass population size was estimated from three northeastern and 11 southeastern ponds surveyed in 1981. Largemouth bass were initially captured with seines and marked in the upper lobe of the caudal fin with a 3 mm paper punch. Fish were returned to ponds and allowed to redistribute for a minimum of 24 hours. Largemouth bass were recaptured by electrofishing to reduce sampling bias.

Angler survey stations were established at 11 eastern ponds during 1981, and maintained through September, 1982. Stations were mounted to fence posts near study ponds. Stations consisted of plywood boxes containing angler survey cards, rulers, pencils, and an accompanying poster explaining program objectives and directions for completing survey cards. Survey cards requested information concerning the numbers and sizes of fish caught and released, numbers and sizes of fish caught and harvested, time spent fishing, numbers of angling trips to study ponds per year, fish species sought and/or preferred, and space for angler comments. Cards were collected bimonthly. Pond owners were contacted and asked to encourage angler cooperation in completing survey cards. Nine ponds were fished by project personnel prior to sampling in 1982. Effort consisted of three anglers fishing artificial baits for a predetermined time period on each pond.

Ten southeastern ponds were surveyed 14 September - 20 September, 1981, to determine relative abundance of young-of-the-year largemouth bass and young-adult ratios. Young-of-the-year largemouth bass were captured by random quadrat shoreline seine hauls using a 4.6 m x .3 m, 6.4 mm mesh minnow seine. Young-adult ratios were determined from fall electrofishing.

Laboratory Methods

A Wildco roller press, Model 110 H10, was used to make scale impressions on acetate slides (Smith 1954). Scale impressions were magnified on an Eberbach scale reader and scale measurements recorded to the nearest mm.

ANALYSIS

Largemouth bass population estimates were calculated using the modified Peterson formula:

$$\hat{N} = \frac{(M+1)(C+1)}{R+1} \quad \text{(Ricker 1975).}$$

where $\hat{N}$ = estimated population size at marking,

M = number of marked fish,

C = catch or sample taken for census,

and R = number of recaptured marks in sample.

Ninety-five percent confidence intervals were determined for each population estimate by the equation:

$$\hat{N} \pm 1.96\ V(N) \quad \text{(Everhard and Youngs 1981),}$$

where $V(\hat{N})$ equals sampling variance of N. V(N) was calculated by the equation:

$$V(\hat{N}) = \frac{\hat{N}^2(C-R)}{(C+1)(R+2)} \quad \text{(Ricker 1975).}$$

Survival of largemouth bass over two growing seasons was estimated by dividing 1981 population estimates by numbers of largemouth bass originally stocked. Survival estimates of age I largemouth bass were calculated by dividing 1981 population estimates by 1980 population estimates calculated by Stone (1981). Standing stock estimates were calculated for largemouth bass during the third growing season for each pond by multiplying 1981 population estimates with 1981 mean body weights of largemouth bass for that pond and dividing by 1979 and 1980 surface area estimates determined for the same ponds by Stone (1981).

Largemouth bass data from 18 ponds containing at least 10 fish were used in computation and statistical analysis of second year growth. Statewide sampling in 1982 yielded only 13 ponds having a sample of at least 10 largemouth bass. Only six ponds sampled in 1982 yielded 10 or more yearling largemouth bass.

Largemouth bass growth after the second and third growing seasons was estimated by back-calculating total lengths at annulus formation using the corrected Lee formula:

$$Ln = a + \frac{Sn}{Sc}(Lc-a) \quad \text{(Carlander 1977)},$$

where Ln = back-calculated length at annulus,

a = correction factor,

Sn = scale radius measurement to annulus, n,

Sc = total scale radius,

and Lc = length of fish at capture.

A correction factor (a) of 22 mm was used in the above equation (Stone 1981).

The condition index of Relative Weight (W_r) was calculated for each fish sampled in 1981 and 1982 allowing comparisions of largemouth bass condition among ponds and combinations within and between regions. Relative Weight was calculated from the equation:

$$W_r = \frac{W}{W_s} \times 100 \quad \text{(Wege and Anderson 1978)}$$

where W_r = relative weight,

W = weight of fish at sampling,

W_s = standard weight for fish of same length.

W_s was determined for each fish using the proposed standard weight-length formula, log W = -5.316 + 3.191(log L).

Analysis of variance by nested classification was utilized to test for differences in total lengths, weights, and W_r of adult and young-of-the-year largemouth bass due to stocking combinations or north-south regional distribution. Data from 1981 sampling were recombined and analyzed on the basis of largemouth bass only or largemouth bass stocked with forage fishes to determine differences in growth due to presence or absence of forage fishes. Information from 1982 samples of adult and age I largemouth bass was used in a two-way analysis of variance with unequal sample sizes to test for differences in largemouth bass total lengths, weights, and W_r due to north-south regional distribution of ponds and presence or absence of forage fishes.

Stepwise multiple regression was utilized to determine effects of select physical, chemical, and biological pond variables (Table 1) on adult and young-of-the-year largemouth bass total lengths, weights, and W_r. Water quality and climatological information presented by Stone (1981) was used in regressions with 1981 length and W_r values since climatic and water conditions in 1980 determined second year growth. Water quality records from ponds sampled in 1981 were used in the regression of third year growth and W_r indices. The variable, growing days (table 1), used in regressions is the number of days in which mean daily air temperatures fell below 10 C for a two week period in the fall. The temperature value of 10 C may serve as a threshold

Table 1. Independent variables used in stepwise multiple regression analysis of largemouth bass (*Micropterus salmoides*) survival, total lengths, and W_r estimated from adult and age I fish sampled from 18 South Dakota ponds in Spring, 1981, and 13 ponds in Spring, 1982.

Independent variables
Alkalinity - total
- carbonate
- bicarbonate
Conductivity
Turbidity
Maximum depth
Growing days
Presence/absence of forage fishes

value for largemouth bass growth (Markus 1932). Regional temperatures were obtained from 1980 and 1981 annual NOAA climatological summaries for South Dakota.

Spawning success of age-II largemouth bass was determined as the percentage of 32 largemouth bass populations sampled in September, 1981, and May, 1982, containing young-of-the-year or yearling largemouth bass. Relative abundance, expressed as mean number of young-of-the-year largemouth bass/seine haul, and young-of-the-year densities were calculated from catch per haul and area sampled, using 1979 and 1980 surface area estimates determined by Stone (1981). Young-adult ratios (YAR), (Reynolds and Babb 1978) were calculated from catch composition of adult and young-of-the-year largemouth bass captured by electrofishing. Largemouth bass angler catch rates (fish/hr) and potential harvest values (kg/hr) were determined from angler survey cards and angling efforts by project personnel.

RESULTS

Water Analysis

Eight physical and chemical variables were measured and recorded at each pond prior to fish sampling in 1981. pH values ranged from 7.7 - 9.3 (Appendix Table 2). Total alkalinity ranged from 20 - 230 mg/l with an average of 164 mg/l in ponds from the glaciated region east of the Missouri River and 73 mg/l for ponds in the non-glaciated region west of the Missouri River. Salinity values varied from 0.0 - 3.2 ^{o}/oo. Total hardness ranged from 70 - 1,080 mg/l. Average hardness valuess in ponds east and west of the Missouri River were 286 mg/l and 427 mg/l, respectively. Specific conductance values, corrected to 25 C, varied from 253 4,829 µmhos/cm Average conductivity from ponds east and west of the Missouri River were 762 and 1,945 µmhos/cm, respectively. Maximum pond depth ranged from 0.9 - 4.9 m with a mean of 2.4 m (7.9 ft), down 0.4 m from 1980 estimates of 2.8 m (9.2 ft) (Stone 1981). The 1980 growing season varied from 165 to 190 days with a northwest to southeast gradient and averaged 181 growing days statewide. The 1981 growing season among ponds ranged from 194 to 214 days on the same gradient, with a statewide average of 202 growing days. Near drought conditions prevailed in South Dakota during the study period. Average annual rainfall amounts during 1979 - 1981 were down 1.63, 10.55, and 0.75 cm, respectively (Lytle unpublished [1]).

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[1] Unpublished meteorlogical reports, W. F. Lytle, Associate Professor, Weather Engineering, Department of Agricultural Engineering, South Dakota State University, Brookings, South Dakota, USA.

Survival

Survival estimates of largemouth bass after two growing seasons ranged from 4.0 - 92.0% with an average survival of original stocks at 26.5% for all stocking combinations (Appendix Table 3). Mean survival values among the four stocking combinations represented varied from 8.4% for largemouth bass-black bullhead combinations to 31.6% for largemouth bass only combinations (Figure 2). Annual survival of age I largemouth bass ranged from 43.2% for largemouth bass-golden shiner combinations to 74.0% for largemouth bass-bluegill combinations (Figure 3), with an overall average annual survival rate of 58.6% (Appendix Table 4).

Analysis of variance did not detect significant differences ($P > 0.05$) in largemouth bass survival due to stocking combinations. Stepwise multiple regression of survival with eight chemical, physical, and biological variables (Table 1) did not indicate any factors which significantly ($P > 0.05$) contributed to variation in largemouth bass survival.

Second Year Growth

Average growth after two growing seasons, back-calculated from age II+ largemouth bass sampled in 1981, ranged from 193 - 428 mm with a statewide mean total length of 286 mm. When grouped by stocking combination, the range in total lengths was from 270 mm for largemouth bass-golden shiners ponds to 324 mm for the Calhoun 4 pond containing largemouth bass and fathead minnows (Figure 4). Annual growth increments for age I largemouth bass averaged 114 mm for largemouth

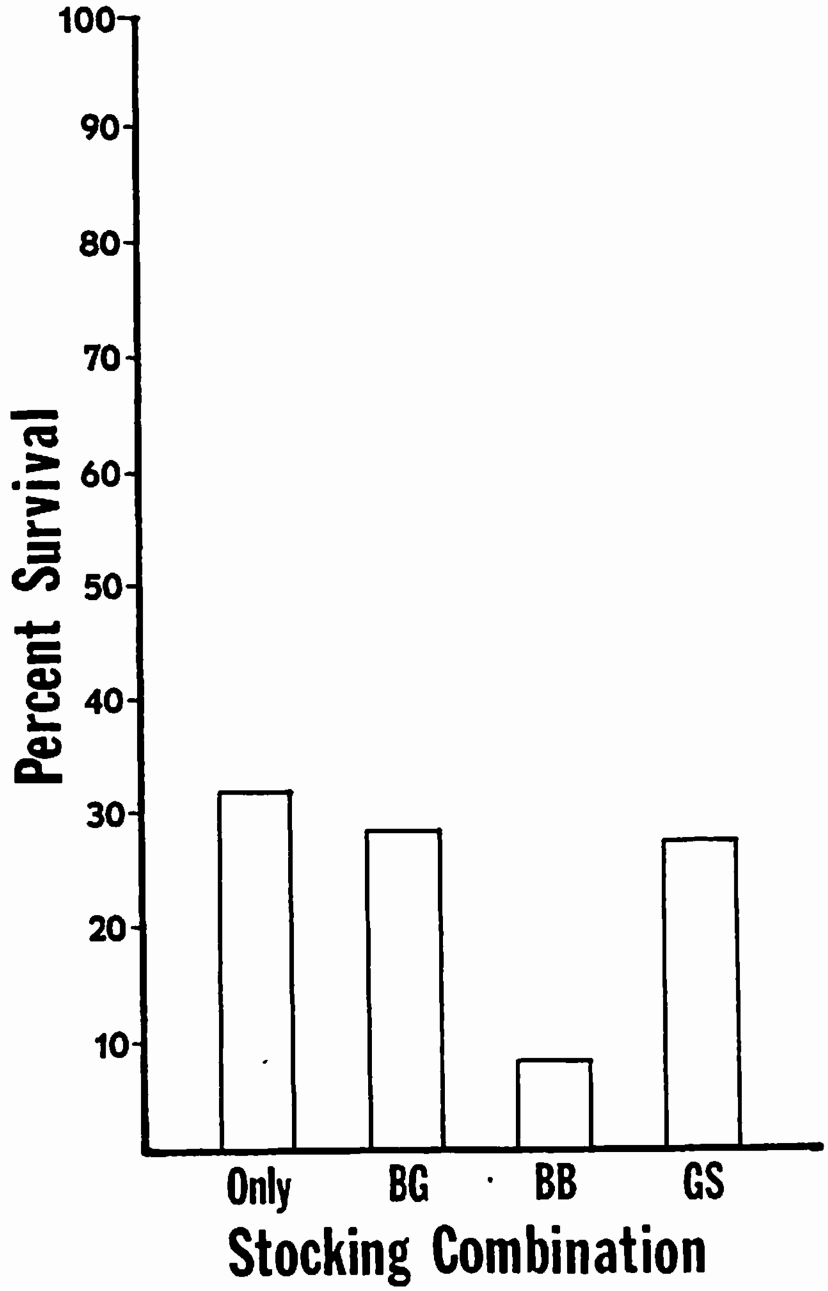

Figure 2. Mean survival of largemouth bass (Micropterus salmoides) after two growing seasons in 18 South Dakota ponds surveyed in 1981, by stocking combination (Only = no forage present; BG = bluegill, Lepomis macrochirus; BB = black bullhead, Ictalurus melas; GS = golden shiner, Notemigonus crysoleucas).

