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Evaluation of Largemouth Bass and Bluegill Stocking Strategies in South Dakota Ponds

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Evaluation of Largemouth Bass and Bluegill Stocking Strategies in South Dakota Ponds

by

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Evaluation of Largemouth Bass and

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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.

Timothy Modde — Date
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Abstract

David M. Gilbraith

Three fish-stocking methods were evaluated to determine the effects of stocking density and chronology on largemouth bass (*Micropterus salmoides*) and bluegill (*Lepomis macrochirus*) survival, growth, and reproductive success during 1983-1985. Two densities of split-stocking largemouth bass with bluegills were compared to the simultaneous introduction of both species. First-year largemouth bass survival was low and variable among treatments. Survival of largemouth bass ranged from 0-85% and averaged 25% among treatments. Bluegill survival, for the first and second years combined, ranged from 0-60% and averaged 22% among two split-stocking treatments. Thirty-six percent of study ponds experienced at least partial winterkill during the study. First-year largemouth bass growth averaged 165 mm in the high-density split, 183 mm in the low-density split, and 176 mm in the simultaneous-stocking treatments. Growth of largemouth bass in the second year was 283 and 285 mm for the high and low-density split stockings, respectively, and 271 mm in the simultaneous-stocking treatment. Means were not significantly ($P>.05$) different between treatments either year. Bluegill mean length was not significantly (P).05) different among split-stocking treatments for three year-classes. Second-year growth in two split treatments averaged 121 mm while the simultaneous stocking averaged 77 mm. Relative Weights of adult largemouth bass and bluegills were not

significantly (P).05) different between treatments. Spawning of age-I largemouth bass occurred in only one study pond, a high-density, split-stocked pond. Bluegill and fathead minnow _(Pimephales promelas)_ reproduction was documented in the majority of split-stocking treatment ponds in 1984 and 1985. No bluegill reproduction was reported in the simultaneous-stocking treatment in 1985. Bluegill fry abundance was similar for split-stocking treatments during both years, 73 and 70 fish/seine haul in the high-density split, and 47 and 45 fish/seine haul in the low-density, split-stocking treatments. Age-I bluegill abundance in 1985 averaged 10 fish/seine haul in the high-density split and 14 fish/seine haul in the low-density, split-stocking treatments. Age-0 and I bluegills, that were spawned in the ponds, were accessible to initially-stocked largemouth bass predation in both split-stocking treatments, while only initially-stocked bluegills were accessible in the simultaneous-stocking treatment. Fathead minnow abundance between 1984 and 1985 declined from 236 to 42 fish/seine haul in the high-density split and 161 to 30 fish/seine haul in the low-density, split-stocking treatments, but means were not significantly ($P>.05$) different by year. The split-stocking method may be acceptable in South Dakota, but only with supplemental stocking of largemouth bass.

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1 Presence or absence of largemouth bass (*Micropterus salmoides*).

Introduction

Largemouth bass *(Micropterus salmoides)* and bluegill *(Lepomis macrochirus)* represent the principal stocking combination in small midwestern impoundments (Novinger and Legler 1978). The largemouth bass-bluegill combination was originally proposed by Swingle and Smith (1941), based upon studies of several species in Alabama ponds. This combination was subsequently recommended by the United States Fish and Wildlife Service and the Soil Conservation Service for stocking in small impoundments throughout the country (Regier 1962), but was reported to be most successful in the southeastern United States (Holloway 1951). Modde (1980) reported that the majority of southern and mid-latitude state management agencies continue to recommend largemouth bass-bluegill in their pond-stocking programs. However, due to the tendency of bluegills to overpopulate and stunt in northern-latitude ponds, alternate prey species were sought by many northern states (Wenger 1972, Dillard and Novinger 1975).

Tanner (1975) stated that the stability of interacting predator-prey populations is determined by the life history characteristics affecting survival and fecundity of each species. Latitude affects life history characteristics in largemouth bass and bluegill populations. Modde and Scalet (1985) found that although growth rates of both largemouth bass and bluegills decreased as latitude increased in the United States, maximum size of bluegills was affected less by latitudinal changes. Reduced efficiency of largemouth bass predation, due to inaccessibility of larger prey, results in increased bluegill survival. Latitude also affects age at first reproduction, the most important contributor to the fecundity of animal populations (Cole 1954). Reproduction by age-I bluegills occurs at both northern and southern latitudes (Shelley and Modde 1982). Largemouth bass reproduction occurs at age-I in the southern United States but not until age-II or III in northern-latitude states (Beck 1985). The combined effects of increased survival and greater fecundity of bluegills, relative to that of largemouth bass, tends to destabilize predator-prey interactions of the two species at northern latitudes.

Manipulation of density and timing of stocking may improve the efficiency of largemouth bass predation upon bluegills. However, due to variation in survival of fish among ponds, stocking density alone may not have a major impact upon future size of largemouth bass and bluegill populations (Eipper and Regier 1983). Variability in bluegill survival may also be influenced by the timing of largemouth bass introduction. Largemouth bass stocked simultaneously with bluegills do not initially benefit from high prey densities. The split-stocking method results in bluegills which spawn the summer following stocking, providing prey for largemouth bass fingerlings stocked the second year (Hackney 1974). Growth rates of largemouth bass may be increased enough by bluegill prey accessibility (Johnson and McCrimmon 1967) to allow age-I spawning. Production of this initial largemouth bass year-class may result in stable population structure (Reynolds and Babb 1978).

