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Growth and Survival of Largemouth Bass in Newly Stocked South Dakota Impoundments

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GROWTH AND SURVIVAL OF LARGEMOUTH BASS IN NEWLY STOCKED SOUTH DAKOTA IMPOUNDMENTS

BY

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GROWTH AND SURVIVAL OF LARGEMOUTH BASS IN NEWLY STOCKED SOUTH DAKOTA IMPOUNDMENTS

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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CCS

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Abstract

Clifton C. Stone

The present study was designed to evaluate the effect of five different stocking combinations and differences in climatic and morphological conditions within South Dakota on initial growth and survival of the largemouth bass (Micropterus salmoides). Forage species stocked with bass included golden shiners (Notemigonus crysoleucas), fathead minnow (Pimephales promelas), black bullhead (Ictalurus melas), and bluegill (Lepomis macrochirus). Bass only stocking was also evaluated.

First year survival values for 16 eastern South Dakota ponds ranged from 0 to 100%, with a mean of 50.2%. Bass exhibited poorest survival when stocked with black bullheads.

Analysis of variance indicated no significant difference ($P > .05$) in first year bass growth due to the different forage options stocked. Differences in first year bass growth were significant due to geographic region of the state stocked, however. First year bass growth rates in 34 ponds ranged from 101.0 to 196.5 mm with a mean of 153.2 mm. Second year growth of bass calculated from fish sampled in September 1980 averaged 275.7 mm for eight southeastern South Dakota ponds.

Index of relative weight (W_r) was computed to determine bass condition. Calculated W_r values ranged from 100.1 to 134.6, with an average for 34 ponds of 113.6. No significant differences were observed among quadrats or combinations.

Stepwise multiple regression of selected chemical, physical, and biological parameters indicated that the number of growing days, turbidity, presence/absence of fathead minnows, and salinity were important factors influencing first year bass growth in this study.

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INTRODUCTION

Many research studies have been conducted in the past in an attempt to define the optimal pond fish stocking combination for different geographical regions (Wenger 1972; Dillard and Novinger 1975). Combinations that have worked well in one geographic region have been questioned in others (Bennett 1950; Regier 1963a). The pond stocking combination recommended in many of the southern states, largemouth bass (*Micropterus salmoides*)-bluegill (*Lepomis macrochirus*) (Modde 1980), does not appear to be highly successful in northern regions of the country (Bennett 1944; Regier 1963a). Researchers in the northern latitudes have questioned the long term effectiveness of the bass-bluegill combination (Ball and Tait 1952; Bennett 1970). Bennett (1970) reported that several years after stocking, bluegill populations tend to overpopulate, stunt, and result in reduced bass recruitment.

South Dakota, with over 100,000 ponds, ranks among the top ten states in total number of small impoundments constructed by the Soil Conservation Service in the continental United States (Modde 1980). The primary purpose for construction of most ponds is to provide water for livestock, but many of these ponds presently contain or are suitable for pondfish populations (Peeters 1978).

Management of fish populations is not practiced by most South Dakota pond owners. This has lead to the need for a stocking strategy that can maintain a balanced population without management. Swingle (1950) defined balanced populations as, "fish populations that yield year after year crops of harvestable fish that are satisfactory in amount when the basic fertilities of the bodies of water containing these populations are considered".

The stocking policy for ponds currently recommended by South Dakota is simultaneous stocking of 247 bass/ha (100/acre) and 741 bluegill/ha (300/acre). Evaluation of 30 South Dakota ponds previously stocked with bass and bluegill indicated that 27 of the pond fish populations were out of balance, according to the A_t and F/C classifications of Swingle (1950), (Peeters 1978).

Investigations in the northern United States have suggested that other fish species may be more suitable for stocking in combination with the largemouth bass. These fishes have included: golden shiners (*Notemigonus crysoleucas*) (Regier 1963b), fathead minnows (*Pimephales promelas*) (Ball and Ford 1953), black bullheads (*Ictalurus melas*) (Rickett 1976), and hybrid sunfish (Lewis and Heidinger 1973). Bennett (1970) recommended stocking bass only in Illinois ponds.

This study was designed to evaluate the success of alternate stocking combinations and also to investigate factors influencing growth and survival of the largemouth bass in South Dakota ponds. The study has a long range goal of providing South Dakota fisheries managers with stocking policies which can be based on characteristics of individual ponds and owner angling preferences.

MATERIALS AND METHODS

Study Area

Privately owned stock ponds located throughout South Dakota served as the study site for this project. A detailed description of the climatic and geophysical conditions of the state can be found in Westin and Malo (1978).

Experimental Design

The state of South Dakota was divided into four study quadrats along climatic and morphological gradients. The north-south separation was made along latitude 44° 21' and the Missouri River served as the east-west dividing line (Figure 1).

Twenty private ponds in each quadrat were selected from South Dakota Department of Game, Fish and Parks stocking applications, solicitation, and by field survey. If more than twenty ponds were available, a random numbers table was used to make the selections. A total of 80 ponds were selected statewide. Pond selection was based upon the following criteria:

1) Size - 0.4 to 2.0 ha (1 to 5 acres).
2) Minimum Depth - 3.0 to 3.6 m (10 to 12 feet).
3) Absence of fish life.

Ponds selected included both newly constructed and older impoundments.

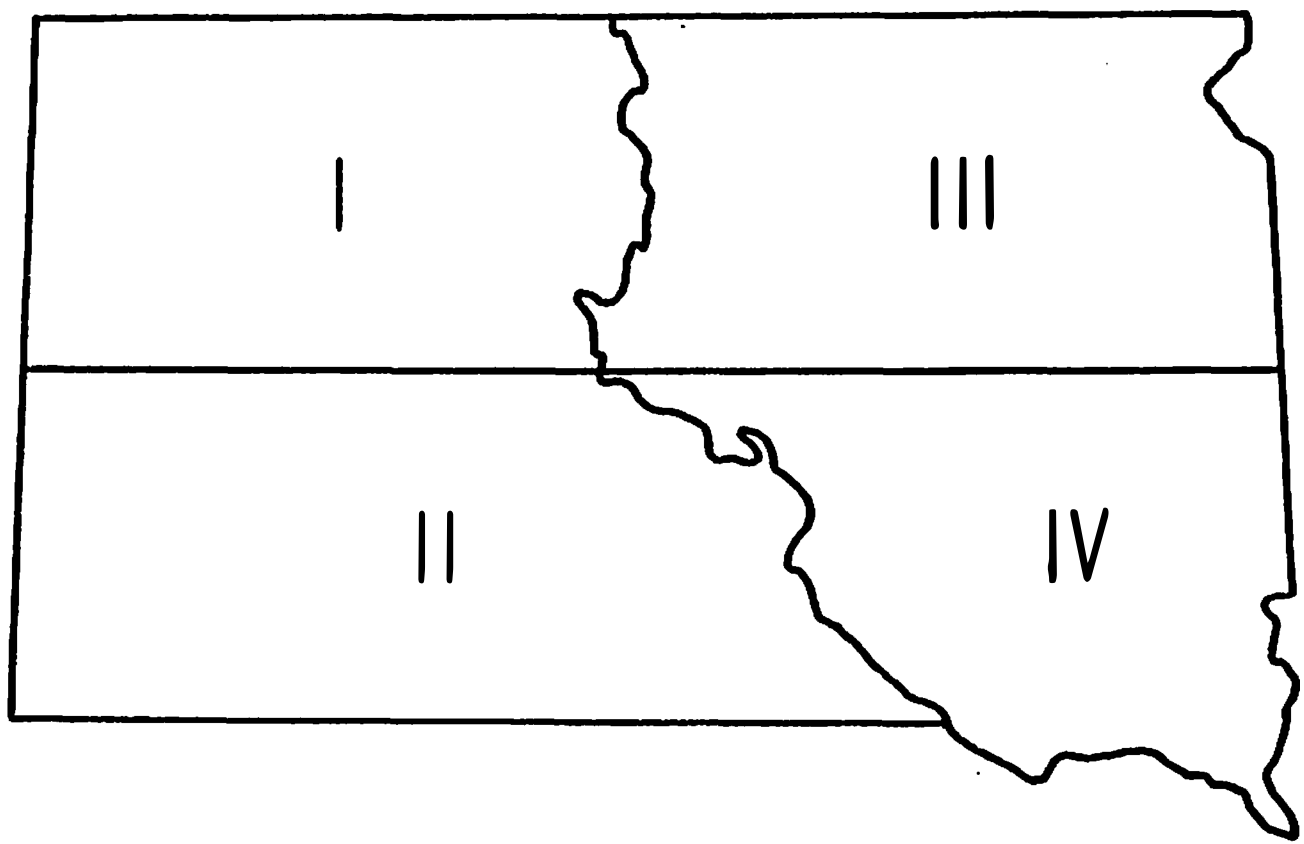

Figure 1. State of South Dakota, indicating division of 4 study quadrats used in the study of largemouth bass (*Micropterus salmoides*) stocking combinations during 1979-1980.

Each study pond was randomly assigned one of five combinations with each quadrat containing four replicates[1] of each combination. The five combinations evaluated were (stocking rates in parenthesis):

1) largemouth bass only, (247/ha)

2) largemouth bass-golden shiners, (247/ha - 617/ha)

3) largemouth bass-fathead minnows, (247/ha - 1235/ha)

4) largemouth bass-black bullheads, (247/ha - 988/ha)

5) largemouth bass-bluegills, (247/ha - 1235/ha)

The stocking of the ponds occurred in the following sequence (Appendix 1): 1) adult golden shiners and fathead minnows obtained from commercial bait dealers and stocked during May and June 1979 prior to gamefish introductions, 2) fingerling largemouth bass ($\overline{X}$ TL=36.7 mm) obtained from Gavins Point National Fish Hatchery and distributed between 9 July and 19 July 1979, 3) fingerling black bullheads ($\overline{X}$ TL=34.1 mm) obtained from Wall Lake, South Dakota and introduced into the ponds in late July, 1979, and 4) fingerling bluegill ($\overline{X}$ TL=27.3 mm) obtained from Gavins Point National Fish Hatchery and stocked in August 1979.

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[1] The study was originally designed to include a largemouth bass-fathead minnow-hybrid sunfish cross combination. After stocking in the southeast quadrat (IV), it was determined that the hybrids were bluegills. This altered the experimental design so that a bass-fathead combination did not exist in the southeastern quadrat, but that several of the bluegill ponds also contained fathead minnows stocked at 1235/hectare.