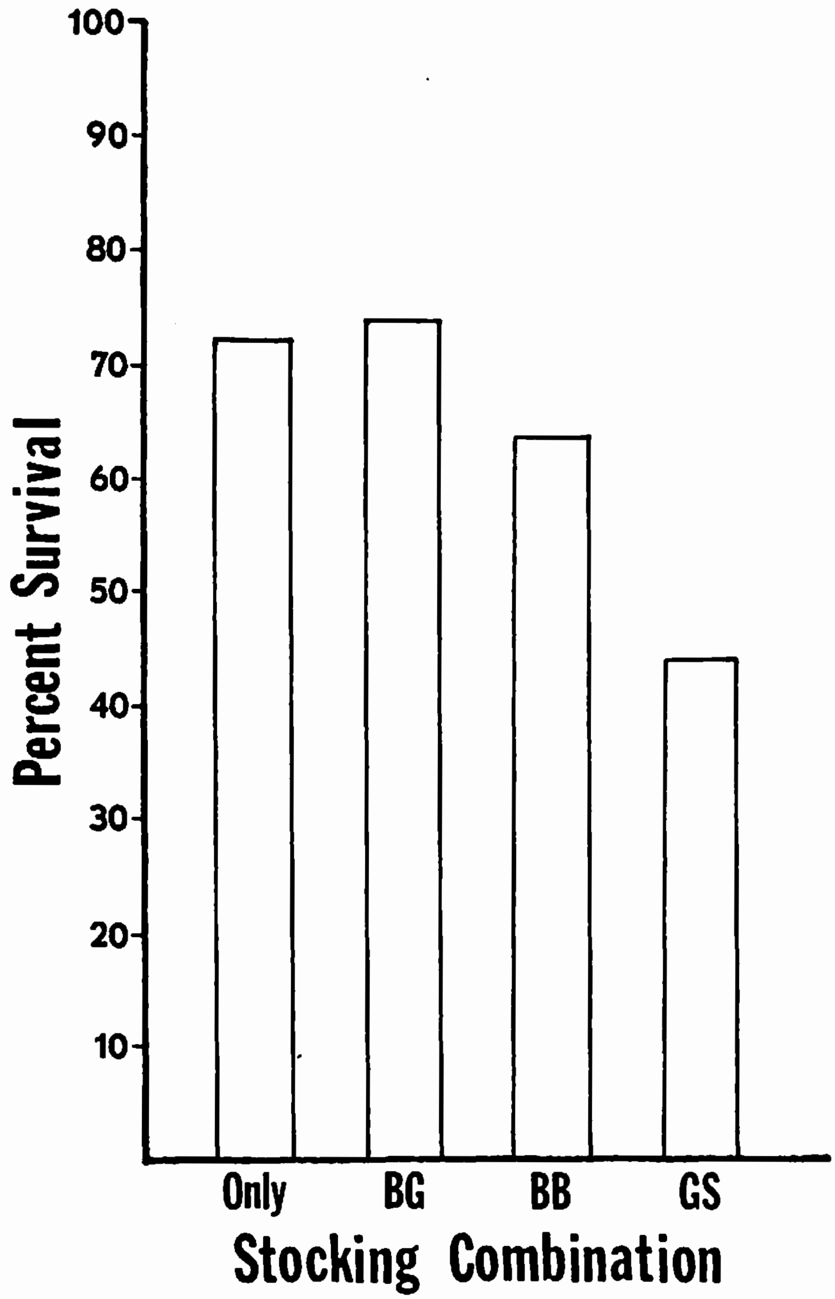

Figure 3. Mean annual survival of age-I largemouth bass (*Micropterus salmoides*) in 14 eastern South Dakota ponds surveyed in 1981, by stocking combination (Only = no forage present; BG = bluegill, *Lepomis macrochirus*; BB = black bullhead; *Ictalurus melas*; GS = golden shiner, *Notemigonus crysoleucas*).

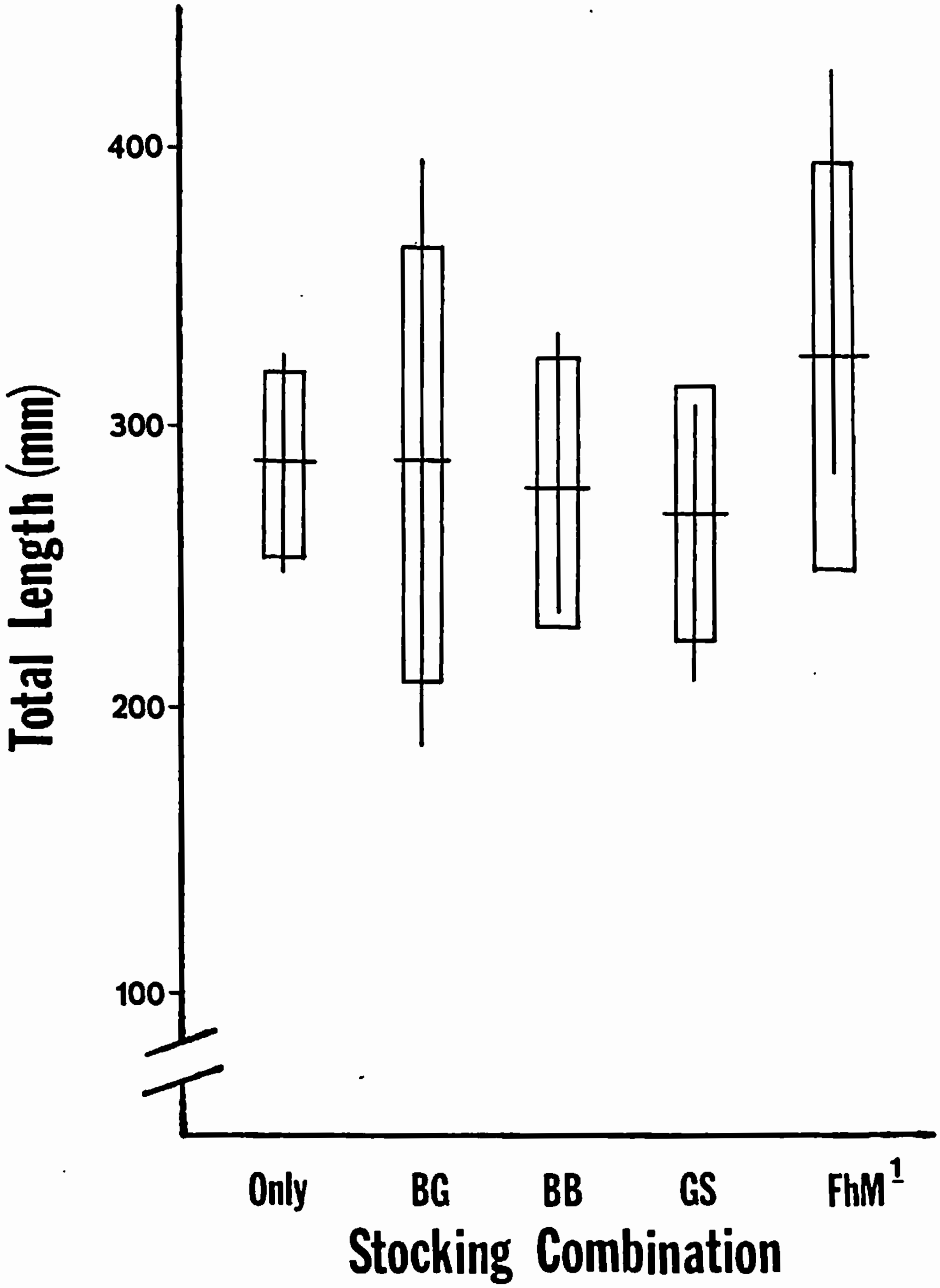

Figure 4. Ranges (vertical lines), standard deviations (rectangles), and means (horizontal lines) for total lengths of largemouth bass (Micropterus salmoides) after two growing seasons in 18 South Dakota ponds surveyed in 1981, by stocking combination (Only = no forage present; BG = bluegill, Lepomis macrochirus; BB = black bullhead, Ictalurus melas; GS = golden shiner, Notemigonus crysoleucas; FhM = fathead minnow, Pimephales promelas).

[1] Denotes only one pond represented.

bass - black bullhead combinations to 146 mm for the Calhoun 4 largemouth bass-fathead minnow pond, with a southern South Dakota grand average of 118 mm (Appendix Table 5).

Analysis of variance indicated no significant differences ($P > 0.05$) in total length after two growing seasons due to stocking combinations. Regrouping data from stocking combinations, separating largemouth bass only stockings from largemouth bass stocked with forage fishes, also failed to detect differences in growth due to presence or absence of stocked forage. Stepwise multiple regression indicated maximum depth to be the only significant ($P < 0.05$) variable effecting largemouth bass growth, explaining 43.0% of the variation in total lengths.

Mean body weights by stocking combination varied from 343 - 756 gm for largemouth bass-black bullhead and largemouth bass-fathead minnow combinations, respectively (Figure 5). Individual weights ranged from 99 - 988 gm. This extreme range in weights may partially reflect differences in prespawning and postspawning conditions during the 1981 sampling period. Prespawn weight for largemouth bass from nine southeastern ponds surveyed in April and May averaged 437 gm, while largemouth bass from nine southwestern ponds surveyed in late June averaged 366 gm.

Standing stock estimates for age II largemouth bass ranged from 3.3 - 104.9 kg/hectare with an overall unweighted mean of 34.3 kg/hectare (Appendix Table 6). Largemouth bass-bluegill ponds supported a greater standing stock of largemouth bass with a mean of 77.0 kg/hectare. Analysis of variance did not detect significant

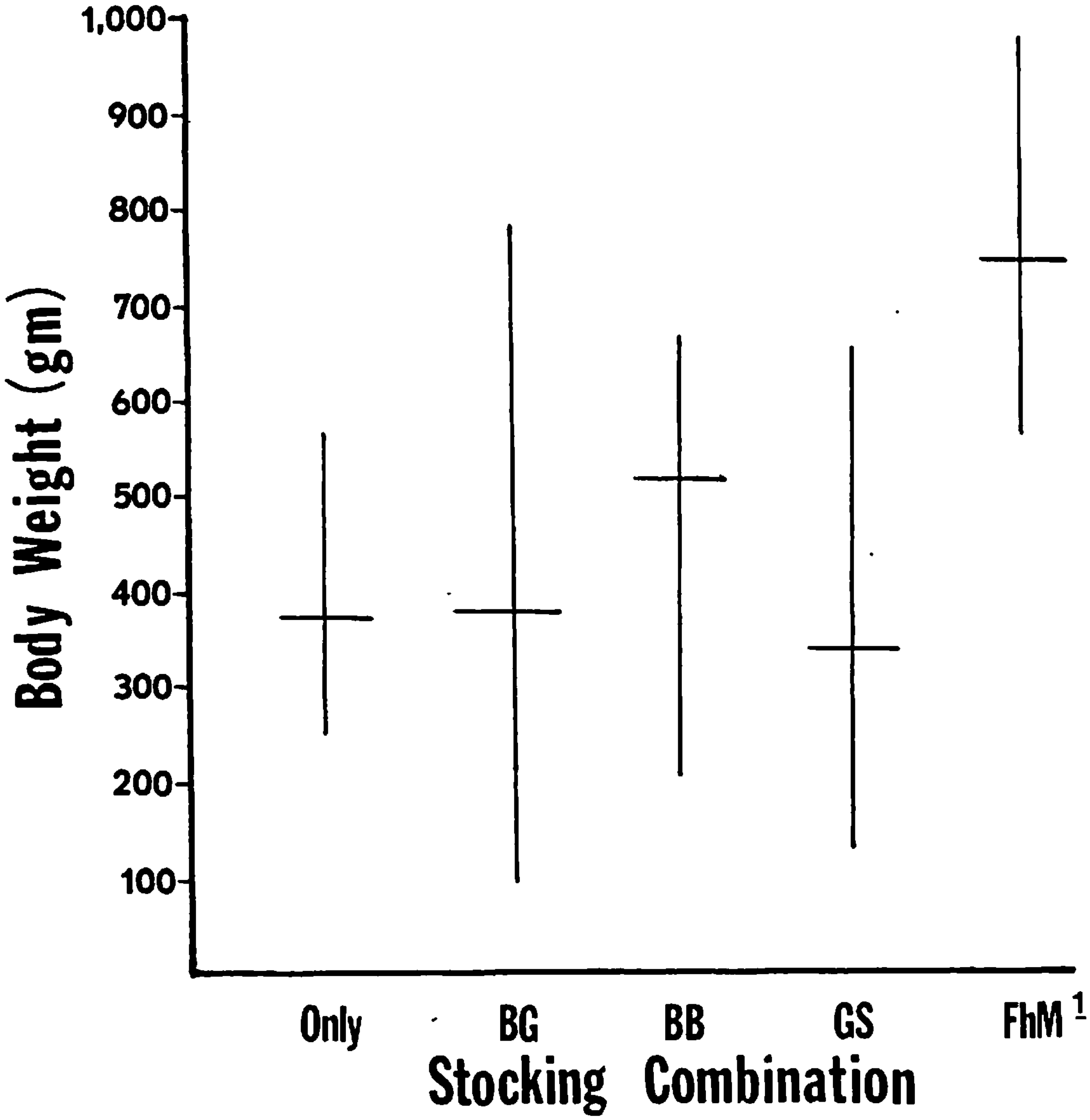

Figure 5. Ranges (vertical lines) and means (horizontal lines) for body weights of largemouth bass (Micropterus salmoides) after two growing seasons in 18 South Dakota ponds surveyed in 1981, by stocking combination (Only = no forage present; BG = bluegill, Lepomis macrochirus; BB = black bullhead, Ictalurus melas; GS = golden shiner, Notemigonus crysoleucas; FhM = fathead minnow, Pimephales promelas).