The split-stocking strategy was first advocated in the 1940's by Swingle (Burress 1952, Hackney 1974) and adopted by the majority of southeastern state management agencies (Modde 1980) to fit hatchery production schedules. Hatchery personnel could harvest largemouth bass fingerlings from extensive culture ponds in early summer and reuse the ponds to culture bluegill fingerlings for fall stocking. Carnes (1960) reported that largemouth bass in North Carolina spawned at age-I in ponds stocked by both the simultaneous and split methods. Burress (1952) reported better growth and reproductive success of age-I largemouth bass in Missouri ponds stocked by the simultaneous method than in those stocked by the split method. Conversely, Novinger (1980) concluded that successful reproduction of age-I largemouth bass in Missouri ponds stocked by the split method at lower densities of 124/hectare (50/acre), resulted in a size structure of largemouth bass and bluegills comparable to that occurring in simultaneously-stocked ponds. Hill (1980) reported successful age-I largemouth bass spawning in split-stocked ponds in Iowa at a reduced stocking density of 173 largemouth bass/hectare (70/acre).

Growth of the predator, largemouth bass, is dependent on optimal use of prey (Savino et al. 1985). Optimal foraging theory predicts that fish will maximize their net rate of energy intake (Pyke 1979), by consuming energetically efficient sizes and species of suitably abundant prey (Schoener 1971). To maximize largemouth bass feeding efficiency, Anderson (1971) recommended stocking a diversity of prey species in ponds. Both bluegills and fathead minnows (*Pimephales promelas*) are prolific, but differ in stability and vulnerability, as defined by Ney (1981). Because adult fathead minnows are vulnerable to largemouth bass predation (Savino et al. 1985), they do not maintain high densities (Modde and Scalet 1986). Bluegills are not as vulnerable to largemouth bass predation (Noble 1981), often resulting in excess recruitment.

The objectives of this study were to: 1) compare survival, growth, and reproductive success of largemouth bass and bluegills among split and simultaneous-stocking methods, and 2) evaluate production of fathead minnows and bluegills as largemouth bass prey.

Methods

Design

Population structure of largemouth bass and bluegills was evaluated in 15 ponds divided among three stocking strategies: high-density split, low-density split, and simultaneous stocking. Study ponds were selected in 1983 and 1984 from pondowner applications to the South Dakota Department of Game, Fish, and Parks and the Soil Conservation Service, Wildlife Conservation Officer solicitations, and field checks. Ponds were confined to the southern (south of latitude 44°, 21') half of South Dakota (Fig. 1). Only ponds meeting the following criteria were selected:

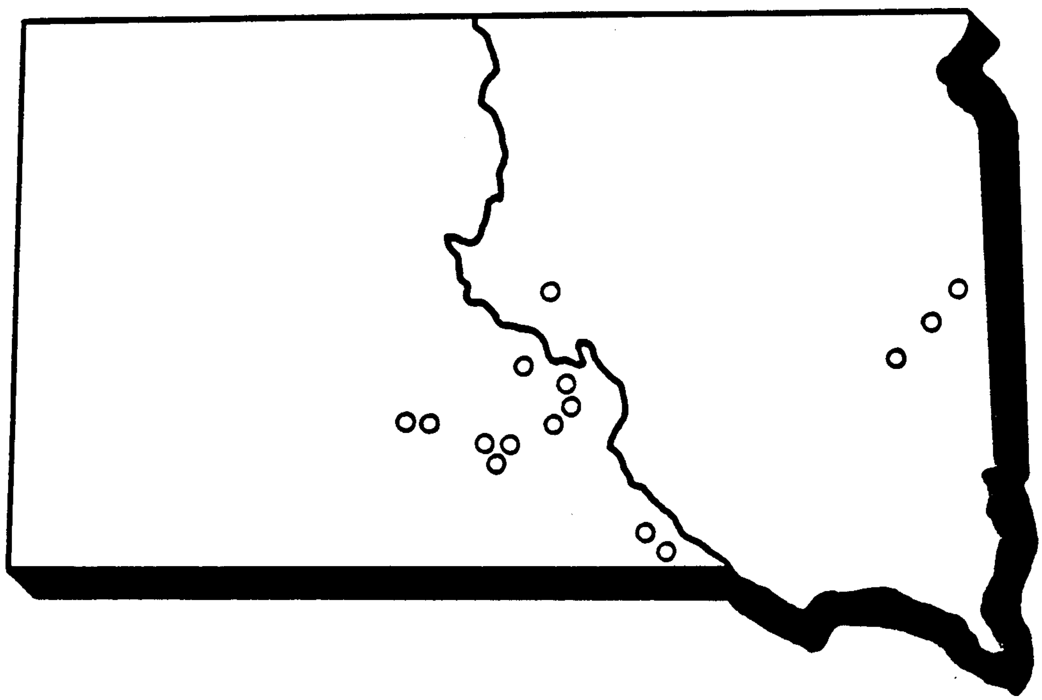


Figure 1.--Locations of 15 ponds selected for largemouth bass (Micropterus salmoides) and bluegill (Lepomis macrochirus) stocking chronology investigations in South Dakota, 1983-1985.

1) 0.4-2.0 hectares (1.0 - 5.0 acres) surface area,

2) 3.8 m (12.0 ft) minimum depth, and

3) no fish present (except fathead minnows).