Field Methods

An attempt was made to visit as many of the ponds as possible prior to stocking to verify the absence of fish life and to determine pond acreage. Surface acreage of ponds not surveyed before stocking was estimated from Soil Conservation Service records, pond owner estimates, and visual observations by field personnel.

At the time of initial bass stocking and again during the period of sampling, various chemical and physical parameters were measured. Hardness, alkalinity, phosphorus, and turbidity were measured using a Hach Kit Model DR-EL/2. A Hach Model 17G Cresol Red wheel or Hach Model 17-J Thymol Blue wheel was used to measure pH. Conductivity, salinity, and surface water temperatures were measured with a Yellow Springs Instrument S-C-T Meter Model 33. Conductivity readings were corrected back to 25 C for analysis. Maximum pond depth was recorded to the nearest tenth meter using a weighted line.

Bass obtained for the population estimate or for growth data were collected with seines, electrofishing gear (3 cycle, 230 volt A.C. generator), or by angling. Two bag seines were used to sample bass (23 m x 2.1 m, with 19 mm mesh and 45.4 m x 4.9 m in the middle, tapering to 2.4 m at both ends, with 19 mm mesh). The bass were marked for population estimates by punching a hole in the upper lobe of the caudal fin using a 3 mm (1/8 in) paper punch.

The population was resampled after at least a 24 hour period. Length and weight measurements, plus scale samples were obtained from bass in each study pond during the 1980 field season to determine first year growth. An attempt was made to obtain a sample of at least 20 to 30 fish. Second year bass growth information was obtained only from ponds in the southeast quadrat (IV) in mid to late September 1980. Total length measurements taken at the time of sampling were used as estimates of second year growth data.

Analysis

First year bass survival was determined from thirteen ponds in the southeast quadrat (IV) and three ponds in the northeast quadrat (III) (Figure 2). Four replicates of each combination were selected (bass-fathead minnow was not represented). The adjusted Peterson formula was used to estimate the bass populations during May and June 1980. The equation:

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

was used where,

$\hat{N}$ = population estimate at time of marking

M = number of fish marked

C = catch or sample taken for census

R = number of recaptured marks in sample

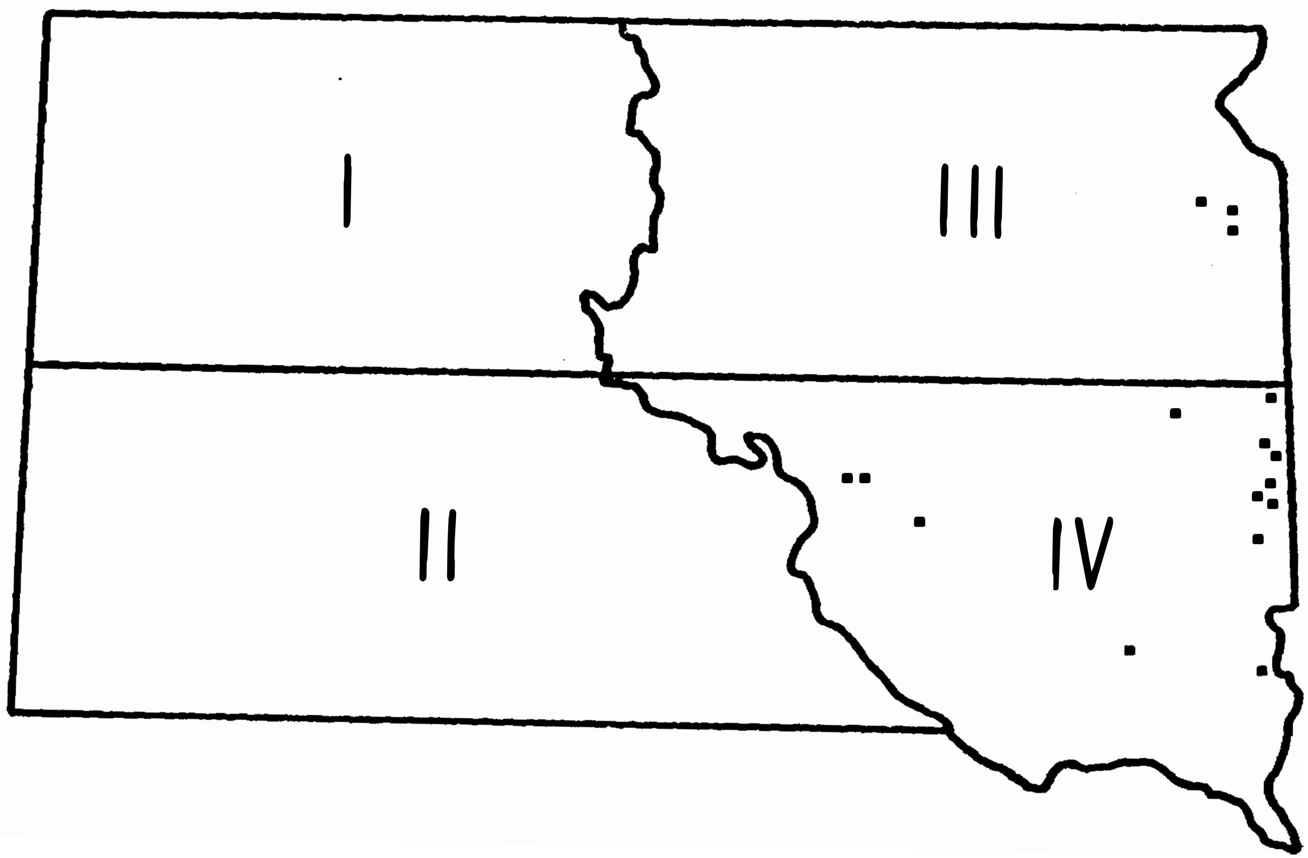

Figure 2. State of South Dakota, indicating location of 16 study ponds in which largemouth bass (*Micropterus salmoides*) populations were estimated using the adjusted Peterson method during the spring of 1980.

The 95% confidence interval around the population estimate was calculated by the equation:

$$\hat{N} \pm 1.96\sqrt{V(N)} \qquad \text{(Everhart and Youngs 1981)}$$

where,

$V(N)$ = sampling variance for $\hat{N}$

$V(N)$ was calculated by the equation:

$$V(N) = \frac{N^2\ (C - R)}{(C + 1)\ (R + 2)} \qquad \text{(Everhart and Youngs 1981)}$$

The survival estimate was obtained by dividing the population estimate by the known number of bass originally stocked.

Estimates of first year growth were obtained by back calculation from scale samples using the corrected Lee formula:

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

where,

Ln = length of fish at time of annulus, n, formation

a = length of fish at time of scale formation

Sn = scale measurements to a given annulus, n

Sc = scale measurement to edge

Lc = length of fish at capture

The corrected Lee method assumes a straight line body-scale regression with an intercept at some other place than zero on the ordinate (Cariander 1977). A constant value of 22 mm was used for a in the above equation in this study (Carlander, personal communications).

Scale impressions were made on acetate slides using a Wildco roller press model 110 H10, similar to the one described by Smith (1954). The scale impressions were magnified on an Eberbach Scale Reader. Measurements of annulus radii were taken from two scales per fish. Readings then were averaged to obtain a single value.

The index of relative weight, developed by Wege and Anderson (1978), was used to compare bass condition between ponds, combinations, and quadrats. Relative weight is calculated by the equation:

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

where,

W_r = relative weight

W = actual weight of the fish

W_s = standard weight for a fish of that same length

100 = factor to bring value near unity

The use of standard weights for largemouth bass appears to compensate for changes in body shape with increasing length (Wege and Anderson 1978). Condition indices such as K and C are not comparable between length-groups of a given species. The use of the relative weight index allows comparison of fish, of the same species, from different length-groups. A relative weight value of 100 is equivalent to the 75th percentile level of all largemouth bass using data compiled from Carlander (1977) (Wege and Anderson 1978).

Analysis of variance was used to determine if differences in bass survival, first year growth, or relative weight were significant due to combination stocked or geographic region of the state. A Duncan's Multiple Range test was used to distinguish where significant differences, found in the analysis of variance, occurred. Stepwise multiple regression was used to determine the influence of selected chemical, physical, and biological parameters, measured during 1980, on survival (Table 1) and first year growth (Table 2). The variable, growing days, used in the growth regression model consisted of the number of days from the time of bass stocking until the mean daily air temperature fell below 10 C for a period of at least two weeks. It has been demonstrated that 10 C is the value at which bass will no longer voluntarily take food (Markus 1932). Temperature data was obtained from the National Oceanic and Atmospheric Administration weather stations located throughout South Dakota. Data from the station closest to each pond was used.

Table 1. Independent variables used in stepwise multiple regression analysis of largemouth bass (*Micropterus salmoides*) survival rates estimated from 16 South Dakota stock ponds during spring 1980.

Independent variables
Salinity
Turbidity
Hardness
Alkalinity - Total
- Carbonate
- Bicarbonate
- Hydroxide
Conductivity
Surface Area
Depth (Maximum)
Presence/absence fathead minnows

Table 2. Independent variables used in stepwise multiple regression analysis of first year growth rate of largemouth bass (*Micropterus salmoides*) sampled from ponds in 1979.

Independent Variables
pH
Salinity
Turbidity
Hardness
Alkalinity - Total
- Carbonate
- Bicarbonate
- Hydroxide
Conductivity
Phosphorus
Surface Area
Depth (Maximum)
Presence/absence of fathead minnows
Number of growing days

RESULTS

Pond Survey

Forty-six of the original 80 ponds stocked were eliminated (Appendix 4) from analysis due to lack of or an inadequate sample size (Figure 3). Ponds in which a sample of less than 20 fish was obtained were excluded. Speculated causes for failure of the ponds included drought, contamination by other fish species, excessive vegetation and toxic algal blooms.

Surface acreages of the 34 study ponds (Figure 3) ranged from 0.2 to 2.9 hectares (Appendix 1). Precipitation levels for 1979 and 1980 were well below average for all areas of the state (SDSU Agricultural Weather Station, unpublished). These drought conditions caused pond surface acreages to vary greatly from time of stocking to time of sampling. The drought conditions also caused maximum pond depth readings (Appendix 1) to be of questionable value since depths continued to decline throughout the sampling period.