[1] Denotes only one pond represented.

differences ($P > 0.05$) in standing stock estimates due to stocking combinations. Adult largemouth bass densities averaged 76.6 largemouth bass/hectare, with a range of means from 16 largemouth bass/hectare for largemouth bass stocked with bullheads to 147 largemouth bass/hectare for largemouth bass stocked with bluegills.

Relative Weights of largemouth bass, varying from 66 - 174, were partially dependent on prespawn or postspawn conditions (Figure 6). Mean W_r values varied from 88 - 136 for southeastern ponds surveyed in June (Appendix Table 5). The W_r value of 136 for the Calhoon 1 pond may represent prespawn weights. Prespawning W_r averaged 120, while postspawning W_r averaged 100.

Reproduction

No largemouth bass reproduction was documented prior to spring sampling in 1981, the beginning of the third growing season for the initially stocked year-class. Fall sampling in 1981 indicated largemouth bass reproduced in 12 of 20 southern ponds. Reproductive success was less complete in northern ponds where only 5 of 12 ponds surveyed in the spring of 1982 contained junvenile largemouth bass. This estimate serves only as an approximation of spawning success in northern ponds because those ponds were not surveyed in 1981 and entire populations were lost to summer drought or winterkill prior to sampling in 1982.

Relative abundance estimates from nine southeastern ponds surveyed in 1981 ranged from 0.5 - 71.0 largemouth bass/seine haul, with a mean of 15.7 young-of-the-year largemouth bass/seine haul (Appendix Table 7). Young-of-the-year densities varied from

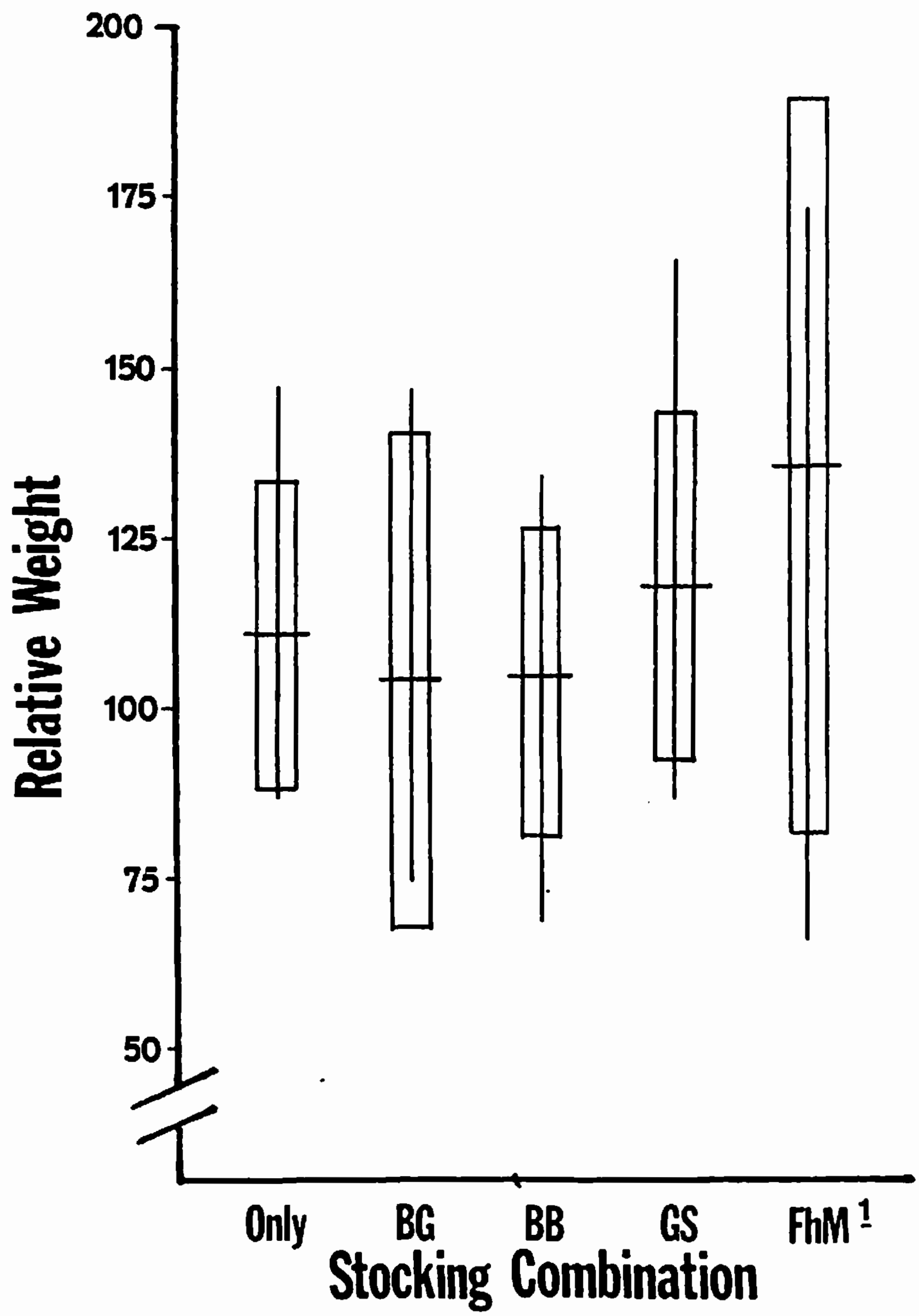

Figure 6. Ranges (vertical lines), standard deviations (rectangles), and means (horizontal lines) for Relative Weights of largemouth bass (*Micropterus salmoides*) after two growing seasons in 18 South Dakota ponds surveyed in 1981 by stocking combination (Only = no forage present; BG = bluegill, *Lepomis macrochirus*; BB = black bullhead, *Ictalurus melas*; GS = golden shiner, *Notemigonus crysoleucas*; FhM = fathead minnow, *Pimephales promelas*).

[1] Denotes only one pond represented.

305 - 43,245 largemouth bass/hectare, averaging 10,720 largemouth bass/hectare. Electrofishing the same ponds yielded YAR values ranging from 1.2:1 - 118:1, with a mean of 34.8:1. A significant ($P < 0.05$) negative relationship ($r = -0.74$) existed between YAR and adult largemouth bass densities. Total lengths of young-of-the-year largemouth bass ranged from 58 - 104 mm with a mean of 74 mm.

Third Year Growth

Adult largemouth bass total lengths after three growing seasons averaged 317 mm, with a range of 211 - 391 mm (Appendix Table 8). Average lengths by stocking combinations ranged from 272 mm for the largemouth bass-black bullhead combination to 343 mm for the largemouth bass-fathead minnow combination (Figure 7). Plotting mean back-calculated lengths at annulus indicated largemouth bass stocked with bluegills attained the greatest total lengths through two growing seasons. During the third growing season, largemouth bass stocked with golden shiners or fathead minnows showed the greatest growth, while growth in the largemouth bass-bluegill combination declined rapidly (Figure 8). Average annual growth increments for the third growing season varied from 96 mm for largemouth bass stocked with black bullheads to 154 mm for largemouth bass in the Blue Cloud Abbey pond stocked with golden shiners.

Body weight ranged from 130 - 1,191 gm and averaged 500 gm. Average body weights by stocking combinations varied from 318 gm for largemouth bass stocked with black bullheads to 696 gm for largemouth bass stocked with fathead minnows (Figure 9). Relative Weight varied from 74 - 143 and averaged from 90 for the largemouth

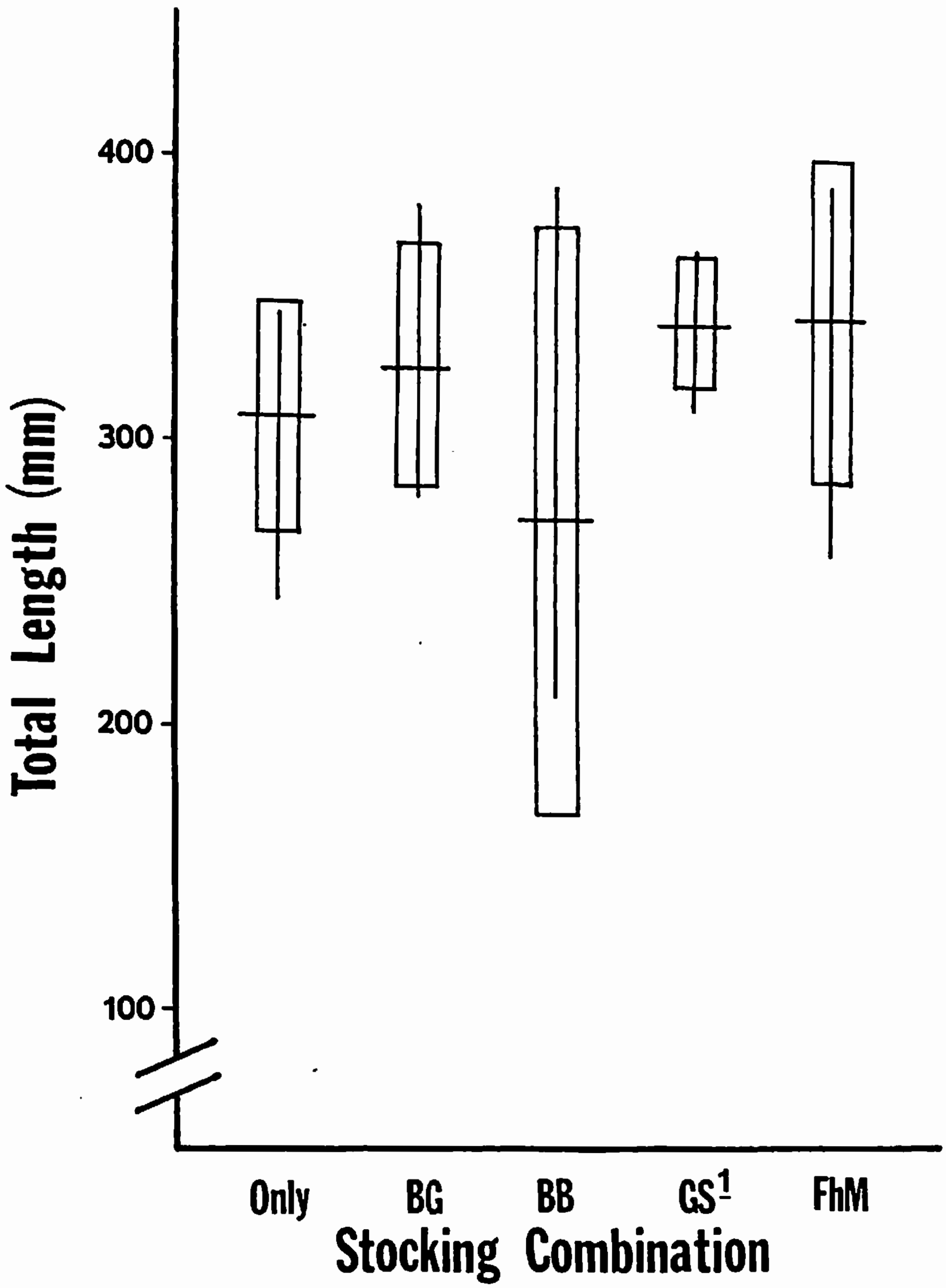

Figure 7. Ranges (vertical lines), standard deviations (rectangles), and means (horizontal lines) for total length of largemouth bass (Micropterus salmoides) after three growing seasons in 13 South Dakota ponds surveyed in 1982, by stocking combination (Only = no forage present; BG = bluegill, Lepomis macrochirus; BB = black bullhead, Ictalurus melas; GS = golden shiner, Notemigonus crysoleucas; FhM = fathead minnow, Pimephales promelas).