Ten ponds selected in 1983 were randomly assigned the two split-stocking treatments using a random-numbers table, while five ponds selected in 1984 were assigned the simultaneous treatment.

The high-density, split-stocking treatment received 1,240 bluegills/hectare (500/acre) on 20-21 September, 1983, at a mean length of 50.0 mm (2.0 in); 2,471 fathead minnows/hectare (1000/acre) on 25-26 May, 1984, as a mixture of adults and juveniles; and 247 largemouth bass/hectare (100/acre) on 12-13 July, 1984, at a mean length of 32.1 mm (1.3 in). The low-density, split-stocking treatment was identical to the latter, except that largemouth bass were stocked at 173/hectare (70/acre). The simultaneous-stocking treatment received the same densities as the low-density, split-stocking treatment, but bluegills were introduced on 11-12 September, 1984, at a mean length of 31.7 mm (1.2 in). Largemouth bass and bluegills were obtained from Gavins Point National Fish Hatchery, Yankton, South Dakota, and fathead minnows were purchased from Porter's Bait Farm, Brookings, South Dakota.

Field Methods

To evaluate similarity of ponds not initially randomly assigned among treatments, 12 physical and chemical variables were measured each month of June, July, and August, 1984. Surface area was originally estimated in 1983 and 1984 with a pond-shape perimeter chart (Missouri Department of Conservation mimeo). Exact surface area was determined in late June, 1984, using an alidade, stadia rod, and planimeter. Maximum depth was recorded during the initial survey with a Lowrance XL-15 chart recorder. Carbonate and bicarbonate alkalinity, hardness, nitrate nitrogen, orthophosphate, sulfate, and turbidity were measured with a Hach Kit, Model DR-EL/2. Conductivity and salinity were measured with a Yellow Springs Instrument S-C-T Meter, Model 33. A Hellige Lilliput meter, Model 750, was used to measure pH. Samples were collected or readings taken at the point of maximum pond depth, 0.3 m (1 ft) below the surface.

Population estimates, using the mark-recapture method, were attempted for age-I bluegills during spring 1984, and age-I largemouth bass and age-II bluegills in 1985. To reduce sampling bias, two methods for marking and recapturing fish were planned. Fish were to be marked by seining and recaptured by electrofishing (3 cycle, 230 volt A.C. generator). Because seining was effective in only one pond, electrofishing was used for both mark and recapture in the remaining ponds. Angling was employed to mark largemouth bass and bluegills in three ponds when seining or electrofishing were not effective. During 1985 electrofishing, catch/unit effort was determined by recording total electrofishing time and fish captured by two collectors with long-handled dip nets. Electrofishing efficiency was increased in 1985 by sampling during dark hours and changing electrode configurations in high conductivity ponds.

Length (mm) and weight (g) were recorded, and scale samples taken, from 30 fish per pond randomly selected from those collected. Scale samples were taken behind the pectoral fin, below the lateral line, for both largemouth bass and bluegills (Jearld 1983). Age-0 and I bluegills and age-0 largemouth bass were too small to weigh with the equipment used. To minimize handling damage during measurement, adult fish were anesthetized in quinaldine or MS-222. Both largemouth bass and bluegills were marked by clipping the left pelvic fin at its base. Following handling, all fish were dipped in a saturated sodium chloride solution.

Permanent seining stations were established every 33 m (100 ft) around the perimeter of study ponds, excluding the face of the dam. Relative abundance of bluegills and fathead minnows was determined with a 4.6 X 1.2 m, 6.4 mm mesh (15 X 3 ft, 1/8 in) straight seine in July and August, 1984, and June, July, and August, 1985. Fish were captured by aligning the seine perpendicular to shore and making quadrant hauls. Bluegills and fathead minnows were sorted and counted. In 1985, lengths were taken from a random sample of 30 each age-0 and I bluegills per pond during each seining session.

A Wildco roller press, Model 110 H10, was used to make impressions of largemouth bass and bluegill scales on acetate slides (Smith 1954). Scale impressions were magnified on a Bell & Howell Model SR-II microfiche reader and each annulus and scale edge were measured and recorded.

Analysis

The adjusted Peterson formula was used to estimate age-I largemouth bass and age-II bluegill population sizes during summer 1985. Survival was determined by dividing the population estimate by the number of fish initially stocked. The equation:

$$N = (M + 1)(C + 1)/(R + 1)$$ (Ricker 1975)

was used where,

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.

Populations were not resampled until at least 24 hours after marking to insure a random distribution of recaptures. The 95% confidence interval around each population estimate was determined using:

$$N + 1.96\ V(N)$$ (Everhart and Youngs 1981)

where,

V(N) = sampling variance for N.

V(N) is calculated by the equation:

$$V(N) = N^2\ (C - R)/(C + 1)(R + 2).$$ (Ricker 1975)

Estimates of first-year growth of largemouth bass and first and second-year growth of bluegills were obtained by back-calculation from scale samples, using the corrected Lee formula:

$$L_n = a + S_n(L_c - a)/S_c$$ (Carlander 1977)

where,

L_n = length of fish at time of annulus, n, °ormation,

a = constant,

S_n = scale radius of annulus, n,

S_c = scale radius,

L_c = length of fish at capture.

Values of 22.0 mm for largemouth bass (Stone and Modde 1982) and 20.0 mm for bluegills (Shelley and Modde 1982) were used for the constant, a, in the above equation. Scale measurements were compared to those of another recorder and differences were rectified.