The range of pH from the study ponds was from 7.6 to 9.4 (Appendix 2). Values of pH can vary several units during the day due to factors such as plant activity (Swingle 1957). Salinity values of the 34 ponds occurred in the range of 0.0 to 2.0 $^{o}/oo$ (Appendix 2). Conductivity values, corrected back to 25 C, varied from 140 micromhos/cm to 3900 micromhos/cm (Appendix 2). Total hardness readings from the study ponds were from 50 to 1400 mg/l (Appendix 2). Turbidity values ranged from 5 to 380 FTU's (Appendix 2). Number of

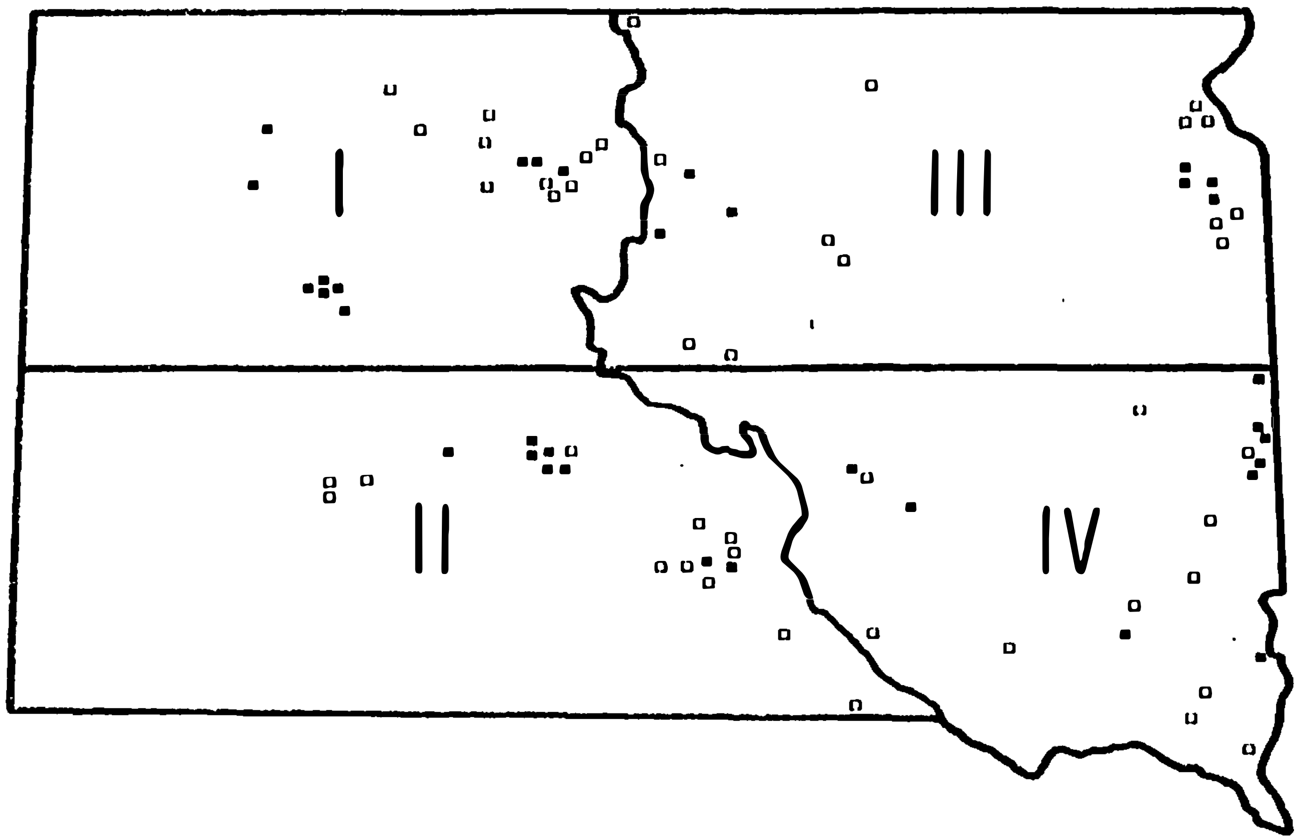

Figure 3. State of South Dakota, indicating locations of the 80 ponds originally stocked and those ponds which were included (■) or excluded (□) in the first year growth analysis of largemouth bass (Micropterus salmoides) during 1980.

growing days for the bass ranged from 102 to 114. Mean values for each of the four quadrats were 105 (Quadrat I), 110 (Quadrat II), 104 (Quadrat III), and 112 (Quadrat IV) (Appendix 2).

Survival

First year survival of largemouth bass in the 16 study ponds varied from 0 to 100% with an average of 50.2% (Appendix 3). Mean survival values among the four different combinations ranged from 7.5% for the largemouth bass-black bullhead combination to 75.5% for the largemouth bass stocked alone (Figure 4).

Analysis of variance (Table 3) indicated a significant difference ($P < .05$) in bass survival due to combination stocked. The use of a Duncan's Multiple Range test revealed significant difference in survival ($P < .05$) between the largemouth bass stocked alone and bass stocked with black bullheads, and also between the bass stocked with golden shiners and bass stocked with bullheads (Table 4). Stepwise multiple regression of eleven different chemical, physical, and biological parameters (Table 1) failed to indicate any factors contributing significant differences in bass survival.

Growth

The average first year (age-0) largemouth bass growth from the 34 ponds (Figure 3) ranged from 101.0 mm to 196.5 mm with a state average of 153.2 mm (Appendix 5). Bass growth grouped according to combination stocked varied from 137.6 mm for bass

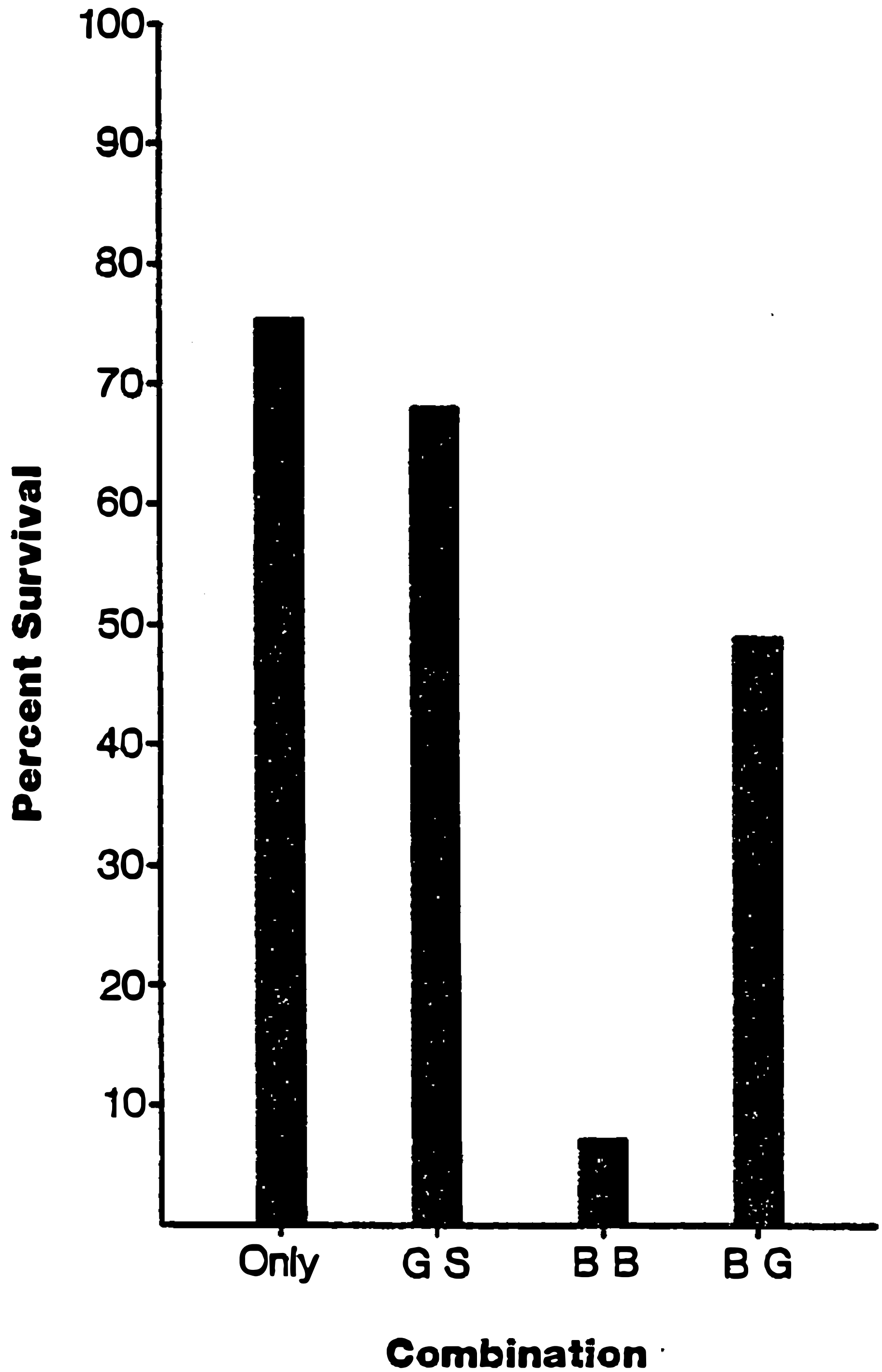

Figure 4. Mean first year survival of largemouth bass (*Micropterus salmoides*) stocked among forage combinations (GS=golden shiner, *Notemigonus crysoleucas*; BB=black bullhead, *Ictalurus melas*; BG=bluegill, *Lepomis macrochirus*) in eastern South Dakota, 1980.

Table 3. Analysis of variance of percent of largemouth bass (*Micropterus salmoides*) survival due to combination stocked, 1980.

Source of variation	Degrees of freedom	Mean square	F
Treatment	3	3732.23	4.09*
Error	12	912.81	

* Significant at .05 level of probability.

Table 4. Duncan's Multiple Range test to determine differences in largemouth bass (*Micropterus salmoides*) survival between combinations stocked, 1980.