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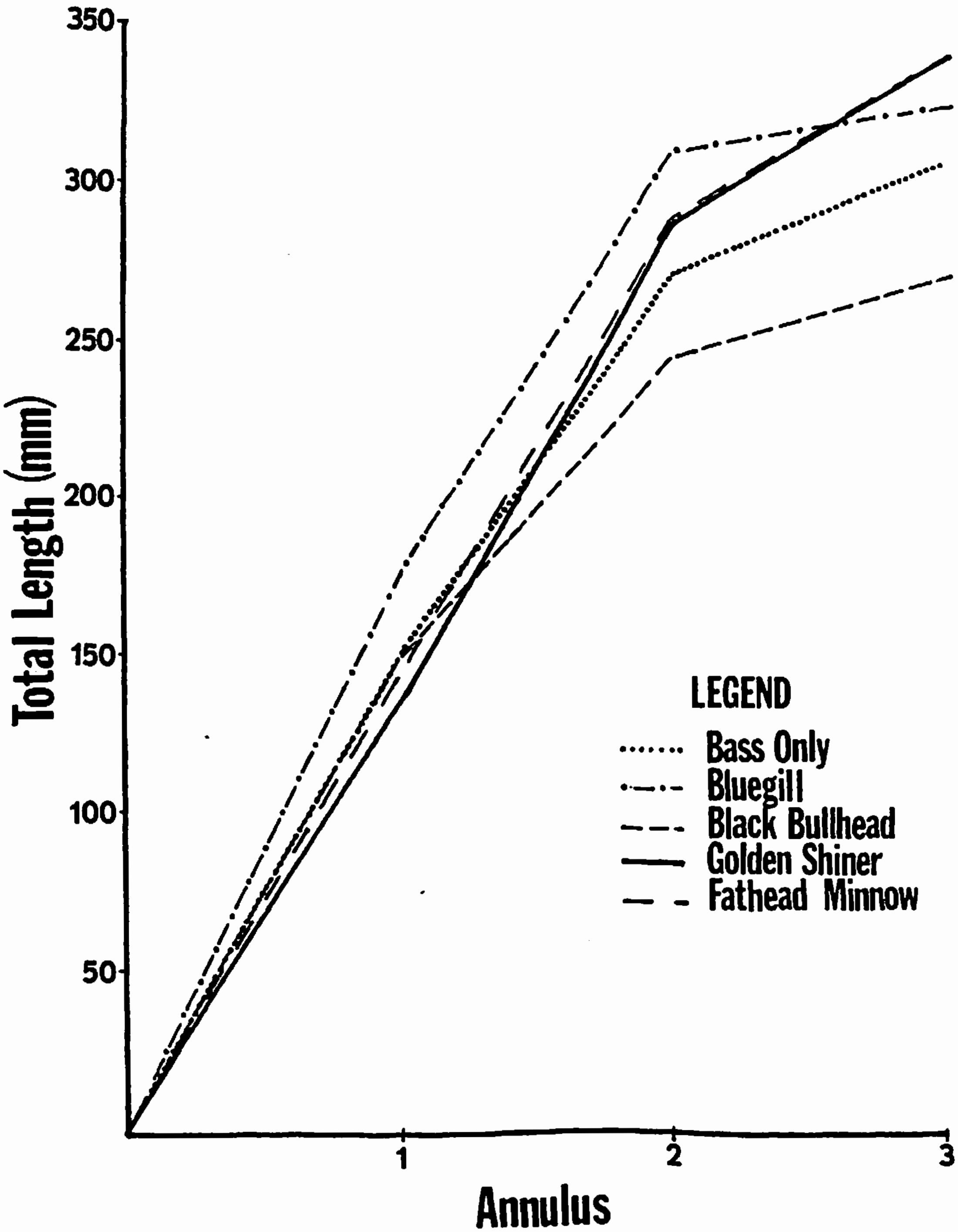

Figure 8. Back-calculated total lengths at annulus for age-III largemouth bass (*Micropterus salmoides*) from 13 South Dakota stock ponds by stocking combination.

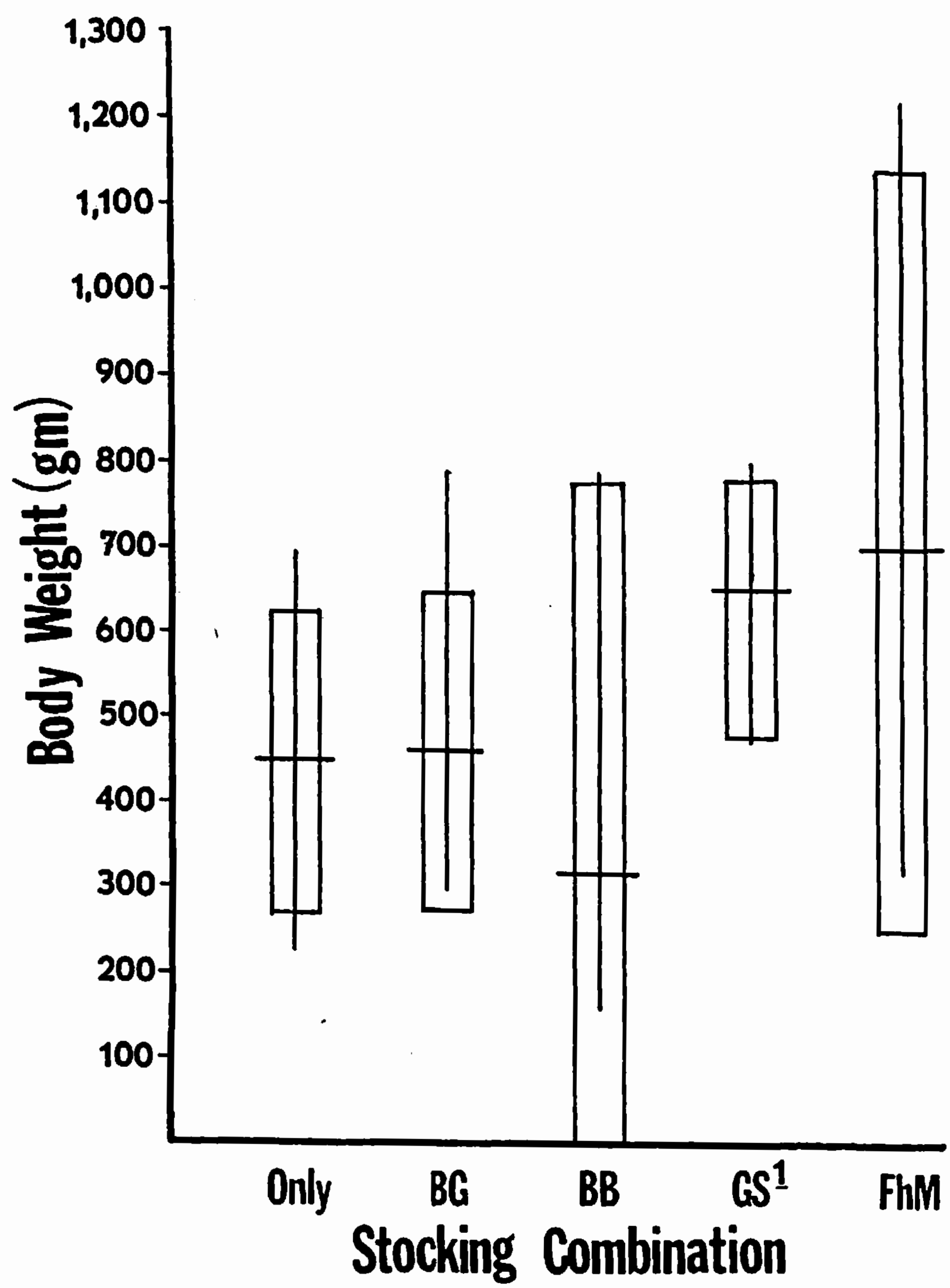

Figure 9. Ranges (vertical lines), standard deviations (rectangles), and means (horizontal lines) for body weights of largemouth bass (Micropterus salmoides) after three growing seasons in 13 South Dakota ponds surveyed in 1982, by stocking combination (Only = no forage present; BG = bluegill, Lepomis macrochirus; BB = black bullhead, Ictalurus melas; GS = golden shiner, Notemigonus crysoleucas; FhM = fathead minnow, Pimephales promelas).

[1] Denotes only one pond represented.

bass-bluegill combination to 114 for the one largemouth bass-fathead minnow combination represented (Figure 10).

Analysis of variance did not indicate significant differences ($P > 0.05$) in total lengths, weights, or W_r attained after three growing seasons due to stocking combinations or geographic location. Regrouping data to largemouth bass only and largemouth bass with forage treatments also failed to indicate significant differences ($P > 0.05$) in total lengths, weights, and W_r due to the presence or absence of forage fishes and geographic location. Stepwise multiple regressions of back-calculated total lengths to annulus III and W_r did not reveal any variables significantly ($P > 0.05$) effecting largemouth bass growth or condition. All eight variables (Table 1) explained only 41.0% of the variation in total lengths and 71.0% of the variation in W_r.

Young-of-the-Year Largemouth bass Growth

Back-calculated lengths at age I ranged from 69 - 141 mm with an average of 92 mm (Appendix Table 9). Mean total lengths by stocking combinations varied from 78 - 107 mm for largemouth bass-black bullhead and largemouth bass-bluegill combinations, respectively (Figure 11). A plot of back-calculated total lengths at age-I indicated the greatest growth of young-of-the-year largemouth bass occurred in largemouth bass-bluegill and largemouth bass-golden shiner ponds (Figure 12). The largemouth bass-fathead minnow combination was not represented in 1982 sampling of junvenile largemouth bass.

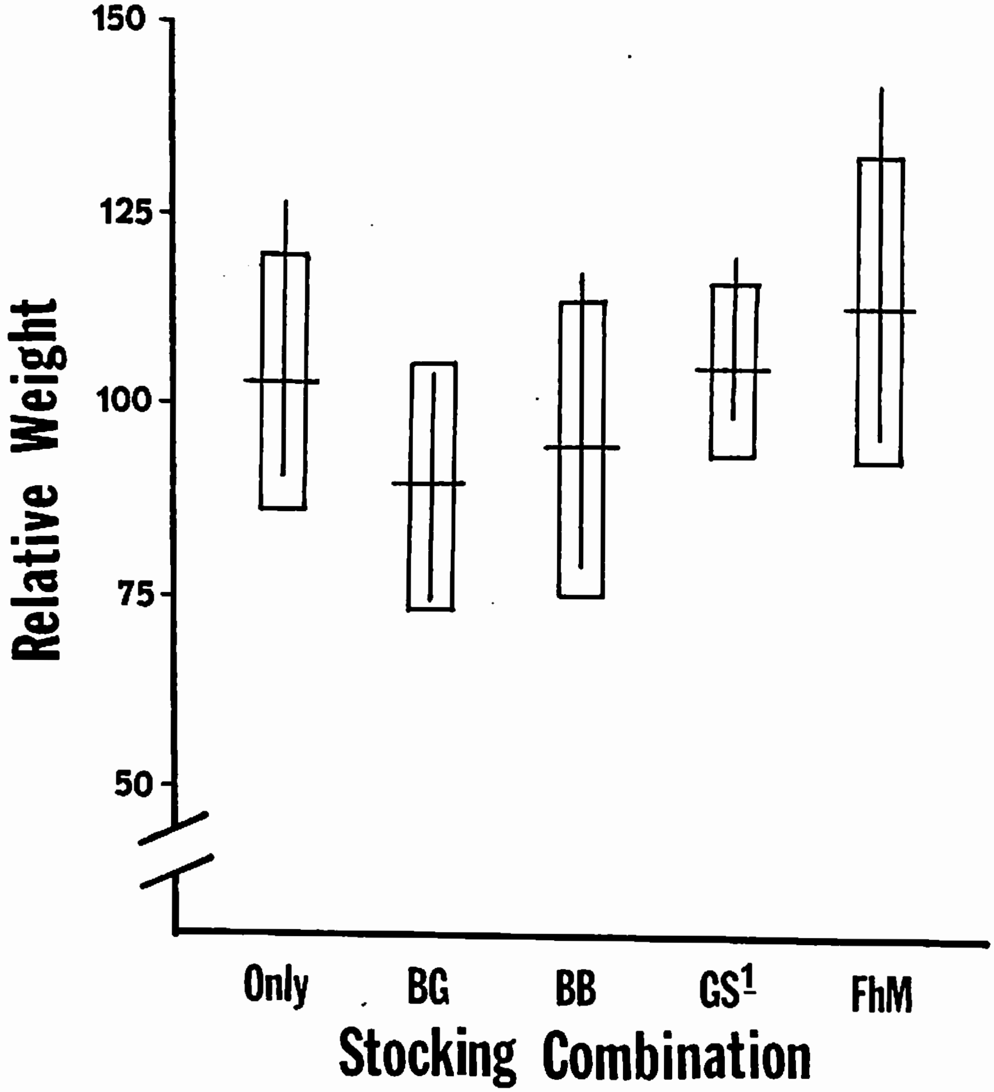

Figure 10. Ranges (vertical lines), standard deviations (rectangles), and means (horizontal lines) for Relative Weights of largemouth bass (Micropterus salmoides) after three growing seasons in 13 South Dakota ponds surveyed in 1982, by stocking combination (Only = no forage present; BG = bluegill, Lepomis macrochirus; BB = black bullhead, Ictalurus melas; GS = golden shiner, Notemigonus crysoleucas; FhM = fathead minnow, Pimephales promelas).

[1] Denotes only one pond represented.