The index of Relative Weight (W_r) (Wege and Anderson 1978) was used to compare largemouth bass and bluegill condition among stocking combinations. Relative Weight was calculated by the equation:

$_wr$ = W/Ws X 100 (Wege and Anderson 1978)

where,

W_r = Relative Weight,

W = weight of fish at sampling,

W_s = standard weight for species of that same length.

For largemouth bass, W_s was determined for each fish, using the proposed standard weight-length formula:

log W_s = -5.316 + 3.191 (log L). (Anderson 1980)

For bluegills, the formula used was:

log W_s = -5.374 + 3.316 (log L). (Anderson 1980)

A modified Young-Adult Ratio (YAR) was used to evaluate reproductive success of bluegills. Normally, this ratio is computed by:

YAR = N $<$ 80 mm / N 150 mm. (Reynolds and Babb 1978)

In this study, initially-stocked bluegills less than the 150 mm criteria were also used to calculate the ratio.

Accessibility of age-0, I, and II bluegills to largemouth bass predation was determined using the formulas developed by Lawrence (1958), based upon body depth of bluegills and throat width of largemouth bass. For largemouth bass, the equations were as follows:

Total Length	
100 - 199 mm	$M = -1.88 + 0.1113L$,
200 - 299 mm	$M = -5.16 + 0.1289L$,

where M is throat width in mm and L is total length in mm. Bluegill body depth was:

$$D = (L - 19.10)/2.3925,$$

where L and D are total length and maximum body depth in mm, respectively.

Statistical Analysis

A nested factorial analysis of variance (ANOVA) (Steel and Torrie 1980) with treatment and session as main factors with ponds nested within treatments was used to test 12 chemical and physical variables. Total length and W_r of age-I and I+ largemouth bass and age-I, II, and II+ bluegills was tested by a nested ANOVA using treatment as the main factor with ponds nested within treatments. A nested factorial ANOVA with treatment, session, and year as main factors and ponds nested within treatments was used to test abundance of fathead minnows and age-0 bluegills. Relative abundance of age-I bluegills in 1985 was tested by a nested factorial ANOVA using treatment and session as main factors with ponds nested within treatments. A nested factorial ANOVA with treatment, session, and qualify as main factors and ponds nested within treatment X qualify was used to test fathead minnow abundance due to the presence or absence of largemouth bass. Regression analysis was used to test whether largemouth bass length at age-I+ was dependent on relative forage abundance.

Results

Due to contamination by unstocked fishes, two ponds were deleted from analysis of fish populations. Black bullheads (*Ictalurus melas*) and green sunfish (*Lepomis cyanellus*) were noted in another pond, Schlobohm, but the pond was included in the analysis because few of these species were captured. Only those ponds where largemouth - bass were captured in fall 1984 or 1985 were included in the analysis of relative prey density. Therefore, Perry #1, Bronemann (in 1985), Wolfe, and Jandreau #1 were eliminated from analysis.

Considerable variation was observed among physical and water-quality measurements during 1984 (Appendix 1). None of the 12 variables measured in 14 ponds analyzed for water quality were significantly ($P>.05$) different by stocking treatment (Appendix 2).

Survival

Age-I largemouth bass survival was variable, ranging from 0.0-85.2% (Appendix 3). Mean survival was 23.9 and 29.8% for the high and low-density, split-stocking treatments, respectively, and 22.0% for the simultaneous-stocking treatment. Densities of age-I largemouth bass, based on estimated survival, were 60 and 51 fish/hectare in the high and low-density, split-stocking treatments, respectively. Due to insufficient replications, treatment means were not. statistically compared.

Age-II bluegill survival was also variable, ranging from 0.2-59.6% (Appendix 4). Bluegill survival averaged 14.9% in the high-density split and 34.9% in the low-density, split-stocking treatments. Due to lack of replication, means for the two treatments were not statistically compared. Survival of bluegills in the simultaneous-stocking treatment, based on catch/unit effort data from fall electrofishing (Appendix 5), could not be directly compared to survival in the split-stocking treatments.

Growth

Age-I largemouth bass averaged 165 mm in the high-density split, 183 mm in the low-density split, and 176 mm in the simultaneous-stocking treatments (Fig. 2). The high and low-density, split-stocking treatments had similar mean length values for age-I+ largemouth bass collected near the end of the second growing season, 283 and 285 mm respectively, while the simultaneous treatment mean was 271 mm. High variability was observed among individual ponds within treatments (Appendix 6). Mean lengths of age-I and I+ largemouth bass were not significantly ($P>.05$) different by treatment (Appendix 7). Mean length of age-I largemouth bass in split-stocking treatments was