$S_{\bar{x}} = \sqrt{912.3/4} = 15.106$

Value of p	2	3	4
Significant Studentized Range	3.08	3.23	3.33
Least Significant Range	46.53	48.79	50.30

Rank the means:

Black Bullhead	Bluegill	Golden Shiner	Only
7.50	49.25	68.50	75.50

Only - Black Bullhead = 68.0 > 50.80*
Only - Bluegill = 26.25 < 48.79
Only - Golden Shiner = 7.0 < 46.53

Golden Shiner - Black Bullhead = 61.0 > 48.79*
Golden Shiner - Bluegill = 19.25 < 46.53

Bluegill - Black Bullhead = 41.75 < 46.53

*Significant at .05 level of probability.

stocked with black bullheads to 158.6 mm for bass only (Figure 5). Analysis of variance revealed no significant differences ($P > .05$) in bass growth due to combination stocked (Table 5).

Mean first year growth of bass among quadrats of the state ranged from 136.3 mm for Quadrat I to 170.7 mm for Quadrat IV (Figure 6). Analysis of variance indicated that differences in growth between quadrats were significant ($P < .01$) (Table 6). The use of a Duncan's Multiple Range test indicated significant differences ($P < .05$) in bass growth between Quadrat I vs Quadrat II, Quadrat I vs Quadrat IV, Quadrat III vs Quadrat II, and Quadrat III vs Quadrat IV (Table 7). This resulted in a north (Quadrat I and III)-south (Quadrat II and IV) growth difference.

Stepwise multiple regression of 14 (Table 2) different chemical, physical, and biological parameters resulted in a four variable growth model for bass (Table 8). The four variables in order of entry were: 1) growing days, 2) turbidity, 3) presence/ absence of fathead minnows, and 4) salinity. These four variables accounted for slightly over 80% of the total variation.

Although the fathead minnow was one of the forage treatments, it was included in the regression analysis since they also appeared in several of the other study ponds (Appendix 5). Since statistical analysis indicated no significant differences in bass growth between northern (Quadrats I and III) and southern (Quadrats II and IV) quadrats, their values were pooled to analyze differences in bass growth due to the presence or absence of fathead minnows.

Table 5.--Analysis of variance of first year largemouth bass (*Micropterus salmoides*) growth due to combination stocked in 34 South Dakota stock ponds, 1980.

Source of variation	Degrees of freedom	Mean square	F
Combination	4	136.3	.76
Quadrat	3	2277.5	
Quadrat * Combination	9	211.4	
Error	17	180.2	

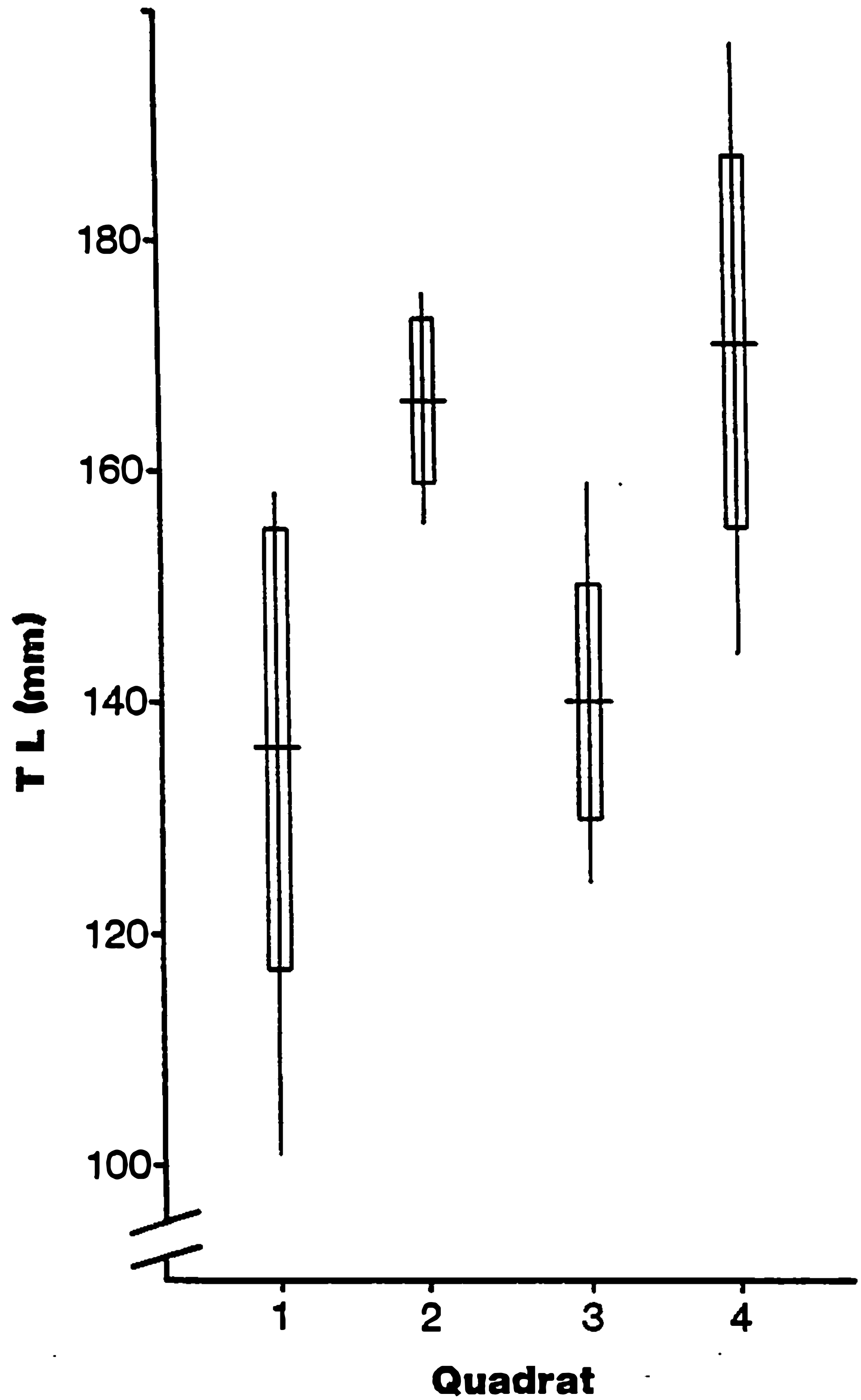

Figure 6. Mean first year growth of largemouth bass (*Micropterus salmoides*) from each study quadrat, during 1979.

Table 6. Analysis of variance of first year largemouth bass (*Micropterus salmoides*) growth due to geographic region of South Dakota stocked for 34 ponds, 1979.

Source of variation	Degrees of freedom	Mean square	F
Quadrat	3	2277.5	12.64*
Combination	4	136.3	
Quadrat * Combination	9	211.4	
Error	17	180.2	

* Significant at .01 level of probability.

Table 7. Duncan's Multiple Range test to determine where significant (.05 level) differences in first year largemouth bass (*Micropterus salmoides*) growth between quadrats occur, 1979.

$S^2 = 130.13$ $N_2 = 17$

Values of p	2	3	4
Significant Studentized Range	2.93	3.13	3.22

Rank the means:

Quadrat 1	Quadrat 3	Quadrat 2	Quadrat 4
136.3	140.2	166.0	170.7

Quadrat 4 vs Quadrat 1 Least Significant Range=14.04

170.7 - 136.3 = 34.4 > 14.04*

Quadrat 4 vs Quadrat 3 Least Significant Range=14.97

170.7 - 140.2 = 30.5 > 14.97*

Quadrat 4 vs Quadrat 2 Least Significant Range=13.74

170.7 - 166.0 = 4.7 < 13.74

Quadrat 2 vs Quadrat 1 Least Significant Range=14.09

166.0 - 136.3 = 29.7 > 14.09*

Quadrat 2 vs Quadrat 3 Least Significant Range=14.64

166.0 - 140.2 = 25.8 > 14.64*

Quadrat 3 vs Quadrat 1 Least Significant Range=13.94

140.2 - 136.3 = 3.9 < 13.94

*Significant at .05 level of probability.

Table 8. Significant contributions ($P < .05$) largemouth bass (*Micropterus salmoides*) growth model for South Dakota ponds, 1979, determined from multiple regression analysis of chemical, physical, and biological parameters.

Rank	Variable	R^2	ΣR^2
1	Growing Days	.564	.564
2	Turbidity	.109	.673
3	Fathead Minnows	.069	.742
4	Salinity	.060	.802

Mean growth of bass, for ponds containing minnows in the north quadrats, was 147.3 versus 131.3 mm for ponds without minnows. In the south quadrat, ponds with minnows averaged 186.9 versus 164.5 mm for ponds without (Figure 7).

The use of an unpaired T-test (Steel and Torrie 1960) showed no significant difference ($P > .05$) in bass growth due to the presence or absence of fathead minnows in the northern region of the state. The difference in bass growth in the south, however, was significant ($P < .05$) (Table 9).

Mean values of relative weight (W_r) for each of the 34 ponds ranged from 100.1 to 134.6 with an average of 113.6 (Appendix 5). W_r values among combinations varied from 108.1 for bass stocked with black bullheads to 119.2 for the bass stocked with fathead minnows (Figure 8). Mean W_r values for the four quadrats ranged from 111.6 for bass in Quadrat I to 116.4 for bass in Quadrat II (Figure 9). Analysis of variance indicated no significant difference ($P > .05$) in relative weight due to forage option stocked (Table 10) or geographic region of the state (Table 11).

Estimates of second year growth of largemouth bass were determined from actual total length information collected from ponds in the southeast quadrat (IV) in mid to late September 1980. Mean growth values ranged from 248.5 to 307.9 mm with an average for the quadrat of about 275.7 mm (Appendix 6).

Relative weight values calculated from bass ponds sampled in the fall, 1980, ranged from 104.6 to 140.2 with a mean for the eight ponds of 116.9. The relative weight values for those same ponds in the spring, 1980, ranged from 105.1 to 134.6 with a mean of 115.3 (Appendix 7).