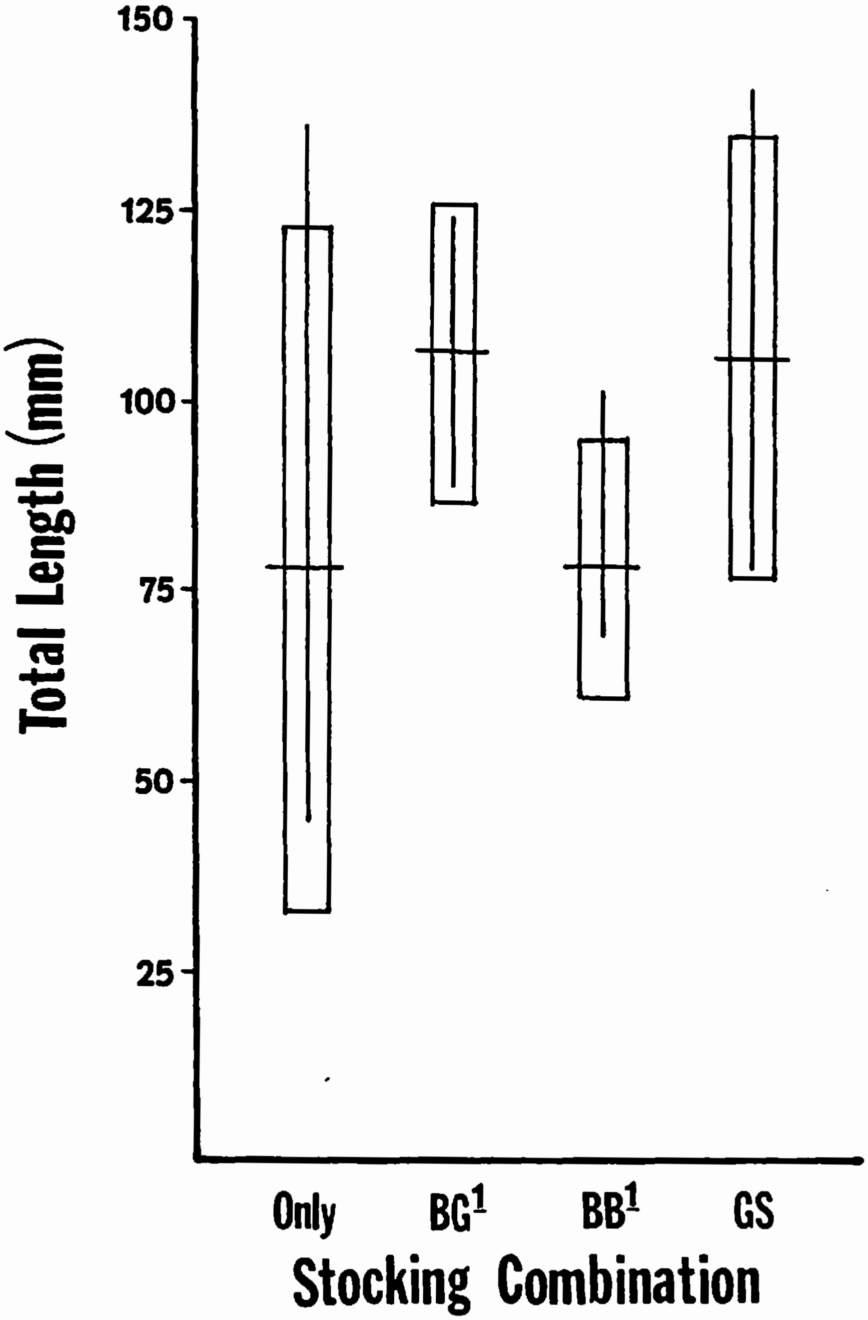

Figure 11. Ranges (vertical lines), standard deviations (rectangles), and means (horizontal lines) for total lengths of age-I largemouth bass (*Micropterus salmoides*) from six South Dakota ponds surveyed in 1982, by stocking combination (Only = no forage present; BG = bluegill, *Lepomis macrochirus*; BB = black bullhead, *Ictalurus melas*; GS = golden shiner, *Notemigonus crysoleucas*).

[1] Denotes only one pond represented.

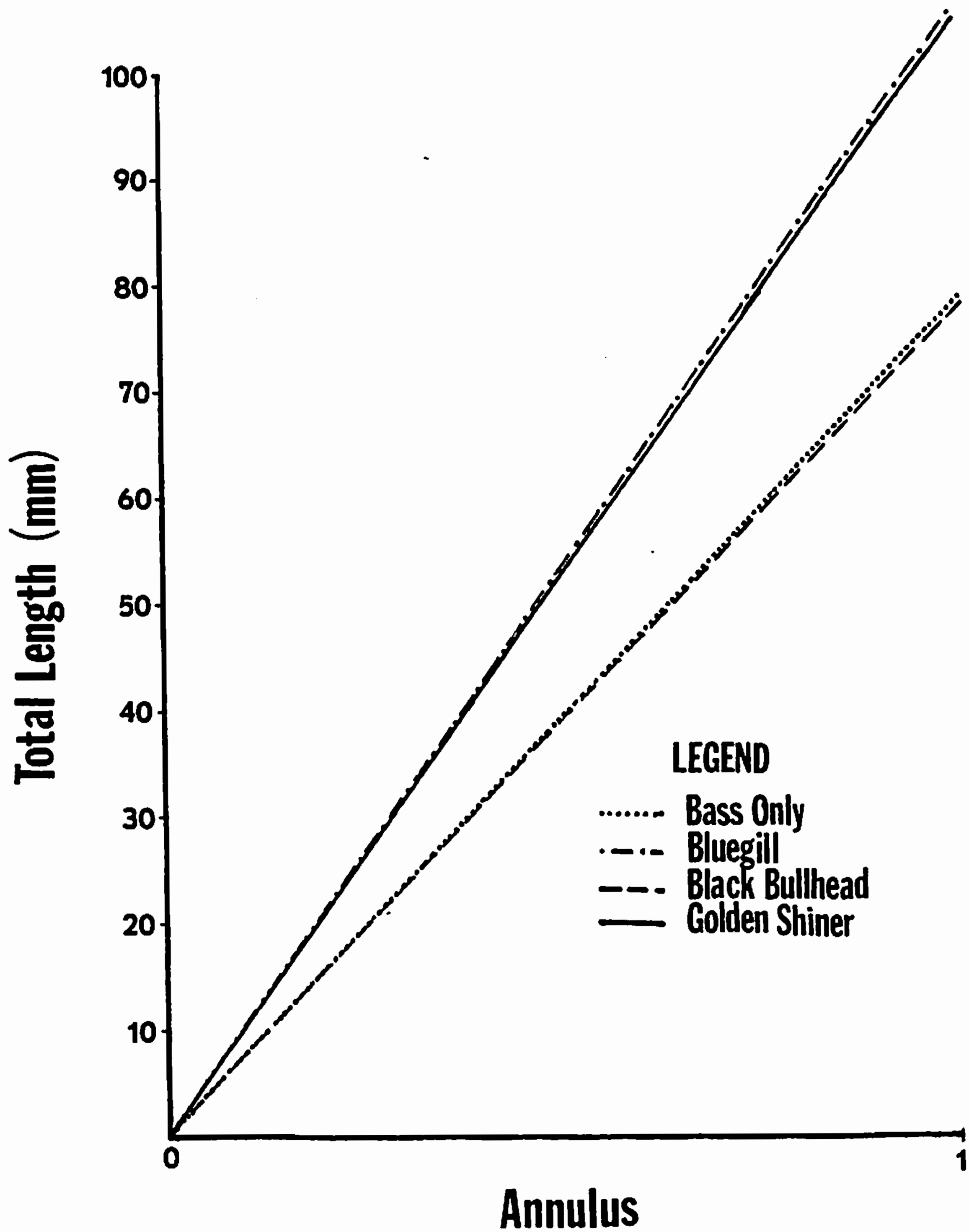

Figure 12. Back-calculated total lengths at annulus for age-I largemouth bass (Micropterus salmoides) from six South Dakota ponds surveyed in 1982, by stocking combination.

Body weights of age-I largemouth bass sampled in 1982 ranged from 2 - 46 gm with an overall mean of 18 gm. Grouping by stocking combinations yielded mean weights varying from 7 gm for the one largemouth bass-black bullhead combination to 28 gm for largemouth bass stocked with bluegills (Figure 13). Relative Weights classified by stocking combinations averaged from 88 - 119 (Figure 14), with a range of 70 - 161 and an overall mean of 102.

Analysis of variance indicated no significant differences in first year growth, weights, and W_r of largemouth bass due to stocking combinations, geographic location, or presence or absence of forage fishes. None of eight independent chemical, physical, or biological factors used in stepwise multiple regression significantly ($P > 0.05$) contributed to variations in total lengths. Young-of-the-year growth was not significantly correlated ($r = -0.44$) with young-of-the-year largemouth bass densities.

Angler Survey Information

Thirty angler survey cards were collected from 6 of 11 survey stations from 1981 through 1982. Angler cooperation was less than satisfactory as indicated by discarded lure packaging and similar signs of fishing activity at ponds from which no cards were completed. Some cards were incompletely filled out. In most cases, values given in reply to the number of fishing trips to the pond per year exceeded the number of cards filled out at survey stations. Interviews with landowners indicated their families and employees were responsible for

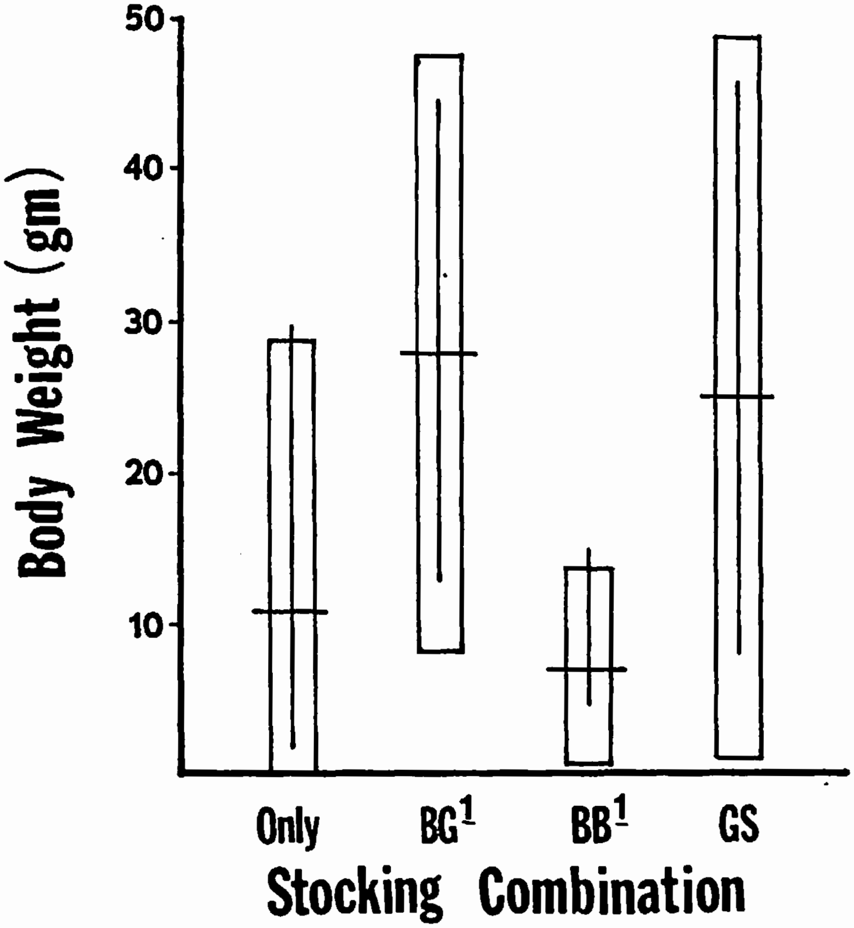

Figure 13. Ranges (vertical lines), standard deviations (rectangles), and means (horizontal lines) for body weights of age-I largemouth bass (Micropterus salmoides) in six South Dakota ponds surveyed in 1982, by stocking combination (Only = no forage present; BG = bluegill, Lepomis macrochirus; BB = black bullhead, Ictalurus melas; GS = golden shiner, Notemigonus crysoleucas).

[1] Denotes only one pond represented.

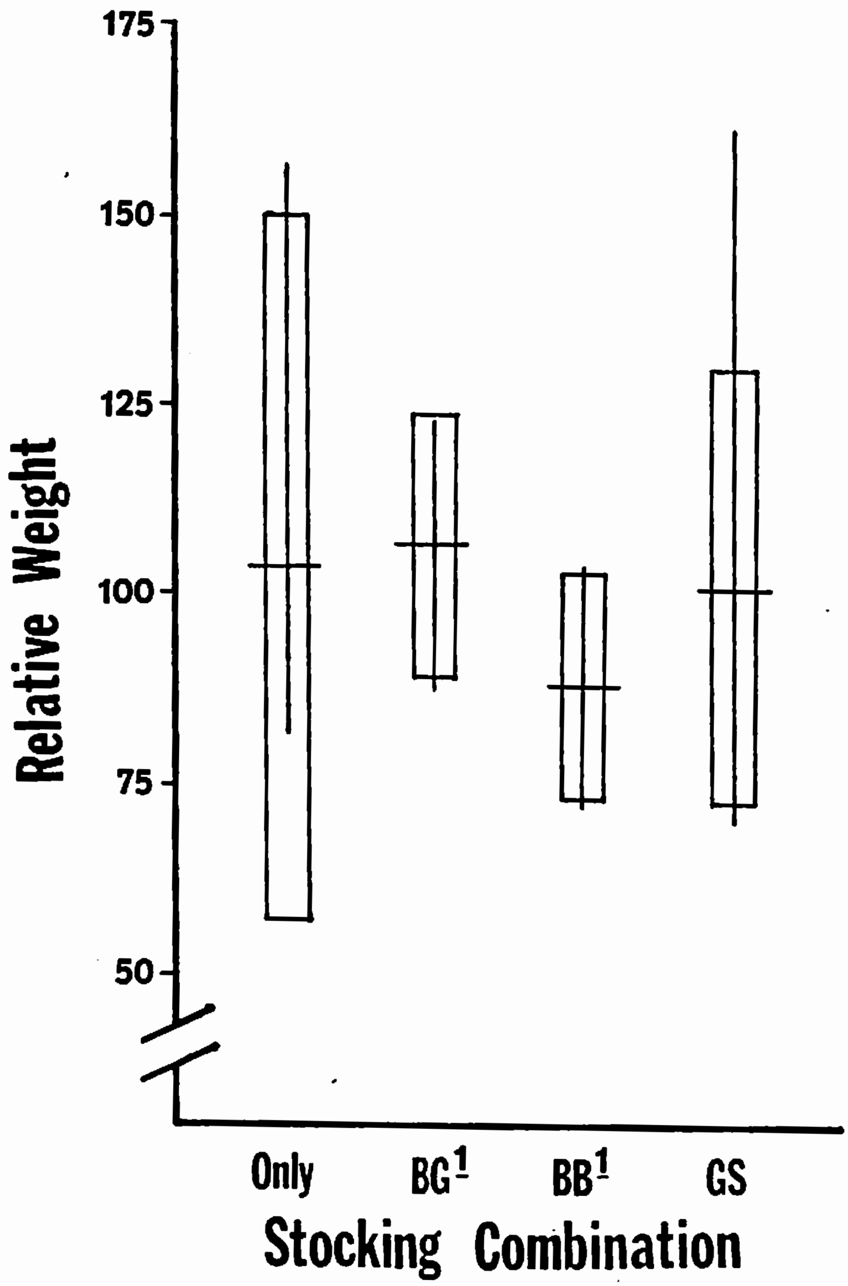

Figure 14. Ranges (vertical lines), standard deviations (rectangles), and means (horizontal lines) for Relative Weights of age-I largemouth bass (Micropterus salmoides) in six South Dakota ponds surveyed in 1982, by stocking combination (Only = no forage present; BG = bluegill, Lepomis macrochirus; BB = black bullhead, Ictalurus melas; GS = golden shiner, Notemigonus crysoleucas).