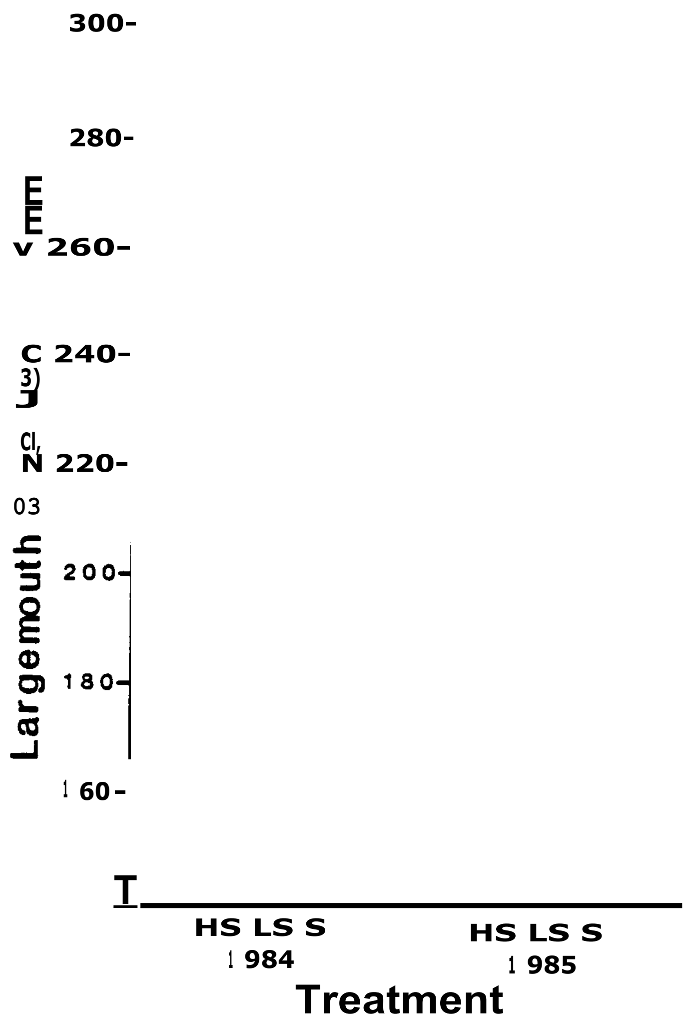
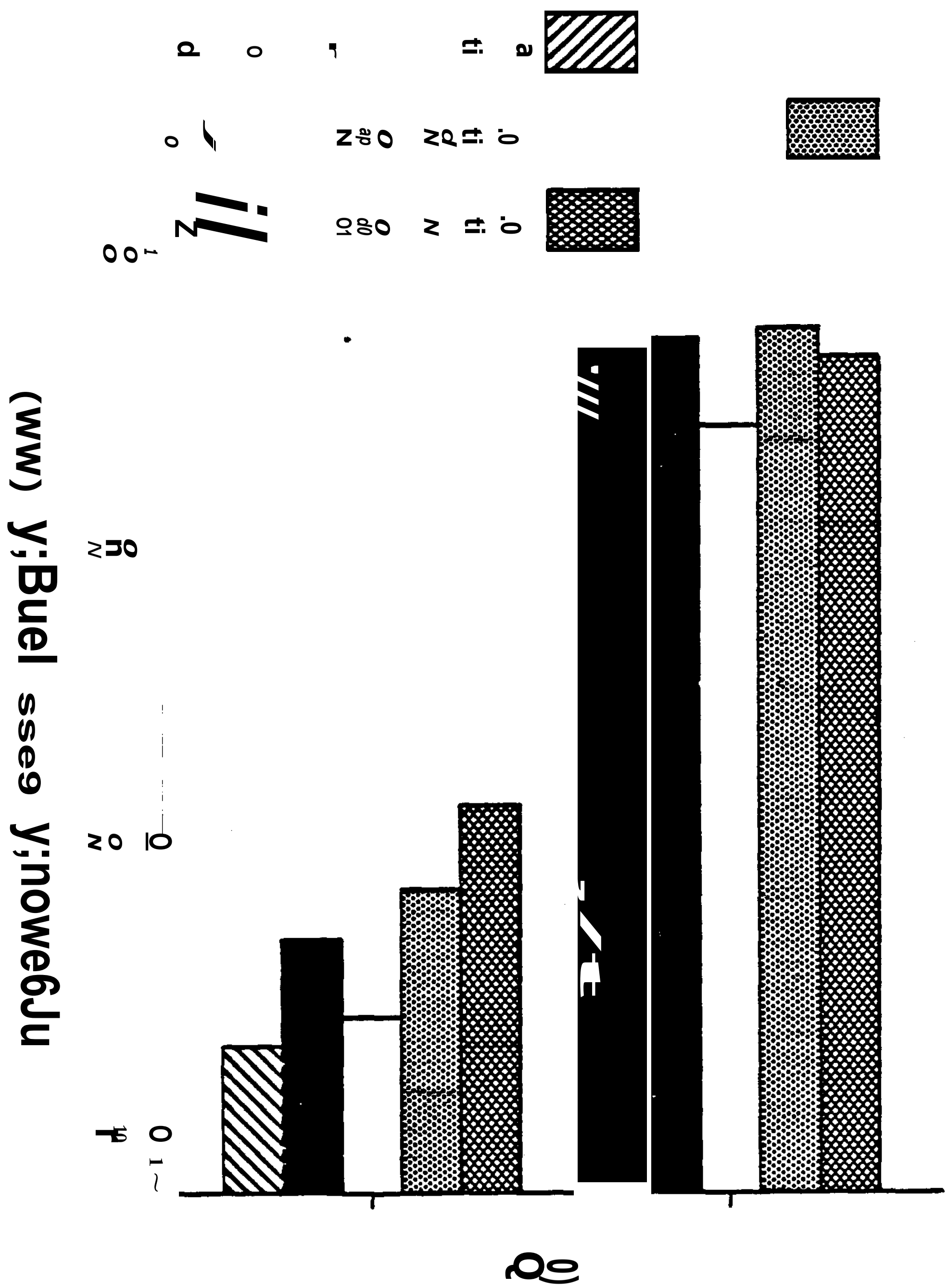