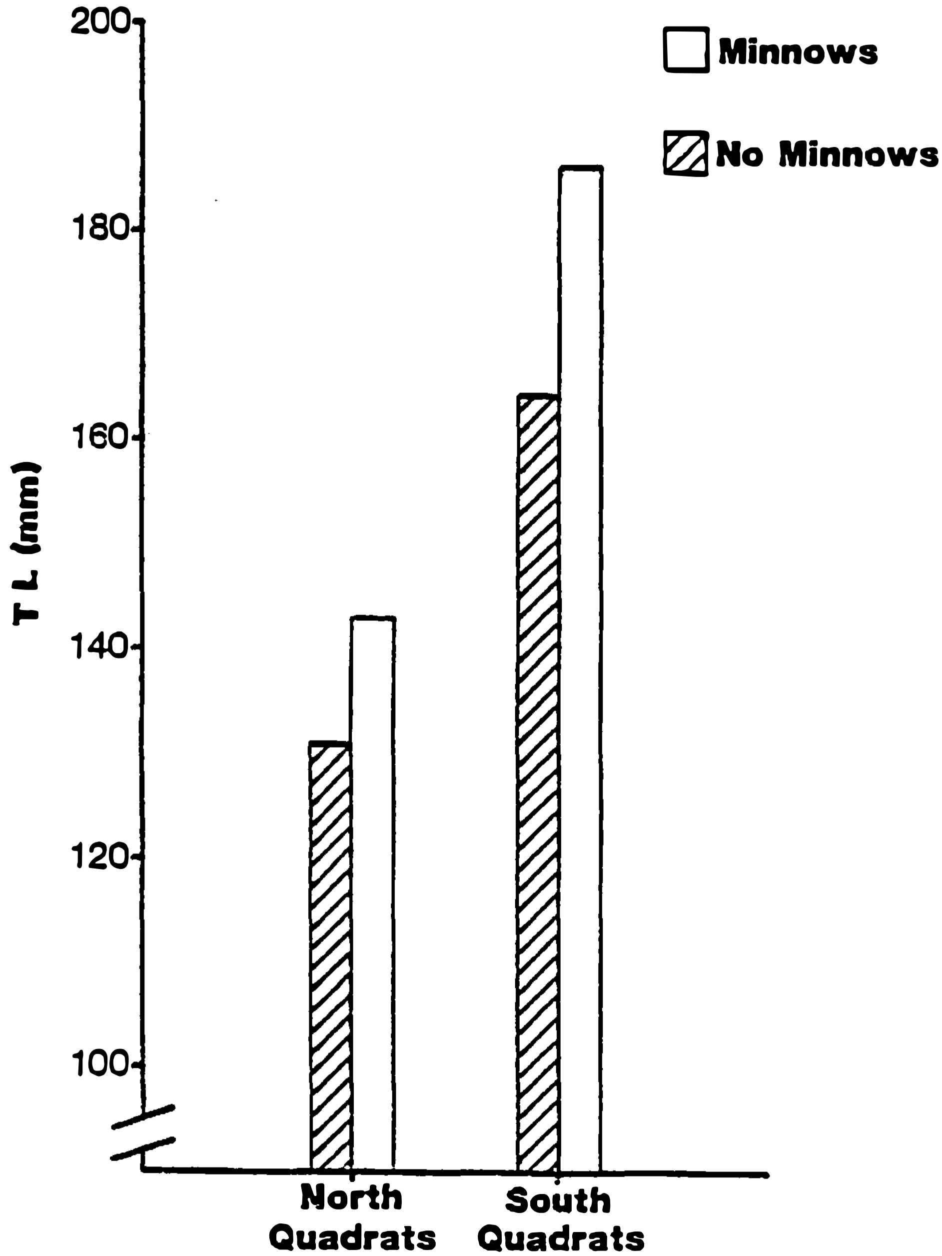

Figure 7. Mean first year growth of largemouth bass (*Micropterus salmoides*) from north and south quadrats in the presence or absence of fathead minnows (*Pimephales promelas*), 1979.

Table 9. Unpaired t-test comparing differences in first year largemouth bass (<u>Micropterus salmoides</u>) growth due to presence/absence of fathead minnows (<u>Pimephales promelas</u>) for 34 South Dakota stock ponds, 1979.

North: df = 15

$$t = \frac{\bar{d}}{S_{\bar{d}}} = \frac{143.3 - 131.3}{7.0} = \frac{12.0}{7.0} = 1.7$$

South: df = 15

$$t = \frac{\bar{d}}{S_{\bar{d}}} = \frac{186.9 - 164.5}{5.9} = \frac{22.4}{5.9} = 3.8^{*}$$

* Significant at .05 level of probability

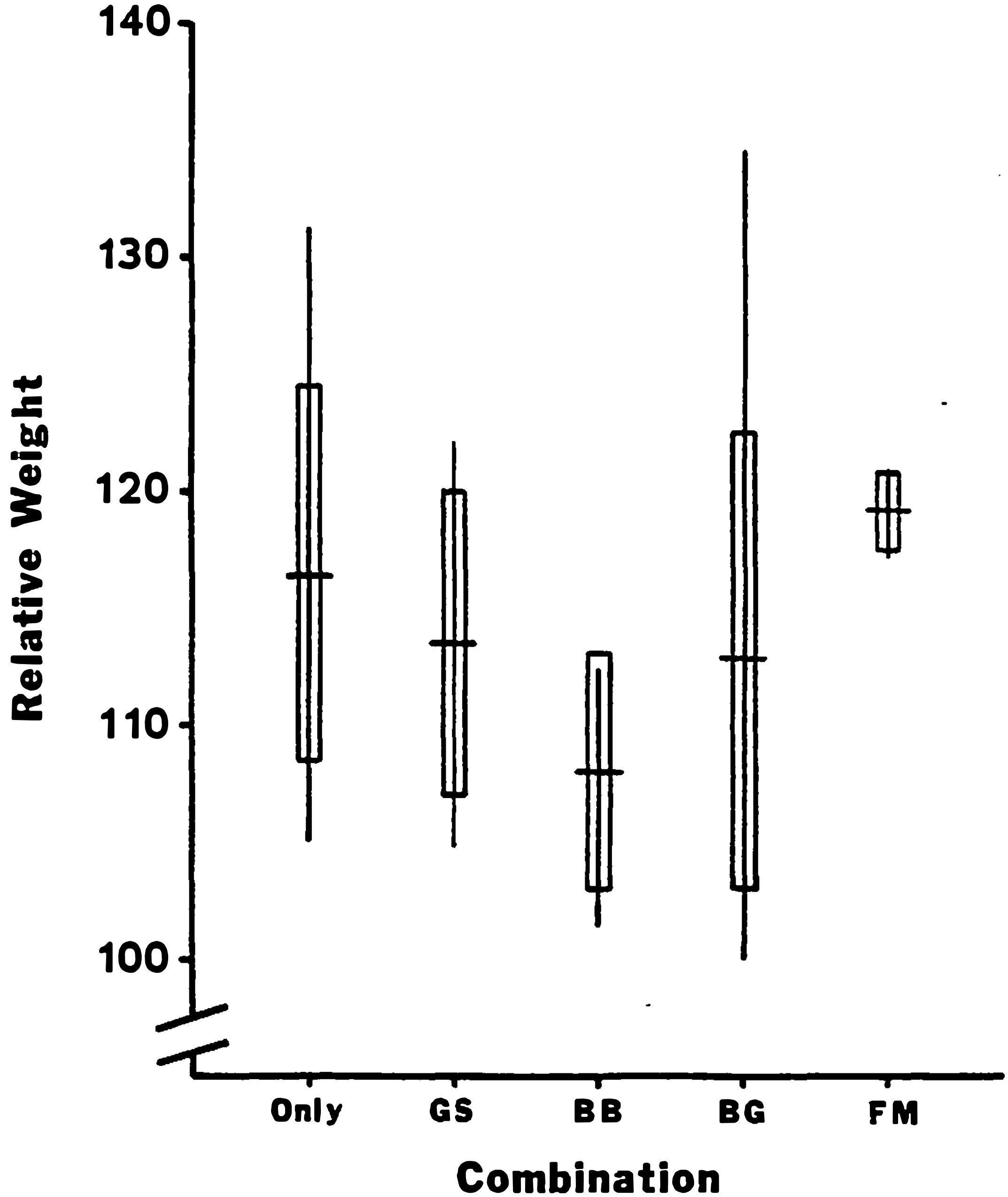

Figure 8. Relative weight values for largemouth bass (*Micropterus salmoides*) from the 34 study ponds, 1980, averaged among forage combination (GS=golden shiner, *Notemigonus crysoleucas*; BB=black bullhead, *Ictalurus melas*; BG=bluegill, *Lepomis macrochirus*; FM=fathead minnow, *Pimephales promelas*) stocked.

INTRODUCTION

Many research studies have been conducted in the past in an attempt to define the optimal pond fish stocking combination for different geographical regions (Wenger 1972; Dillard and Novinger 1975). Combinations that have worked well in one geographic region have been questioned in others (Bennett 1950; Regier 1963a). The pond stocking combination recommended in many of the southern states, largemouth bass (*Micropterus salmoides*)-bluegill (*Lepomis macrochirus*) (Modde 1980), does not appear to be highly successful in northern regions of the country (Bennett 1944; Regier 1963a). Researchers in the northern latitudes have questioned the long term effectiveness of the bass-bluegill combination (Ball and Tait 1952; Bennett 1970). Bennett (1970) reported that several years after stocking, bluegill populations tend to overpopulate, stunt, and result in reduced bass recruitment.

South Dakota, with over 100,000 ponds, ranks among the top ten states in total number of small impoundments constructed by the Soil Conservation Service in the continental United States (Modde 1980). The primary purpose for construction of most ponds is to provide water for livestock, but many of these ponds presently contain or are suitable for pondfish populations (Peeters 1978).