[1] Denotes only one pond represented.

completing most survey cards, but they were often negligent in completing cards after each fishing trip. Therefore, actual fishing pressure is probably underestimated.

Angler survey information indicated 77 anglers fished 139.6 hours on 3.1 hectares of pond surface; an overall fishing pressure of 45.6 hours per hectare. Anglers averaged 1.8 hours per fishing trip. Four stocking combinations were represented by the six ponds. Eighty-three percent of surveyed anglers fished primarily for largemouth bass. Forty-seven percent of anglers fishing largemouth bass-bluegill ponds fished for bluegills in addition to largemouth bass. Two cards from the Hinricher 2 largemouth bass-black bullhead pond indicated black bullheads were the only species sought.

Largemouth bass catch rates were determined from 23 fully completed survey cards representing 49 anglers fishing five ponds or 2.6 hectares. Largemouth bass anglers fished an average of 1.6 hr/fishing trip and caught 2.0 fish/hr, representing a potential harvest of 30.9 kg/hectare. Total angling pressure for largemouth bass averaged 31.2 hr/hectare.

Project personnel fished 14.3 hours on 2.6 hectares of pond surface catching 35 largemouth bass for a yield of 2.1 fish/hr or 0.9 kg/hr. Statistical analysis of mean catch rates from angler survey cards and project personnel angling indicated no significant differences ($P > 0.05$) in estimates; therefore, information was pooled. Fishing quality in terms of largemouth bass caught per hour was determined for 12 ponds representing all five stocking combinations (Appendix Table 10). Even though catch rates were not significantly different

($P > 0.05$) due to variation within treatments, the average number of largemouth bass caught per hour from largemouth bass only ponds, 2.8 fish/hr, appeared greater than from largemouth bass-bluegill ponds, 2.0 fish/hr; but weight of largemouth bass caught per hour was better in largemouth bass-bluegill ponds, 1.11 kg/hr versus 1.05 kg/hr for largemouth bass only ponds.

DISCUSSION

Differences in largemouth bass survival, growth, and reproductive success based on availability of select forage fishes could not be determined. Extreme variations in largemouth bass survival, growth, and young-of-the-year densities among ponds within individual stocking combinations were largely due to adverse environmental conditions during the study period ultimately shaping largemouth bass population dynamics regardless of forage availability. Below average precipitation during the study period resulted in failure of most pondfish populations. Partial or complete loss of largemouth bass populations due to low water levels and subsequent drying or winterkill eliminated 62 of 80 (78%) ponds stocked in 1979 from 1982 analyses (Appendix Table 1). An additional five ponds were eliminated due to gross contamination with unstocked fishes including walleyes (Stizostedion vitreum), green sunfish (Lepomis cyanellus), and bullheads (Ictaluras sp.).

Average survival of 26.5% after two years in the present study was much lower than the 48.0% largemouth bass survival in Ontario ponds (Johnson and MacCrimmon 1967) or 60.0% survival of age-II+ largemouth bass stocked as fingerlings in Michigan ponds (Ball and Tait 1952). Estimated average survival to age-I of 58.6% was comparable to 55.0% for largemouth bass in privately owned Iowa ponds (Hill 1980). Largemouth bass only, largemouth bass-bluegill, and largemouth bass-golden shiner combinations exhibited similar survival rates after two years (31.6, 28.8, and 27.8%, respectively) and although not statistically different, appeared to have better overall survival rates than the largemouth bass-black bullhead combination.

No explanations for increased mortality of largemouth bass stocked with black bullheads were discernable from the study.

Growth of original largemouth bass stocks in all stocking combinations was good. This may have been characteristic of expanding fish populations, low survival rates of largemouth bass throughout the study, or the high fertility of South Dakota waters. Novinger (1980) indicated water fertility could be quantified by specific conductance, with values greater than 200 µmhos/cm indicating high fertility. All South Dakota ponds surveyed in 1981 and 1982 exhibited conductivities in excess of 200 µmhos/cm.

Largemouth bass growth after two growing seasons was equivalent to the 286 mm average length of largemouth bass stocked in Iowa ponds at reduced densities of 173 largemouth bass/hectare (Hill 1980). Largemouth bass attained 282 mm average lengths after two growing seasons in Ontario ponds (Johnson and MacCrimmon 1967). Novinger (1980) reported an average length of 282 mm for largemouth bass simultaneously stocked in drainable ponds in Missouri. Age-III largemouth bass growth averaged slightly greater than the approximate 300 mm mean length reported for largemouth bass stocked in Missouri ponds (Novinger 1980) and the average weight of 0.47 kg presented by Anderson (1975) for Oklahoma largemouth bass. Based on information from Carlander (1977), growth in established sustaining largemouth bass populations was considered adequate in central United States ponds if largemouth bass were 200 mm at age-II and 250 mm at age-III, the length at which largemouth bass approach sexual maturity (Reynolds and Babb 1978).

High Relative Weight values for age-II and-III largemouth bass were indicative of expanding populations or reduced competition (Wege and Anderson 1978). A decline in W_r from 1981 and 1982 samples of the largemouth bass-bluegill combination may have signaled proximity to carrying capacity in those ponds or greater competition for available food sources due to diet similarities.

Data in the present study suggested that largemouth bass stocked with bluegills attained the greatest growth after two growing seasons and those ponds supported the greatest biomass of largemouth bass. However, largemouth bass growth declined sharply in the third growing season, probably due to poor survival of bluegills (Morris 1985) and excessive vegetation which may have impeded largemouth bass predation on bluegills. Bluegill PSD values determined in 1982 averaged 65 (Morris 1985), indicating low densities of small bluegills required for good largemouth bass growth (Novinger and Legler 1978). The largemouth bass-golden shiner combination showed the poorest initial largemouth bass growth possibly due to interspecific competition of adult golden shiners and fingerling largemouth bass and lack of golden shiner reproduction until the second growing season. However, largemouth bass stocked with golden shiners and fathead minnows exhibited greater total lengths at age-III than largemouth bass stocked with bluegills.

Growth of young-of-the-year largemouth bass was poor. Reynolds and Bass (1978) determined growth to be adequate if largemouth bass were 100 mm at age-I. Reasons for slow growth of young-of-the-year largemouth bass may include high young-of-the-year largemouth bass densities, low adult largemouth bass densities, excessive vegetation which increased survival of young largemouth bass, poor forage production, adverse environmental conditions, and a short growing season associated with northern latitudes. Stone (1981) determine length of growing season explained 56.0% of the variation in the initial largemouth bass growth. Young largemouth bass appeared to grow fastest in the presence of bluegills or golden shiners. Stone (1981) observed the greatest largemouth bass growth in a pond containing both bluegills and fathead minnows.

Even though growth of original largemouth bass stocks was good, spawning did not occur until the third growing season, with young-of-the-year largemouth bass documented in only 53.0% of 32 study ponds surveyed in 1981 and 1982. Young-of-the-year largemouth bass numbers appeared excessive with only four of nine populations within the YAR range of 1 -10 suggested by Reynolds and Babb (1978). Excessive young-of-the-year largemouth bass numbers correlated with low adult largemouth bass densities. At a harvest rate of 49 largemouth bass/hectare and a survival rate of 38.0% over two growing seasons, only 79 young-of-the year largemouth bass/hectare need to be produced for adequate recruitment of harvestable largemouth bass to the fishery.

Initial largemouth bass harvest in new or renovated impoundments is critical in the establishment of a desirable pond fishery. Underharvest of largemouth bass, which is more likely to occur with older established South Dakota ponds, may lead to stunted, slow growing largemouth bass, while overharvest of recently stocked largemouth bass may lead to insufficient predation on forage species with a high reproductive potential such as bluegills or black bullheads. Largemouth bass in South Dakota study ponds did not spawn until the third growing season and then with only partial success. One missing year-class could result in grossly unbalanced population without some degree of management. This is further complicated if successful spawning does not occur until the fourth year after stocking and original stocks must maintain angler harvest for five years.

Angler catch rates determined for this study indicated a potential harvest of 2.1 largemouth bass/hour; however, this information was based largely on catch and release data and may be overestimated. Graham (1972) indicated a quality largemouth bass fishery has a catch rate of 0.5 fish/hour, and based on 70.0% survival, 40.0% of the fish could be harvested each year. Assuming a constant 60% survival in South Dakota ponds and a 40.0% harvest beginning the third growing season, only 19 largemouth bass should be removed the first year of harvest, followed by seven fish the fourth growing season, and only three fish the fifth season. At a potential catch rate of 2.1 largemouth bass/hour in newly stocked ponds, only nine hours of fishing effort would be necessary to harvest those initial 19 fish. The remaining population density would be well below the 49 largemouth bass/hectare recommended by Reynolds and Babb (1978) to maintain population balance in largemouth bass-bluegill ponds. If bluegills or black bullheads are desired and stocked with largemouth bass in South Dakota stock ponds, pond owners will have to take an active role in managing those ponds, not only to prevent initial overharvest of largemouth bass, but also to harvest escess recruitment of forage species.

RECOMMENDATIONS

Ponds used in fish production must have a permanent water supply. The Soil Conservation Service (1971) recommends a minimum depth of 2.1 - 3.7 m for newly constructed ponds in South Dakota. Three years of below average precipitation resulted in complete or partial winterkill of 78.0% of 80 ponds selected for this study on a criterion of a minimum depth of 3.7 - 4.6 m. Based on this information and annual evaporative losses of 81.0 - 112.0 cm (Spuhler et al. 1971), a minimum pond depth of 6.1 m or greater may be necessary to insure long term development of pondfish populations. Ponds should also be constructed with adequate slope (3,2:1) to inhibit excessive growth of aquatic vegetation.

Educational material explaining proper pond management practices, probable survival rates, stocking and harvest alternatives based on pond characteristics and pond owner desires should accompany stocking applications. After receipt of stocking applications, ponds should be surveyed by state personnel to determine depth and surface acreage so that stocking rates can be accurately calculated, to determine the presence of other fish species, and to research the pond history including previous stockings and waterkill frequency.

Largemouth bass exhibited faster growth and better condition when stocked with forage fishes; however, stocking largemouth bass with black bullheads does not appear prudent, especially at study stocking rates of 988 black bullheads/hectare. Reduced black bullhead stocking densities may prove more successful in establishing a balanced population with largemouth bass (Shelley 1981). Black bullheads were harvestable in one year and could be stocked alone in marginal ponds subject to frequent winterkill. Stocking largemouth bass with fathead minnows or golden shiners would be justifiable in ponds subject to overgrowths of vegetation and occasional winterkill. Vegetative cover may limit overpredation and short-term extinction of these forage species (Regier 1963b). Fathead minnows and golden shiners are fairly tolerant to low dissolved oxygen levels and may maintain a good forage population in ponds subject to partial winterkill.

Research should continue on largemouth bass-bluegill and largemouth bass-bluegill-fathead minnow combinations with emphasis on stocking chronology, supplemental stocking, and stocking densities in an effort to eliminate missing year-classes of largemouth bass.

LITERATURE CITED

Anderson, R. O. 1975. Factors influencing the quality of largemouth bass fishing. Pages 183-194 in H. Clepper, editor. Black bass biology and management. Sport Fishing Institute, Washington, District of Columbia, USA.

Anderson, R. O., J. B. Reynolds, A. C. Lopinot, P. A. Hackney, and F. R. Lockard. 1978. The state of pond resources in the Midwest -- study justification, objectives, methods, and general findings. Pages 6-10 in G. D. Novinger and J. G. Dillard, editors. New approaches to the management of small impoundments. Special Publication Number 5. North Central Division, American Fisheries Society, Bethesda, Maryland, USA.