Figure 2.--Total length of age-I and I+ largemouth bass (*Micropterus salmoides*) in nine South Dakota ponds in 1985 by stocking method; mean horizontal line), range (vertical line), and one standard error above and below the mean (rectangle). HS = High-density split, LS = Low-density split, and S = Simultaneous-stocking treatments.



isons of Dakota,

lower than that of Missouri (Novinger 1980) and Iowa (Hill 1980), 206 and 192 mm, respectively **(Fig. 3)**. Mean length of age-I+ largemouth bass was similar in all three states, ranging between 282 and 287 mm, excluding the 247/hectare treatment in Iowa. First-year growth of the spawned largemouth bass cohort in the Beauchamp pond in 1985 was 50.4 mm. Bluegill growth to age-II averaged 77 mm in the simultaneous, 120 mm in the high-density split, and 123 mm in the low-density, split-stocking treatments (Fig. 4) (Appendix 8). There was no significant ($P>.05$) difference in mean lengths of age-I, II, and II+ bluegills collected near the end of the third growing season among the two split-stocking treatments (Appendix **9**).

Variation in weights of age-I+ largemouth bass and age-II+ bluegills within ponds was high. Mean weights for age-I+ largemouth bass ranged from 393 g in the high-density and 364 g in the low-density, split-stocking treatments to 335 g in the simultaneous-stocking treatment. Mean weights for age-II+ bluegills were 86 g in the high-density split and 64 g in the low-density, split-stocking treatments.

Relative Weights (W_r) of age-I+ largemouth bass were 120 and 109 for the high and low-density split treatments, respectively, and 117 for the simultaneous-stocking treatment. Relative Weight was not significantly ($P>.05$) different among treatments (Appendix 7). Relative Weights of age-II+ bluegills were 103 in the high-density and 96 in the low-density, split-stocking treatments, and were not significantly ($P>.05$) different (Appendix 9).

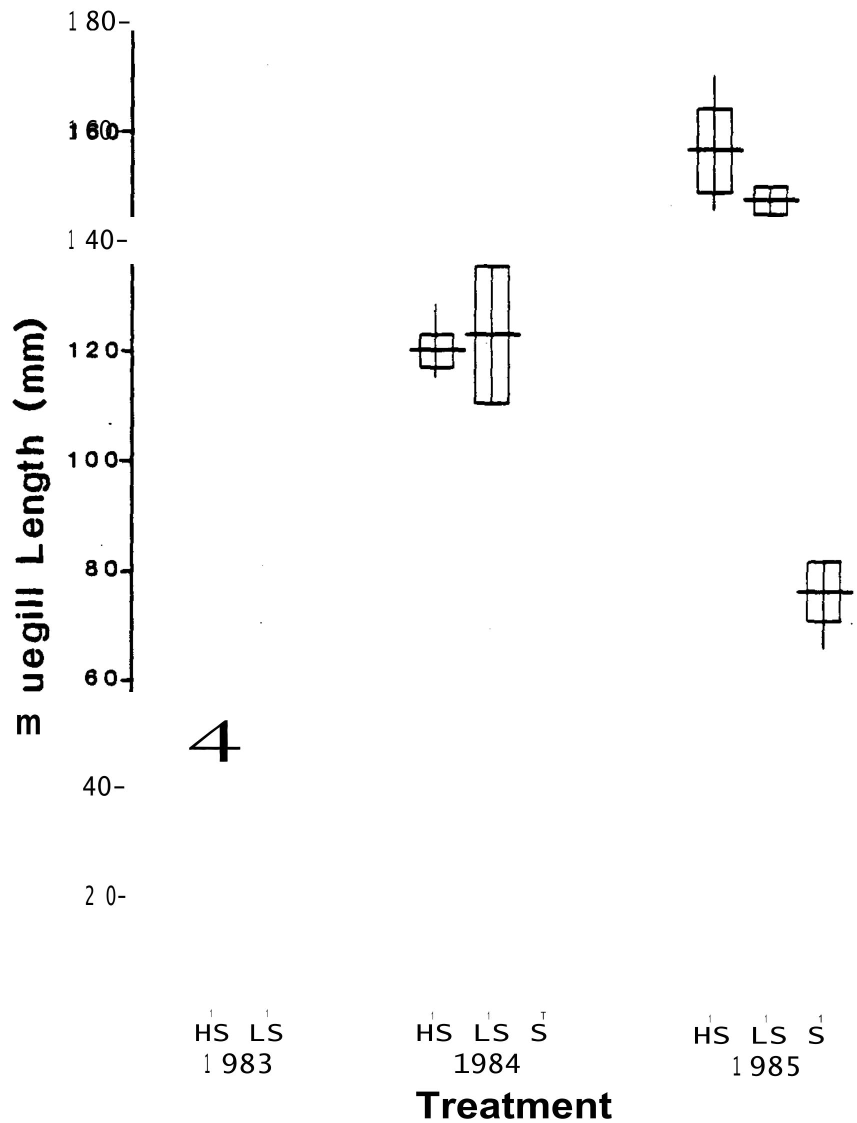


Figure 4.--Total length of age-I, II, and II+ bluegills (*Lepomis macrochirus*) in nine South Dakota ponds in 1985 by stocking method; mean (horizontal line), range (vertical line), and one standard error on each side of the mean (rectangle). HS = High-density split, LS = Low-density split, and S = Simultaneous-stocking treatments.