Management of fish populations is not practiced by most South Dakota pond owners. This has lead to the need for a stocking strategy that can maintain a balanced population without management. Swingle (1950) defined balanced populations as, "fish populations

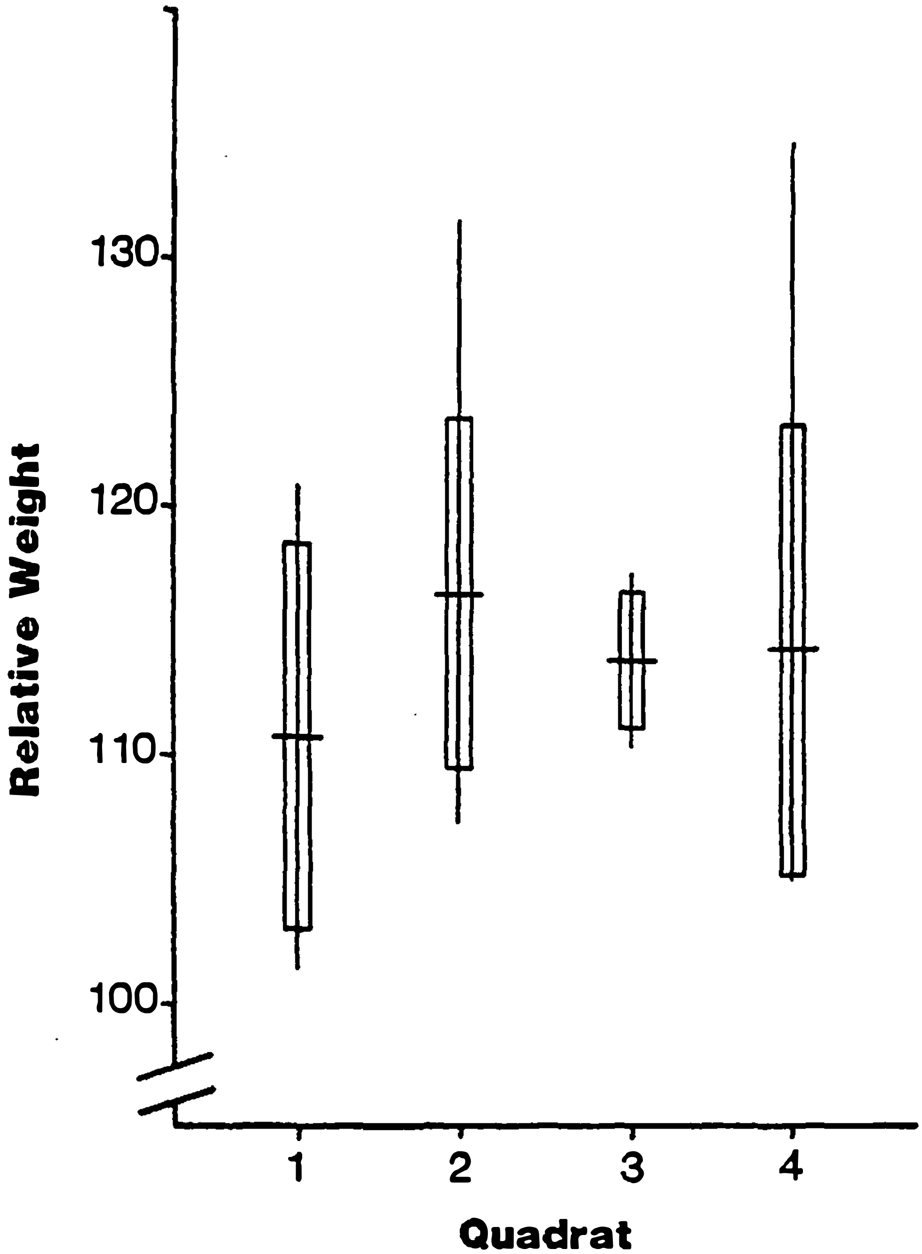

Figure 9. Relative weight values for largemouth bass (*Micropterus salmoides*) from the 34 study ponds, 1980, averaged according to study quadrat stocked.

Table 10. Analysis of variance of largemouth bass (*Micropterus salmoides*) relative weights due to combination stocked in 34 South Dakota stock ponds, 1980.

Source of variation	Degrees of freedom	Mean square	F
Combination	4	68.3	1.28
Error	17	53.5	

Table 11. Analysis of variance of largemouth bass (*Micropterus salmoides*) relative weight due to geographic region of South Dakota stocked for 34 ponds, 1980.

Source of variation	Degrees of freedom	Mean square	F
Quadrat	3	17.1	.32
Error	17	53.5	

DISCUSSION AND CONCLUSIONS

The mean survival rate of largemouth bass observed in the present study of 50.2% was comparable to the 50% reported by Hill (1980) in private Iowa ponds and the 55% observed by Johnson and McCrimmon (1967) from private ponds in Ontario. In Missouri, bass simultaneously stocked with bluegill at 247/ha (100/acre) in controlled hatchery ponds had an average first year survival of 72% (Novinger 1980).

The unusually poor survival of bass, when stocked in combination with black bullheads during this study, was unclear. Inadequate pond depth was suspected in Murphy and Johnson #2 where survival rates of 3.0% and 0.0% were found. However, depth appeared adequate in Hanson and Hinricker #3, two ponds that also exhibited poor bass survival (12.0% and 15.0%, respectively).

The variable, in this study, exhibiting the greatest influence upon bass growth was the number of growing days. The five to eight day difference in number of growing days between north and south quadrats was probably the major factor accounting for the significant growth differences. Other researchers have also attributed differences in bass growth to growing season (Bennett 1937; Eddy and Carlander 1942; Clugston 1964). The growing season in South Dakota exhibits a southeast (150 days/yr) to northwest (120 days/yr) gradient (Spuhler et al. 1971). First year bass growth rates in the present study followed this pattern with the highest bass growth found in the southeast and the lowest in the northwest. Some variation in the number of growing days for each pond can also be attributed to date of stocking (Appendix 1). Turbidity was second in importance in effecting bass growth. As sight feeders, turbidity would affect bass feeding activity (Fessler 1950; Buck 1956). The presence or absence of fathead minnows was the third ranking variable influencing bass growth. Although fathead minnows appeared to affect growth of first year bass in this study, Applegate and Kruckenburg (1978) suggested that in the presence of large numbers of aquatic insects, young of the year bass did not heavily utilize them. Lagler and DeRoth (1952), however, have indicated that bass are a more effective predator on fishes having a rather terete body shape than on those having a more compressed body form, such as sunfishes (lepomids). The final variable with a significant contribution to the growth model was salinity. The variation explained by this parameter may represent the combined effect of three variables since salinity was highly correlated to hardness and conductivity. A previous study of South Dakota ponds by Peeters (1978) indicated that salinity was not a limiting factor to fish production.

The 153 mm statewide mean growth for age-1 bass in the present study compares to the 159 mm age-1 growth mean reported by Applegate and Kruckenburg (1978) for bass stocked in a South Dakota borrow pit. This value exceeded those reported by Modde and Stone (1980) for an established bass pond in western South Dakota and for an existing bass population in Lake Francis Case (Gasaway 1970).

First year growth rates for initially stocked bass (247/ha) in other midwestern impoundments, ranged from 170 mm in Iowa (Hill 1980) to over 205 mm for Missouri (Novinger 1980).

Estimates of second year growth rates of bass, computed from total length measurements collected in September 1980 for eight southeastern (Quadrat IV) South Dakota ponds, averaged 276 mm. This value exceeded that of 270 mm for bass stocked at 247/ha, but was below the 286 mm average attained by bass stocked at 173/ha, reported by Hill (1980) for Iowa ponds (Figure 10). Bass in Missouri averaged 281 mm at the end of the second year (Novinger 1980).

Relative weight values computed in this study were comparable with the 106 mean value reported by Modde and Stone (1980) for bass in a western South Dakota pond. In Missouri, relative weight values for 26 ponds ranged from 68 to 144 with a mean of 80.0 (Novinger 1980), where as, relative weights from 34 ponds in this study ranged from 100 to 135 with an average of 113.6. Relative weight values calculated from the fall sample were nearly identical with those obtained from same ponds during the spring.

Statistical analysis of combinations stocked in the present study indicated no significant differences in age-1 bass growth. However, when bass growth rates were pooled by similar means (northern and southern quadrats), ponds with fathead minnows in the southern quadrats (II and IV) exhibited greater growth than those without. Significant differences in the presence or absence of

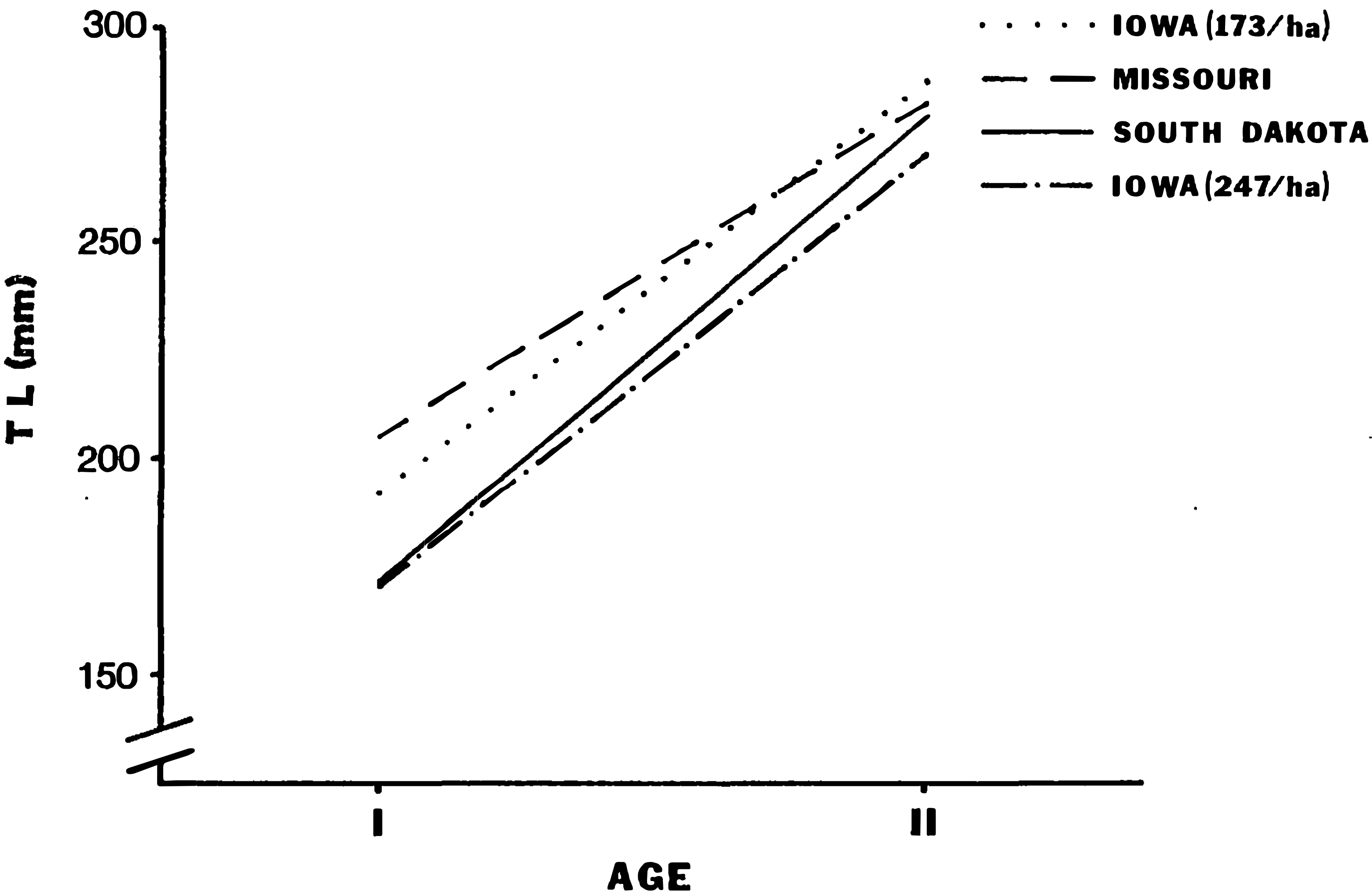

Figure 10. Comparison of first and second year growth of largemouth bass (*Micropterus salmoides*) from Iowa (Hill 1977, 1980), Missouri (Novinger 1980), and the present study.

minnows, but not among combinations, was partially due to confounding of the presence of fathead minnows with other combinations stocked. Although ponds with fathead minnows exhibited greater growth rates than those without in the northern quadrats (I and III), no significant difference was observed. Lack of significance in the northern ponds may have been due to a shorter growing season.