Ball, R. C. 1952. Farm pond management in Michigan. The Journal of Wildlife Management 16:266-269.

Ball, R. C., and J. R. Ford. 1953. Production of food fish and minnows in Michigan ponds. Quarterly Bulletin of the Michigan Agricultural Experiment Station 35:384-391.

Bennett, G. W. 1970. Management of lakes and ponds. Second edition. Van Nostrand Reinhold Company, New York, New York, USA.

Carlander, K. D. 1977. Handbook of freshwater fishery biology. Volume II. Iowa State University Press, Ames, Iowa, USA.

Everhart, W. H., and W. D. Youngs. 1981. Principles of fishery science. Cornell University Press, Ithaca, New York, USA.

Graham, L. K. 1972. Effects of four harvest rates on pond fish populations. Pages 29-38 in J. L. Funk, editor. Symposium on overharvest and management of largemouth bass in small impoundments. Special Publication Number 3. North Central Division, American Fisheries Society, Bethesda, Maryland, USA.

Hill, K. 1980. Evaluation of the split stocking method in Iowa farm ponds. Dingell-Johnson Project F-90-R, Study Number 403.1. Iowa Conservation Commission, Des Moines, Iowa, USA.

Johnson, M. D., and H. R. MacCrimmon. 1967. Survival, growth, and reproduction of largemouth bass in southern Ontario Ponds. The Progressive Fish-Culturist 29:216-221.

Krumholz, L. A. 1950. New fish stocking policies for Indiana ponds. Transactions of the Fifteenth North American Wildlife Conference: 251-270.

Lopinot, A. C. 1978. Pond owner perceptions — use and management. Pages 62-72 in G. D. Novinger and J. G. Dillard, editors. New approaches to the management of small impoundments. Special Publication Number 5. North Central Division, American Fisheries Society, Bethesda, Maryland, USA.

Markus, H. C. 1932. The extent to which temperature changes influence food consumption in largemouth bass (Micropterus salmoides). Transactions of the American Fisheries Society 62:202-210.

Modde, T. 1980. State stocking policies for small warmwater impoundments. Fisheries (Bethesda, Maryland) 5:13-17.

Morris, C.W. 1985. Evaluation of structure and growth on bluegill and black bullheads stocked with largemouth bass in South Dakota ponds. Masters thesis. South Dakota State University, Brookings, South Dakota, USA.

Novinger, G. D. 1980. A comparison of the simultaneous and split methods of stocking largemouth bass and bluegill in ponds. Dingell-Johnson Project F-1-R-28, Study I-21. Missouri Department of Conservation, Jefferson City, Missouri, USA.

Novinger, G. D., and R. E. Legler. 1978. Bluegill population structure and dynamics. Pages 37-49 in G. D. Novinger and J. G. Dillard, editors. New approaches to the management of small impoundments. Special Publication Number 5. North Central Division, American Fisheries Society, Bethesda, Maryland, USA.

Peeters, P. J. 1978. Evaluation of fish stocking in southeastern South Dakota ponds. Masters thesis. South Dakota State University, Brookings, South Dakota, USA.

Regier, H. A. 1963a Ecology and management of largemouth bass and bluegill in farm ponds in New York. New York Fish and Game Journal 10:1-89.

Regier, H. A. 1963b. Ecology and management of largemouth bass and golden shiners in farm ponds in New York. New York Fish and Game Journal 10:139-169.

Reynolds, J. B., and L. R. Babb. 1978. Structure and dynamics of largemouth bass populations. Pages 50-61 _in_ G. D. Novinger and J. G. Dillard, editors. New approaches to the management of small impoundments. Special Publication Number 5. North Central Division, American Fisheries Society, Bethesda, Maryland, USA.

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

Rickett, J. D. 1976. Growth and reproduction of largemouth bass and black bullheads cultured together. The Progressive Fish-Culturist 38:82-85.

Shelley, J. J. 1981. Initial growth and survival of bluegills and black bullheads stocked with largemouth bass in South Dakota ponds. Masters thesis. South Dakota State University, Brookings, South Dakota, USA.

Smith, S. H. 1954. Method of producing plastic impressions of fish scales without using heat. The Progressive Fish-Culturist 16:75-78.

Soil Conservation Service. 1971. Ponds for water supply and recreation. Handbook Number 387. United States Department of Agriculture, Washington, District of Columbia, USA.

Spuhler, W., W. F. Lytle, and D. Moe. 1971. The climate of South Dakota. Bulletin 582. South Dakota Agricultural Experiment Station, South Dakota State University, Brookings, South Dakota, USA.

Stone, C. C. 1981. Growth and survival of largemouth bass in newly stocked South Dakota impoundments. Masters thesis. South Dakota State University, Brookings, South Dakota, USA.

Swingle, H. S. 1949. Experiments with combinations of largemouth black bass, bluegills and minnows in ponds. Transactions of the American Fisheries Society 76:46-62.

Swingle, H. S. 1950. Relationships and dynamics of balanced and unbalanced fish populations. Bulletin 274. Alabama Polytchnic Agricultural Experiment Station, Auburn, Alabama, USA.

U.S. Fish and Wildlife Service. 1982. 1980 National survey of fishing, hunting and wildlife associated recreation. U.S. Fish and Wildlife Service, Department of Interior, Washington, District of Columbia, USA.

Wege, G. J., and R. O. Anderson. 1978. Relative Weight (W_r): a new index of condition for largemouth bass. Pages 79-91 _in_ G. D. Novinger and J. G. Dillard, editors. New approaches to the management of small impoundments. Special Publication Number 5. North Central Division, American Fisheries Society, Bethesda, Maryland, USA.

Appendix 1. Ponds originally stocked in 1979 but not included in 1982 analyses (LMB = largemouth bass, Micropterus salmoides; BG = bluegill, Lepomis macrochirus; BB = black bullhead, Ictalurus melas; GS = golden shiner, Notemigonus crysoleucas; FHM = fathead minnow, Pimephales promelas).

Pond owner	Quadrat	Combination	Reason for exclusion from analyses
Bickel	I	FHM	No sample (1980)
Imslad	I	BG	Pond dry (1981)
Merkel #1	I	GS	Insufficient sample (1982)
Merkel #2	I	BB	Winterkill (1981)
Reich	I	LMB only	Winterkill (1981)
Scofield #1	I	GS	Winterkill (1981)
Scofield #2	I	FHM	Insufficient sample (1982)
Scofield #3	I	BB	Winterkill (1981)
Shamboo #1	I	BB	No sample (1980)
Shamboo #2	I	BG	No sample (1980)
Sieker #1	I	FHM	No sample (1980)
Sieker #2	I	GS	No sample (1980)
Sternard	I	FHM	Winterkill (1981)
Stradinger	I	LMB only	Winterkill (1981)
Thompson #1	I	LMB only	Winterkill (1981)
Thompson #2	I	BG	Winterkill (1981)
Van Den Burg	I	BG	Winterkill (1981)
Voegele #1	I	LMB only	Pond dry (1981)
Voegele #2	I	GS	Pond dry (1981)
Buls	II	GS	Insufficient sample (1982)
Calhoon #1	II	FHM	Winterkill (1981)
Calhoon #2	II	FHM	Winterkill (1981)
Calhoon #3	II	LMB only	Winterkill (1981)
Calhoon #4	II	BB	Insufficient sample (1982)
Chocholousek	II	LMB only	Contamination (1980)

Appendix 1. (Continued)

Pond owner	Quadrat	Combination	Reason for exclusion from analyses
Frantz #1	II	GS	Winterkill (1981)
Frantz #2	II	GS	Winterkill (1981)
Hauck	II	BG	Contamination (1980)
Kjerstad #1	II	FHM	Pond dry (1980)
Kjerstad #2	II	LMB only	Pond dry (1980)
Olsen #1	II	BB	Winterkill (1981)
Olsen #2	II	GS	Winterkill (1981)
Olsen #3	II	BB	Winterkill (1981)
Olsen #4	II	BG	Winterkill (1981)
Olsen #6	II	BG	Winterkill (1981)
Swanda	II	FHM	No sample (1980)
Willinski	II	BB	Winterkill (1981)
Amman, C.	III	GS	No sample (1980)
Amman, G.	III	GS	Winterkill (1981)
Amman, M.	III	GS	No sample (1980)
Breitag	III	LMG only	No sample (1980)
Cronin	III	BB	Contamination (1981)
Hansen	III	BB	Insufficient sample (1982)
Johnson #1	III	BG	No sample (1980)
Johnson #2	III	BB	Winterkill (1981)
Nolte	III	FHM	No sample (1980)
Pollman	III	BG	Insufficient sample (1982)
Richter	III	LMB only	Winterkill (1981)
Schilder	III	LMB only	No sample (1980)
Sherman	III	BG	Insufficient sample (1982)
Van Beek	III	FHM	No sample (1980)

Appendix I. (Continued)

Pond owner	Quadrat	Combination	Reason for exclusion from analyses
Anderson	IV	BB	No sample (1980)
Armstrong #1	IV	GS	Winterkill (1981)
Baughman	IV	GS	Winterkill (1981)
Borah	IV	BG	Pond dry (1981)
Bush	IV	BG	Summerkill (1981)
Grosz	IV	BB	Contamination (1980)
Halstead	IV	GS	Winterkill (1981)
Koerner	IV	BG	No sample (1980)
Mayer #1	IV	GS	Insufficient sample (1982)
Mayer #2	IV	LMB only	Insufficient sample (1982)
McMurry	IV	LMB only	Pond dry (1981)
Murphy	IV	BB	Winterkill (1981)
Paulson	IV	BG	Pond dry (1980)
Heeren	IV	BG	No sample (1980)
Hemmingson	IV	BG	Contamination (1980)

Appendix 2. Hydrological, physical, and biological data for 24 South Dakota study ponds surveyed in 1981

Pond owner	Quadrat	Sampling date	Maximum depth (m)	pH	Hydroxide Alk. (mg/l)	Carbonate Alk. (mg/l)	Bicarbonate Alk. (mg/l)	Hardness (mg/l)	Conductivity (mmhos/cm)	Salinity o/oo	Turbidity (FTU)	Growing days
Buls	II	6/23	1.8	9.3	0	40	0	490	1,543	0.1	3	203
Calhoun 1	II	6/28	1.7	8.1	0	0	130	70	332	0.0	50	203
Calhoon 4	II	6/27	3.7	---	20	20	0	150	1,062	0.9	8	203
Frantz 3	II	6/26	3.5	9.1	0	20	20	1,080	4,829	2.9	8	203
Olsen 1	II	6/24	1.2	9.1	0	20	20	800	3,795	3.2	12	198
Olsen 3	II	6/24	1.1	8.8	0	20	40	150	619	0.1	70	198
Olsen 4	II	6/25	1.1	8.4	20	0	70	420	2,090	1.0	18	198
Olsen 5	II	6/25	1.5	9.2	10	20	0	580	2,930	2.8	10	198
Olsen 6	II	6/25	0.9	9.3	0	20	0	120	927	0.1	80	198
Wilinski	II	6/28	1.8	7.7	0	0	210	130	442	0.0	245	203
Amdahl	III	5/18	1.7	8.5	0	0	130	110	308	0.0	65	208
Hansen	III	5/18	4.9	8.1	0	0	230	330	907	0.0	30	204
Johnson 2	III	6/12	1.7	7.7	0	0	150	280	750	0.0	78	204

Appendix 2. (Continued)

Pond owner	Quadrat	Sampling date	Maximum depth (m)	pH	Hydroxide Alke. (mg/l)	Carbonate Alk. (mg/l)	Bicarbonate Alk. (mg/l)	Hardness (mg/l)	Conductivity (mmhos/cm)	Salinity °/oo	Turbidity (FTU)	Growing days
Armstrong 1	IV	4/29	3.0	7.7	0	0	150	320	838	0.3	30	194
Armstrong 2	IV	4/29	3.2	8.0	0	0	160	300	774	0.3	25	194
Baughman	IV	5/11	0.9	7.7	0	0	110	210	540	0.2	8	203
Bush	IV	4/22	2.3	8.5	0	0	200	820	2,114	1.0	45	216
Edgecomb	IV	5/05	3.7	7.8	0	0	160	650	1,760	0.9	35	214
Halstead	IV	5/07	2.8	7.9	0	0	210	250	614	0.2	12	197
Hinricher 1	IV	4/28	2.1	8.5	0	20	80	100	253	0.0	15	194
Hinricher 2	IV	4/27	4.0	8.4	0	0	180	220	550	0.2	20	194
Hinricher 3	IV	4/28	2.6	8.3	0	0	170	170	426	0.1	20	194
Mayer 1	IV	5/19	3.8	8.1	0	0	200	130	428	0.0	60	210
Mayer 2	IV	5/19	2.1	8.0	0	0	160	150	400	0.0	27	210

Appendix 3. Second year survival rates and population estimates of largemouth bass (<u>Micropterus salmoides</u>) populations in 14 eastern South Dakota stock ponds surveyed in spring, 1981, listed by stocking combination (Only = no forage present; BG = bluegill, <u>Lepomis macrochirus</u>; BB = black bullhead, <u>Ictalurus melas</u>; GS = golden shiners, <u>Notemigonus crysoleucas</u>).