Reproductive Success

Age-I largemouth bass reproduction occurred in only one study pond, a high-density, split-stocking treatment pond. Five largemouth bass fry were collected on three occasions; 27 July, 13 August, and 31 August, 1985. Bluegills spawned in all eight split-stocking treatment ponds in 1984 but only six in 1985. Fall Young-Adult Ratios (YAR) for bluegills were 3.6 and 52.6 in 1984 and 50.7 and 0.7 in 1985 for high and low-density, split-stocking treatments, respectively (Appendix 10). No bluegill reproduction was detected in any simultaneous-stocking treatment pond in 1985. Fathead minnows spawned in all study ponds in 1984; fathead minnow fry were observed in several ponds by June 1984.

Prey Abundance

Fathead minnow abundance declined substantially in both split-stocking treatments between 1984 and 1985 (Fig. 5). Fish/seine haul (fish) decreased between 1984 and 1985 from 236 to 42 in the high-density split and 161 to 30 in the low-density, split-stocking treatments. There was a reduction in mean numbers of fathead minnows between 1984 and 1985 in the simultaneous treatment, from 111 to 87 fish. Fathead minnow abundance between years and stocking treatments was not significantly ($P>.05$) different (Appendix 11). Fathead minnow abundance of 54 fish in 1985 in ponds with largemouth bass populations was not significantly ($P>.05$) different than the 50 fathead minnows/seine haul in ponds where largemouth bass survival was less than 5% (Appendix 12).

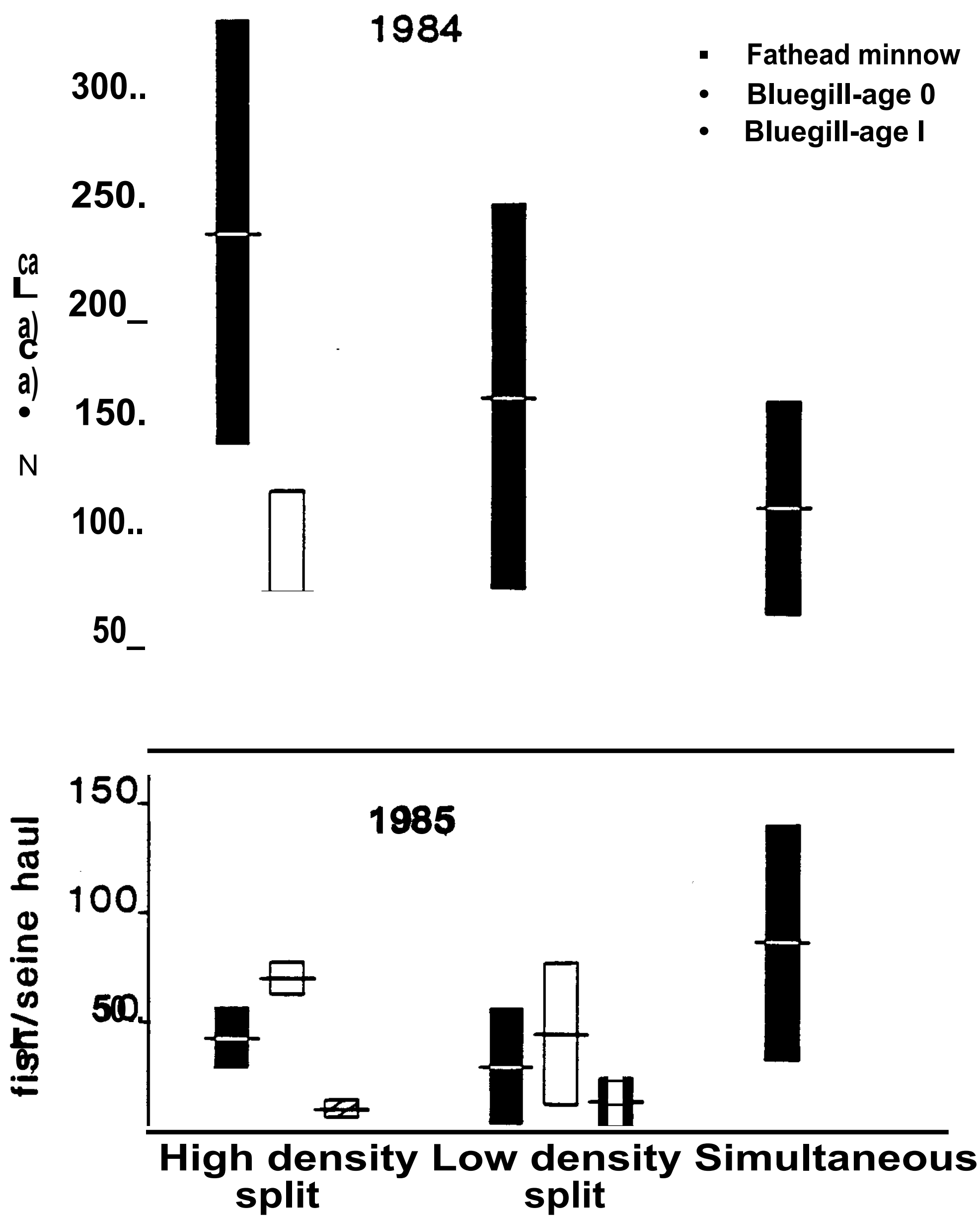


Figure 5.--Relative abundance of fathead minnows (*Pinephales promelas*) and age-0 and I bluegills (*Lepomis macrochirus*) as fish/seine haul in ten South Dakota ponds in 1984 and nine ponds in 1985 by treatment; mean (horizontal line) and one standard error on either side of the mean (rectangle).