The results of this study indicate that growing season and the presence of fathead minnows are important to South Dakota pond management and stocking strategies. Bass growth at age-1 in southern South Dakota ponds was only 6 mm shorter than bass split-stocked at a density of 173/ha with bluegills in Iowa (Hill 1980). Hill (1980) reported successful reproduction of age-1 bass in 80% of his study ponds by split-stocking bass at densities of 173/ha with bluegills which had been stocked the preceding fall. Previous stocking of 247 bass per hectare in Iowa ponds produced mean first year bass growth of only 170 mm and did not result in successful second year reproduction (Hill 1977).

The highest bass growth observed in this study was from a pond containing both fathead minnows and bluegills as forage and with a first year survival of 54%. Therefore, both forage species and bass density may be important in increasing bass growth rates in South Dakota. Other researchers have also attributed increased bass growth to stocking density (Eddy and Carlander 1942; Pardue and Hester 1966; Hill 1980).

Comparing bass growth rates from ponds containing fathead minnows in the southern quadrats (II and IV) to research by Hill (1980) in Iowa, it suggests that age-1 bass may achieve spawning in the southern portion of South Dakota. A stocking strategy to achieve second year reproduction of bass in southern South Dakota would include a split-stocking chronology of bass and bluegills, stocking bluegill the fall previous to bass introductions. Bass should be stocked at a reduced density of 173/ha preceded by fathead minnow introductions. In Missouri (Novinger 1980) and Iowa (Hill 1980), split-stocking of bluegills resulted in mature bluegills the following summer which spawned and provided excellent forage for the bass stocked that same summer. If spawning of age-1 bass can be achieved, it would eliminate the missing year-class that has been attributed to the failure of the bass-bluegill combination in the past (Hill 1980). Although fathead minnows have been reported to be eliminated rapidly from bass ponds (Elrod 1971), the additional forage available to young-of-the-year bass may be sufficient to produce bass large enough to spawn during their second year.

The use of a multiple species forage base may provide more efficient growth of bass (Werner 1979) by providing a wider size range of forage. Since bass can swallow a longer length minnow than bluegill (Lawrence 1957), the minnows may provide a more energy efficient forage as bass first become piscivorous while bluegills may be a better forage for large bass (Werner 1979).

Results from ponds in the northern quadrats of South Dakota suggested that spawning of age-I bass is not possible. The slower growth rates suggested that this fishery will take longer to develop and that alternative stocking strategies are necessary. Pond owners in the northern regions of the state, whose main desire is bass fishing, may have better results by stocking bass-golden shiners as suggested by Regier (1963b). Stocking strategies for the northern pond owner who desires a bluegill fishery will have to include successive stocking of bass as recommended by Anderson (1971) and Hill (1980) to provide the otherwise missing bass year class or by using a split-stocking of bass and bluegills, stocking bass the first year followed by bluegills the next summer (Regier 1963a).

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Appendix 1. Physical description of 34 study ponds and dates and numbers of fishes (LMB = largemouth bass, Micropterus salmoides; GS = golden shiner, Notemigonus crysoleucas; BB = black bullhead, Ictalurus melas; BG = bluegill, Lepomis mucrochirus; FHM = fathead minnow, Pimephales promelas) stocked during 1979.

Pond					Stocking Data					
Owner's Name	Quadrat	County	Size Hectares	Maximum Depth (meters)	Date	Number Stocked LMB	GS	BB	BG	FHM
Hoff	1	Perkins	.8	1.8	7-14-79	550				
					7-27-79			2000		
Imslad	1	Meade	.3	1.7	7-15-79	350				
					8-23-79				1750	
Merkel #2	1	Dewey	.4	1.5	7-14-79	140				
					7-28-79			560		
Scofield #1	1	Meade	.8	2.1	6-5-79		1000			
					7-15-79	400				
Scofield #2	1	Meade	.9	2.1	5-23-79					1750
					7-15-79	400				
Scofield #3	1	Meade	.3	3.2	7-15-79	200				
					7-27-79			800		
Sternad	1	Meade	.4	2.6	5-23-79					500
					7-14-79	200				
Thompson #1	1	Dewey	.4	2.4	7-14-79	300				

Appendix 1. (Continued)

Pond					Stocking Data					
						Number Stocked				
Owner's Name	Quadrat	County	Size Hectares	Maximum Depth (meters)	Date	LMB	GS	BB	BG	FHM
Thompson #2	I	Dewey	.3	3.0	7-14-79	250				
					8-24-79				1250	
Van Den Burg	I	Perkins	.2	1.0	7-14-79	300				
					8-23-79				1500	
Buls	II	Haakon	.3	1.8	6-5-79		375			
					7-10-79	150				
Calhoon #3	II	Tripp	.7	3.0	7-10-79	182				
Frantz #3	II	Tripp	1.1	6.1	7-11-79	300				
					8-22-79				1500	
Olsen #1	II	Haakon	1.0	2.1	7-10-79	300				
					7-27-79			1200		
Olsen #2	II	Stanley	3.9	3.7	6-6-79		1500			
					7-10-79	971				
Olsen #4	II	Haakon	.3	2.0	7-10-79	200				
					8-22-79				1000	
Olson #5	II	Haakon	1.0	3.0	7-10-79	300				

Appendix I. (Continued)

Pond					Stocking Data					
Owner's Name	Quadrat	County	Size Hectares	Maximum Depth (meters)	Date	Number Stocked LMB	GS	BB	BG	FHM
Olsen #6	II	Haakon	.5	2.1	7-10-79	300				
					8-22-79				1500	
Amdahl	III	Grant	.4	2.4	7-17-79	90				
					8-15-79				450	
Bamesperger	III	Wallworth	.5	3.0	7-18-79	200				
Blue Cloud Abbey	III	Grant	1.9	5.0	6-28-79		1320			
					7-17-79	460				
Cronin	III	Potter	2.0	4.9	7-18-79	200				
					7-28-79			800		
Hanson	III	Grant	1.6	3.7	7-17-79	210				
					7-24-79			840		
Knott	III	Potter	.6	1.8	5-16-79					750
					7-17-79	200				
Richter	III	Grant	.6	3.2	7-17-79	150				

Appendix 1. (Continued)

Pond					Stocking Data					
Owner's Name	Quadrat	County	Size Hectares	Maximum (meters)	Date	Number Stocked LMB	GS	BB	BG	FHM
Armstrong #1	IV	Moody	.6	3.7	6-27-79		660			
					7-9-79	134				
Armstrong #2	IV	Moody	.5	3.4	7-9-79	83				
Baughman	IV	Aurora	.4	1.2	6-8-79		250			
					7-9-79	86				
Bush	IV	Hutchinson	.8	2.3	5-22-79					1050
					7-9-79	195				
Halstead	IV	Brookings	1.0	3.8	6-27-79		500			
					7-10-79	241				
Hinricher #1	IV	Moody	.4	2.7	7-9-79	95				
Hinricher #3	IV	Moody	.4	2.7	5-17-79					1000
					7-9-79	100				
McMurry	IV	Lincoln	.5	2.0	7-9-79	132				
Mayer #1	IV	Buffalo	.7	4.3	6-8-79		500			
					7-9-79	171				

Appendix 2. Hydrological data, 1980, and number of growing days, 1979, for the 34 study ponds.

Pond Owner	Quadrat	pH	Hydroxide (mg/l)	Carbonate (mg/l)	Bicarbonate (mg/l)	Salinity o/oo	Hardness (mg/l)	Conductivity (umhos)	Phosphorus (mg/l)	Turbidity (FTU)	Growing Days
Hoff	I	9.4	40	40	0	0.5	220	1250	.65	8	103
Imslad	I	7.8	00	00	120	0.0	50	210	.76	265	106
Merkel #2	I	7.6	00	0	80	0.1	100	315		380	106
Scofield #1	I	8.3	00	0	300	0.6	80	1000	.74	70	105
Scofield #2	I	8.6	00	0	500	0.5	60	1200	.47	70	105
Scofield #3	I	8.2	00	0	190	0.1	80	390	.35	330	105
Sternad	I	9.1	00	0	105	0.0	65	160	.70	85	106
Thompson #1	I	9.0	00	30	90	0.0	90	330	.60	30	103
Thompson #2	I	8.0	00	0	150	0.1	100	310		30	106
Van Den Burg	I	8.4	00	0	200	0.0	65	345	.60	30	103
Buls	II	8.8	0	20	60	0.3	260	850	.62	15	110
Calhoon #3	II	8.7	0	20	100	1.0	250	1800	.20	10	111
Frantz #3	II	8.9	0	60	0	2.0	1400	3900	.45	20	110
Olsen #1	II	8.8	0	10	40	1.2	500	2150	.45	15	110
Olsen #2	II	8.9	0	60	60	0.2	80	720	.30	35	110
Olsen #4	II	9.0	0	20	50	1.0	340	1850	.40	15	110
Olsen #5	II	9.0	0	20	50	1.3	420	2450	.33	15	110
Olsen #6	II	8.7	0	20	90	0.1	120	720	.36	20	110

Appendix 2. (Continued)