Pond owner	Stocking combination	Number stocked	M	C	R	$\hat{N}$	95% CI	% Survival
Armstrong 2	Only	83	47	46	32	68	56 - 81	82.0
Hinricher 1	Only	95	70	33	32	73	69 - 77	77.0
Mayer 2	Only	150	5	4	4	6	6	4.0
								$\bar{X}$ = 31.6
Amdahl	BG	90	5	4	4	6	6	7.0
Bush	BG	195	36	14	14	91	52 - 111	42.0
Edgecomb	BG	166	84	60	60	124	107 - 141	75.0
Hinricher 3	BG	100	33	19	19	92	61 - 123	92.0
								$\bar{X}$ = 28.8
Hansen	BB	210	11	11	7	18	16 - 20	9.0
Hinricher 2	BB	155	7	6	3	14	6 - 22	9.0
Johnson 2	BB	85	8	6	6	9	9	11.0
								$\bar{X}$ = 8.4

Appendix 3. (Continued)

Pond owner	Stocking combination	Number stocked	M	C	R	$\hat{N}$	95% CI	% Survival
Armstrong 1	GS	134	32	25	17	48	45 - 50	36.0
Baughman	GS	86	34	33	32	36	34 - 38	42.0
Halstead	GS	241	72	48	42	83	75 - 92	35.0
Mayer 1	GS	171	5	8	2	18	4 - 32	11.0
								$\bar{X}$ = 27.8
								Grand average survival = 26.5

Appendix 4. Age-I survival estimates for largemouth bass (*Micropterus salmoides*) populations in 14 eastern South Dakota stock ponds, listed by stocking combination (Only = forage present; BG = bluegill, *Lepomis macrochirus*; BB = black bullhead, *Ictalurus melas*; GS = golden shiner, *Notemigonus crysoleucas*.

Pond owner	Stocking combination	Number stocked	1980 N*	1981 N	% Survival
Armstrong 2	Only	83	76	68	89.0
Hinricher 1	Only	95	103	73	76.0
Mayer 2	Only	150	26	6	23.0
					$\overline{X}$ = 71.7
Amdahl	BG	90	34	6	18.0
Bush	BG	195	106	81	76.0
Egdecomb	BG	166	---	124	----
Hinricher 3	BG	100	102	92	92.0
					$\overline{X}$ = 74.0
Hansen	BB	210	32	18	56.0
Hinricher 2	BB	155	19	14	74.0
Johnson 2	BB	85	0	9	----
					$\overline{X}$ = 62.7
Armstrong 1	GS	134	91	48	53.0
Baughman	GS	86	75	36	48.0
Halstead	GS	241	198	83	42.0
Mayer 1	GS	171	64	18	28.0
					$\overline{X}$ = 43.2
			Grand average survival		= 58.6

Appendix 5. Mean back-calculated body lengths, annual growth increments, and W_r of age-II largemouth bass (Micropterus salmoides) sampled for 18 South Dakota stock ponds in spring, 1981, listed by stocking combination (Only = no forage present, BG = bluegill, (Lepomis macrochirus; BB = black bullhead, Ictalurus melas; GS = golden shiner, Notemigonus crysoleucas; FhM = fathead minnow, Pimephales promelas).

Pond owner	Stocking combination	Quadrat	Date	Sample size	Mean total length (mm)	Annual growth increment (mm)	Mean W_r
Armstrong 2	Only	IV	4/29	38	284	115	111
Hinricher 1	Only	IV	4/28	35	285	116	118
Olsen 5	Only	II	6/25	21	300	129	99
					$\bar{X}$ = 288	$\bar{X}$ = 119	
Bush	BG	IV	4/22	36	313	128	126
Edgecomb	BG	IV	5/05	36	322	131	117
Hinricher 3	BG	IV	4/28	33	300	115	114
Frantz 3	BG	II	6/26	22	309	134	99
Olsen 4	BG	II	6/25	35	252	88	89
Olsen 6	BG	II	6/25	19	258	110	88
					$\bar{X}$ = 288	$\bar{X}$ = 117	

Appendix 5. (Continued)

Pond owner	Stopcking combination	Quadrat	Date	Sample size	Mean total length (mm)	Annual growth increment (mm)	Mean W_r
Hinricher 2	BB	IV	4/27	7	310	147	123
Olsen 1	BB	II	6/24	21	264	96	102
Olsen 3	BB	II	6/24	12	313	140	116
Wilinski	BB	II	6/28	32	268	108	98
				$\bar{X}$	$\overline{278}$	$\bar{X} = \overline{114}$	
Armstrong 1	GS	IV	4/29	32	283	124	126
Baughman	GS	IV	5/11	35	258	113	107
Halstead	GS	IV	5/07	36	283	131	127
Bi;s	GS	OO	6/23	16	243	90	106
				$\bar{X}$	$\overline{270}$	$\bar{X} = \overline{118}$	
Calhoon 1	FhM	II	6/28	13	324	147	136

Grand average total length = 286 mm (11.2 in)

Grand average annual growth increment = 118 mm (4.6 in)

Appendix 6. Standing stock and population density of age II largemouth bass (*Micropterus salmoides*) estimated from 14 South Dakota stock ponds surveyed in spring, 1981, listed by stocking combination (Only = no forage present, BG = bluegill, *Lepomis macrochirus*; BB = black bullhead, *Ictalurus melas*: GS = golden shiner, *Notemigonus crysoleucas*).

Pond owner	Stocking combination	$\bar{X}$ Total length (mm)	$\bar{X}$ Body weight (gm)	1981 Population estimates	Standing stock (kg/ha)	Population density (bass/ha)
Armstrong 2	Only	284	365	68	49.6	136
Hinricher 1	Only	285	393	73	71.8	182
Mayer 2	Only	275	341	6	3.3	10
					$\bar{X}$ = 37.0	$\bar{X}$ = 98
Amdahl	BG	266	312	6	10.5	15
Bush	BG	313	557	81	56.4	101
Edgecomb	BG	322	567	124	104.9	185
Hinricher 3	BG	300	441	92	101.5	230
					$\bar{X}$ = 77.0	$\bar{X}$ = 147
Hansen	BB	296	490	18	5.5	11
Hinricher 2	BB	310	527	14	11.7	22
Johnson 2	BB	305	479	9	12.6	26
					$\bar{X}$ = 8.0	$\bar{X}$ = 16

Appendix 6. (Continued)

Pond owner	Stocking combination	$\bar{X}$ Total length (mm)	$\bar{X}$ Body weight (gm)	1981 Population estimates	Standing stock (kg/ha)	Population density (bass/ha)
Armstrong 1	GS	283	407	48	32.5	80
Baughman	GS	258	259	36	23.3	90
Halstead	GS	283	414	83	43.4	83
Mayer 1	GS	267	311	18	8.0	26
					$\bar{X}$ = 25.5	$\bar{X}$ = 68.5

Grand average standing stock = 34.3 kg/ha

Grand average population density - 76.6 bass/ha

Appendix 7. Total lengths, relative abundance, young-of-the-year densities, and young-adult ratios determined from quadrant minnow seine hauls and electrofishing largemouth bass (Micropterus salmoides) from nine South Dakota stock ponds in September, 1981, listed by stocking combination (Only = no forage present; BG = bluegill, Lepomis macrochirus; BB = black bullhead, Ictalurus melas; GS = golden shiner, Notemigonus crysoleucas).

Pond owner	Stocking combination	$\bar{X}$ Total length (mm)	YOY Density ash/ha	$\bar{X}$ Age 0 bass/ seine haul	YAR
Armstrong 2	Only	58	43,245	71.0	49.1
Hinricher 1	Only	95	305	0.5	4.2
Mayer 2	Only	104	-----*	0.0*	118.0
Edgecomb	BG	64	3,959	6.5	1.2
Hinricher 3	BG	50	8,771	14.4	3.4
Hinricher 2	BB	80	4,629	7.6	38.1
Armstrong 1	GS	78	5,543	9.1	6.6
Baughman	GS	65	2,254	3.7	72.0
Halstead	GS	73	17,055	28.0	20.3

* Young-of-the-year largemouth bass were not captured by seining; however, they were detected while electrofishing. Young-of-the-year densities and relative abundances were determined from seining efforts.

Appendix 8. Mean calculated body lengths, annual growth increments, and W_r of age-III largemouth bass (*Micropterus salmoides*) sampled from 13 South Dakota stock ponds in spring, 1982, listed by stocking combination (Only = no forage present; BG = bluegill, *Lepomis macrochirus*; BB = black bullhead, *Ictalurus melas*; GS = golden shiner, *Notemigonus crysoleucas*; FhM = fathead minnow, *Pimephales promelas*).

Pond owner	Stocking combination	Quadrat	Date	Sample Size	Mean total length (mm)	Annual growth increment (mm)	Mean weight (gm)	Mean W_r
Armstrong 2	Only	IV	5/19	21	310	116	433	100
Bamesberger	Only	III	6/02	15	306	129	423	103
Hinricher 1	Only	IV	5/18	19	302	118	455	111
Olsen 5	Only	II	5/28	13	321	128	491	96
					$\bar{X}$ = 309	$\bar{X}$ = 122	$\bar{X}$ = 449	$\bar{X}$ = 103
Edgecomb	BG	IV	5/17	29	341	135	522	89
Frantz 3	BG	II	5/25	20	331	143	447	84
Hinricher 3	BG	IV	5/18	17	298	120	374	98
					$\bar{X}$ = 326	$\bar{X}$ = 136	$\bar{X}$ = 460	$\bar{X}$ = 90
Allerding	BB	III	6/02	10	324	125	539	106
Hinricher 2	BB	IV	5/19	8	359	162	706	102
Hoff	BB	I	5/31	35	237	73	166	90
					$\bar{X}$ = 272	$\bar{X}$ = 96	$\bar{X}$ = 318	$\bar{X}$ = 95

Appendix 8. (Continued)

Pond owner	Stocking combination	Quadrat	Date	Sample size	Mean total length (mm)	Annual growth increment (mm)	Mean weight (gm)	Mean W_r
Blue Cloud Abbey	GS	III	6/10	35	341	154	626	105
Calhoun	FhM	III	6/04	21	367	166	917	121
Knott	FhM	III	6/03	35	329	135	570	109
					$\bar{X}$ = 343	$\bar{X}$ = 147	$\bar{X}$ = 696	$\bar{X}$ = 114

Grand average total length = 317 mm (12.5 in)

Grand average growth increment = 129 mm (5.1 in)

Grand average weight - 500 gm (1.1 lb)

Grand average W_r = 101

Appendix 9. Mean calculated body length and W_r of age-I largemouth bass (<u>Micropterus salmoides</u>) sampled from six South Dakota stock ponds in spring, 1982, listed by stocking combination (Only = no forage present; BG = bluegill, <u>Lepomis macrochirus</u>; BB = black bullhead, <u>Ictalurus melas</u>; GS = golden shiner, <u>Notemigonus crysoleucas</u>).

Pond owner	Stocking combination	Quadrat	Date	Sample Size	Mean total Length (mm)	Mean Weight (g)	Mean W_r
Bamesberger	Only	III	6/02	35	93	15	96
Olsen 5	Only	II	5/28	21	55	4	121
					$\bar{X}$ = 78	$\bar{X}$ = 11	$\bar{X}$ = 104
Pollman	BG	III	6/04	20	107	28	107
Hinricher 2	BB	IV	5/19	19	79	7	88
Blue Cloud Abbey	GS	III	6/10	37	107	25	96
Mayer 1	GS	IV	5/24	10	103	25	119
					$\bar{X}$ = 106	$\bar{X}$ = 25	$\bar{X}$ = 101

Grand average total length - 92 mm (3.6 in)

Grand average weight = 18 g (.04lb)

Grand average W_r = 102

Appendix 10. Average catch per hour and poundage harvested per hour of largemouth bass (Micropterus salmoides) from 12 South Dakota stock ponds, listed by stocking combination (Only = no forage present; BG = bluegill, Lepomis macrochirus; BB = black bullhead, Ictalurus melas; melas; GS = golden shiner, Notemigonus crysoleucas; and FhM = fathead minnow, Pimephales promelas).

Pond owner	Stocking combination	Number anglers	Total hours fished	Number fish caught	Average fish weight (gm)	Mean C/E (fish/hr)	Weight harvested (kg/hr)
Armstrong 2	Only	18	16.7	48	365	2.9	0.91
Bamesberger	Only	3	3.0	9	423	3.0	1.27
Hinricher 1	Only	3	1.0	1	455	1.0	0.46
					Unweighed	$\bar{X} = \overline{2.8}$	$\bar{X} = \overline{1.05}$
Edgecomb	BG	30	55.0	109	565	2.1	1.19
Hinricher 3	BG	5	6.0	10	434	1.4	0.61
Frantz 3	BG	3	2.5	10	447	4.0	1.79
					Unweighed	$\bar{X} = \overline{2.0}$	$\bar{X} = \overline{1.11}$
Allerding	BB	3	1.0	4	539	4.0	2.16
Croin	BB	3	1.0	0	737	0.0	0.00
Hinricher 2	BB	11	18.0	--	527	---	----

Appendix 10. (Continued)

Pond owner	Stocking combination	Number anglers	Total hours fished	Number fish caught	Average fish weight (gm)	Mean C/E (fish/hr)	Weight harvested (kg/hr)
Armstrong 1	GS	3	1.7	1	407	0.8	0.33
Baughman	GS	3	6.0	--	259	---	----
Knott	FhM	3	1.5	5	570	3.3	1.88