Pond Owner	Quadrat	pH	Hydroxide (mg/l)	Carbonate (mg/l)	Bicarbonate (mg/l)	Salinity %	Hardness (mg/l)	Conductivity (umhos)	Phosphorus (mg/l)	Turbidity (FTU)	Growing Days
Amdahl	III	8.1	0	0	160	0.0	140	330	.07	15	104
Bamesperger	III	8.9	10	60	0	0.3	190	420	.31	25	102
B C Abbey	III	8.4	0	0	200	0.1	250	560	.40	45	105
Croin	III	8.5	0	0	140	0.8	290	1225	.18	30	102
Hanson	III	8.2	0	0	360	0.2	350	600	.20	20	105
Knott	III	7.8	0	0	130	0.0	100	220	.08	30	103
Richter	III	8.6	0	0	120	0.0	90	200	.10	55	104
Armstrong #1	IV	8.3	0	0	180	0.0	240	380	.50	5	113
Armstrong #2	IV	8.5	0	0	170	0.0	280	420	.08	10	113
Baughman	IV	8.0	0	0	170	0.0	140	230	.15	57	110
Bush	IV	8.7	0	0	180	1.0	580	1150	.50	40	113
Halstead	IV	8.1	0	0	230	0.0	230	380	.40	36	112
Hinricker #1	IV	8.2	0	20	100	0.0	100	140	.30	20	113
Hinricker #3	IV	8.5	0	40	180	0.0	130	210	.15	50	113
Mayer #1	IV	9.2	0	40	100	0.0	100	265	.18	10	111
McMurry	IV	8.1	0	0	150	0.0	135	220	.25	39	114

Appendix 3. First year survival rate and 95% confidence limits for largemouth bass (*Micropterus salmoides*) populations in 16 eastern South Dakota stock ponds, sampled in spring 1980, (GS = golden shiner, *Notemigonus crysoleucas*; BB = black bullhead, *Ictalurus melas*; BG = bluegill, *Lepomis macrochirus*).

Pond Owner	Combination	Number Stocked	Cumulative Number Marked	Total Catch During Recapture	Number Recaptures	Population Estimate	95% Confidence Limits	% Survival
Armstrong #2	Only	83	64	41	35	76	67- 85	92.0
Hinricker #1	Only	95	46	21	9	103	58-148	100.0
Mayer #2	Only	150	12	3	1	26	5- 47	17.0
McMurry	Only	132	103	65	55	123	111-135	93.0
								$\bar{X}$ = 75.5
Armstrong #1	GS	134	59	46	30	91	73-109	68.0
Baughman	GS	86	63	74	68	75	70- 80	87.0
Halstead	GS	241	98	61	30	198	149-247	82.0
Mayer #1	GS	171	24	35	13	64	39- 87	37.0
								$\bar{X}$ = 68.5
Hanson	BB	210	17	3	4	32	13- 51	15.0
Hinricker #2	BB	155	18	6	6	19	19	12.0
Johnson #2	BB	85	0	0	0	0	0	0.0
Murphy	BB	100	2	2	2	3	3	3.0
								$\bar{X}$ = 7.5

Appendix 3. (Continued)

Pond Owner	Combination	Number Stocked	Cumulative Number Marked	Total Catch During Recapture	Number Recaptures	Population Estimate	95% Confidence Limits	% Survival
Amdahl	BG	90	33	16	16	34	34	38.0
Borah	BG	177	11	7	6	9	6- 12	5.0
Bush	BG	195	52	35	17	106	72-140	54.0
Hinricker #3	BG	100	62	77	47	102	84-120	100.0
								$\overline{X} = 50.2$

Appendix 4. Ponds originally stocked but not included in analysis, 1980 (LMB = largemouth bass, *Micropterus salmoides*; GS = golden shiner, *Notemigonus crysoleucas*; BB = black bullhead, *Ictalurus melas*; BG = bluegill, *Lepomis mucrochirus*; FHM = fathead minnow, *Pimephales promelas*).

Pond Owner	Quadrat	Combination	Reason for exclusion from analysis
Bickel	I	FHM	No sample
Merkel #1	I	GS	Insufficient sample
Reich	I	Only	Insufficient sample
Shambo #1	I	BB	No sample
Shambo #2	I	BG	No sample
Sieker #1	I	FHM	No sample
Sieker #2	I	GS	No sample
Stradinger	I	Only	Insufficient sample
Voegele #1	I	Only	Algal bloom
Voegele #2	I	GS	No sample
Calhoon #1	II	FHM	Insufficient sample
Calhoon #2	II	FHM	No sample
Calhoon #4	II	BB	Insufficient sample
Chocholousek	II	Only	Contamination
Frantz #1	II	GS	Insufficient sample
Frantz #2	II	GS	Vegetation
Hawk	II	BG	Contamination
Kjerstad #1	II	FHM	Pond dry
Kjerstad #2	II	Only	Pond dry

Appendix 4. (Continued)

Pond Owner	Quadrat	Combination	Reason for exclusion from analysis
Olsen #3	II	BB	Insufficient sample
Swanda	II	FHM	No sample
Willinski	II	BB	Insufficient sample
Allerding	III	BB	Insufficient sample
Amman, C	III	GS	No sample
Amman, G	III	GS	Insufficient sample
Amman, M	III	GS	No sample
Breitag	III	Only	No sample
Calhoon	III	FHM	Insufficient sample
Johnson #1	III	BG	No sample
Johnson #2	III	BB	No sample
Nolte	III	FHM	No sample
Pollman	III	BG	Insufficient sample
Schilder	III	Only	No sample
Sherman	III	BG	Insufficient sample
Van Beek	III	FHM	No sample
Anderson	IV	BB	No sample
Borah	IV	BG	Insufficient sample

Appendix 4. (Continued)

Pond Owner	Quadrat	Combination	Reason for exclusion from analysis
Edgecomb	IV	BG	Contamination
Grosz	IV	BB	Contamination
Heeren	IV	BG	No sample
Hemmingson	IV	BG	Contamination
Hinricker #2	IV	BB	Insufficient sample
Koerner	IV	BG	No sample
Mayer #2	IV	Only	Insufficient sample
Murphy	IV	BB	Insufficient sample
Paulson	IV	BG	Pond dry

Appendix 5. Mean calculated total lengths and relative weight for Age I largemouth bass (Microoterus salmoides) sampled from 34 South Dakota ponds, during 1980.

Pond Owner	Quadrat	Combination	$\bar{X}$ TL (mm)	$\bar{X}$ Wr
Hoff	I	BB	153.2	109.1
Imslad	I	BG	147.0	100.1
Merkel #2	I	BB	107.5	102.0
Scofield #1	I	GS*	141.3	118.2
Scofield #2	I	FH	151.9	119.7
Scofield #3	I	BB	101.0	101.4
Sternad	I	FH	158.2	120.7
Van Den Burg	I	BG	130.0	104.0
Thompson #1	I	Only	136.5	120.6
Thompson #2	I	BG	136.3	110.4
		Quad	TL=136.3	Quad $\bar{X}$ Wr=111.64
Buls	II	GS	155.4	118.9
Calhoon #3	II	Only	167.4	131.5
Frantz #3	II	BG	171.2	118.2
Olsen #1	II	BB	175.3	112.1
Olsen #2	II	GS	161.0	107.4
Olsen #4	II	BG	160.1	112.4
Olsen #5	II	Only	174.3	116.7
Olsen #6	II	BG	163.0	114.2
			Quad $\bar{X}$ TL=166.0	Quad $\bar{X}$ Wr=116.4

Appendix 5. (Continued)

Pond Owner	Quadrat	Combination	$\bar{X}$ TL (mm)	$\bar{X}$ Wr
Amdahl	III	BG	142.3	111.8
Bamesperger	III	Only	124.5	110.3
Blue Cloud Abbey	III	GS	135.0	116.3
Croin	III	BB*	158.7	112.4
Hanson	III	BB*	140.4	111.9
Knott	III	FHM	141.3	117.3
Richter	III	Only*	139.1	116.4
			Quad $\bar{X}$ TL=140.2	Quad $\bar{X}$ Wr=113.8
Armstrong #1	IV	GS	167.0	114.5
Armstrong #2	IV	Only	170.8	105.2
Baughman	IV	GS	144.2	122.0
Bush	IV	BG*	196.5	134.6
Halstead	IV	GS	152.0	106.3
Hinricker #1	IV	Only	169.2	110.7
Hinricker #3	IV	BG*	177.2	109.7
Mayer #1	IV	GS	172.6	104.8
McMurry	IV	Only*	187.0	119.8
			Quad $\bar{X}$ TL=170.7	Quad $\bar{X}$ Wr=114.2
			State X TL=153.2	State X Wr=113.6

* Also contained fathead minnows (Pimephales promelas).

Appendix 6. Mean total lengths for Age-I and Age-II largemouth bass (*Micropterus salmoides*) from 8 southeastern (Quadrat IV) South Dakota stock ponds, during September 1980.

		$\bar{X}$ TL (mm)	
Pond Owner	Combination	I	II
Armstrong #1	GS	167.0	269.8
Armstrong #2	Only	170.8	271.5
Baughman	GS	144.2	248.5
Bush	BG	196.5	307.9
Halsteads	GS	152.0	261.8
Hinricker #1	Only	169.2	274.0
Hinricker #3	BG	177.2	292.8
McMurry	Only	187.0	279.4
		$\bar{X}$ =170.5	$\bar{X}$ =275.7

Appendix 7. Mean largemouth bass (*Micropterus salmoides*) relative weight (W_r) values for spring and fall samples from 8 southeastern (Quadrat IV) South Dakota stock ponds, 1980.

		SPRING		FALL	
Pond Owner	Combination	Date	W_r	Date	W_r
Armstrong #1	GS	5-6-80	114.5	9-9-80	123.0
Armstrong #2	Only	5-6-80	105.1	9-7-80	116.9
Baughman	GS	5-20-80	122.0	9-25-80	102.1
Bush	BG	5-14-80	134.6	9-24-80	140.2
Halstead	GS	5-1-80	106.3	9-9-80	120.6
Hinricker #1	Only	5-8-80	110.7	9-29-80	117.3
Hinricker #2	BG	5-7-80	109.7	9-16-80	110.3
McMurry	Only	5-13-80	119.8	9-19-80	104.6
			$\bar{X}$=115.3		$\bar{X}$=116.9