Relative abundance of age-0 bluegills was similar in each split-stocking treatment from 1984 to 1985. Age-0 bluegills from the high-density, split-stocking treatment numbered 73 fish in 1984 and 70 fish **in 1985**. Age-0 bluegills in the low-density, split-stocking treatment numbered 47 fish in 1984 and 45 fish in 1985. Means were not significantly (P>.05) different by treatment or session (Appendix 13). Numbers of age-I bluegills in 1985 were similar in each split-stocking treatment, averaging 10 fish in the high density and 14 fish in the low density. The abundance of age-I bluegills declined from 15 to **9** fish in combined split-stocking treatment ponds from June to September 1985, but there was no significant (P).05) difference between sampling sessions (Appendix 14).

Prey Accessibility

Initially-stocked bluegills were never accessible to largemouth bass predation in split-stocking treatments but were always vulnerable in the simultaneous-stocking treatment (Fig. 6). Age-0 and I bluegills spawned in each split-stocking treatment were accessible to largemouth bass predation until study completion in September, 1985. Based on accessibility of age-0 and I bluegills and fathead minnows, a regression of total prey abundance as the independent variable and largemouth bass length at age-I+ as the dependent variable was calculated (Fig. 7). Although there appeared to be an association between largemouth bass growth and prey density, the correlation was not significant (P).05; coefficient of determination, r^2 = 0.34).

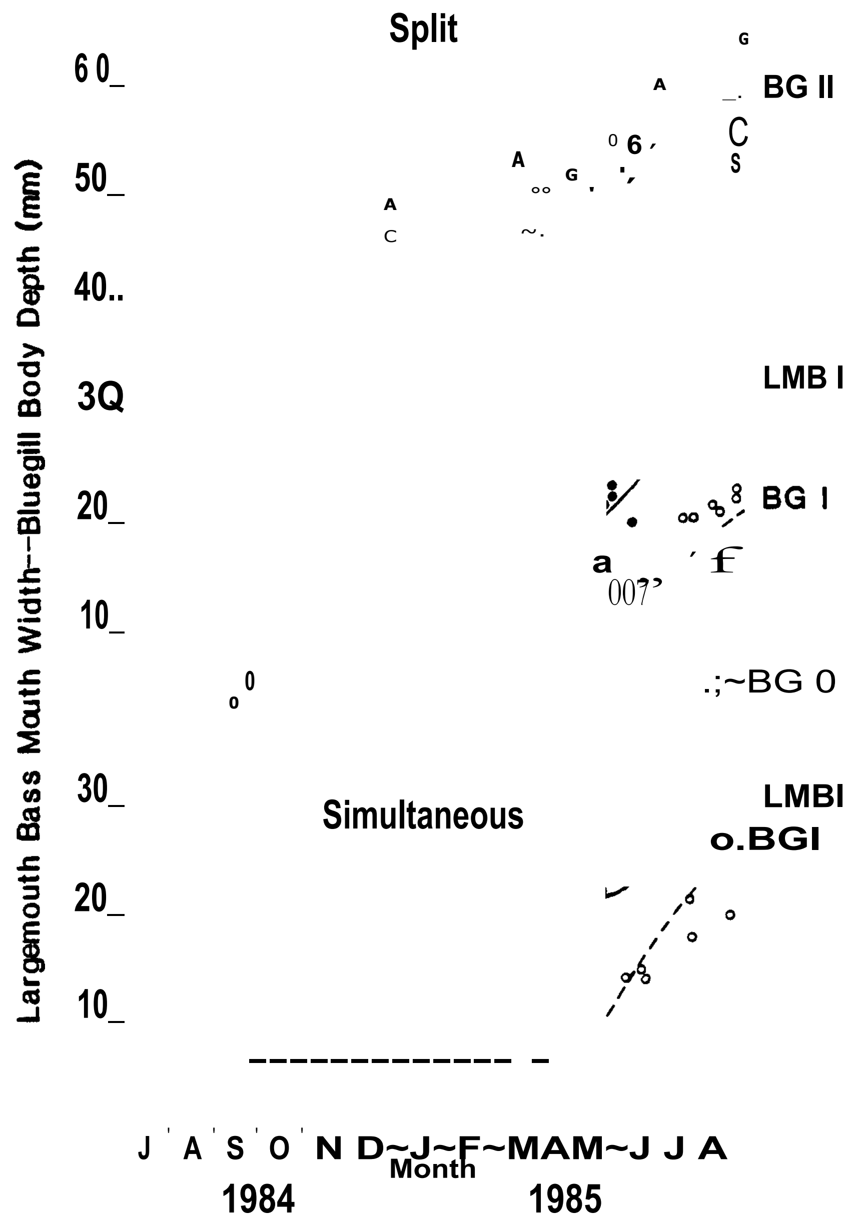


Figure 6.--A comparison of bluegill (*Lepomis macrochirus*) accessibility to largemouth bass (*Micropterus salmoides*) predation in split and simultaneous-stocking treatments. Throat width of age-0 and I largemouth bass and body depth of age-0, I, and II bluegills was calculated from mean length at capture or length at annulus, 1984 and 1985. All curves were fitted by inspection.

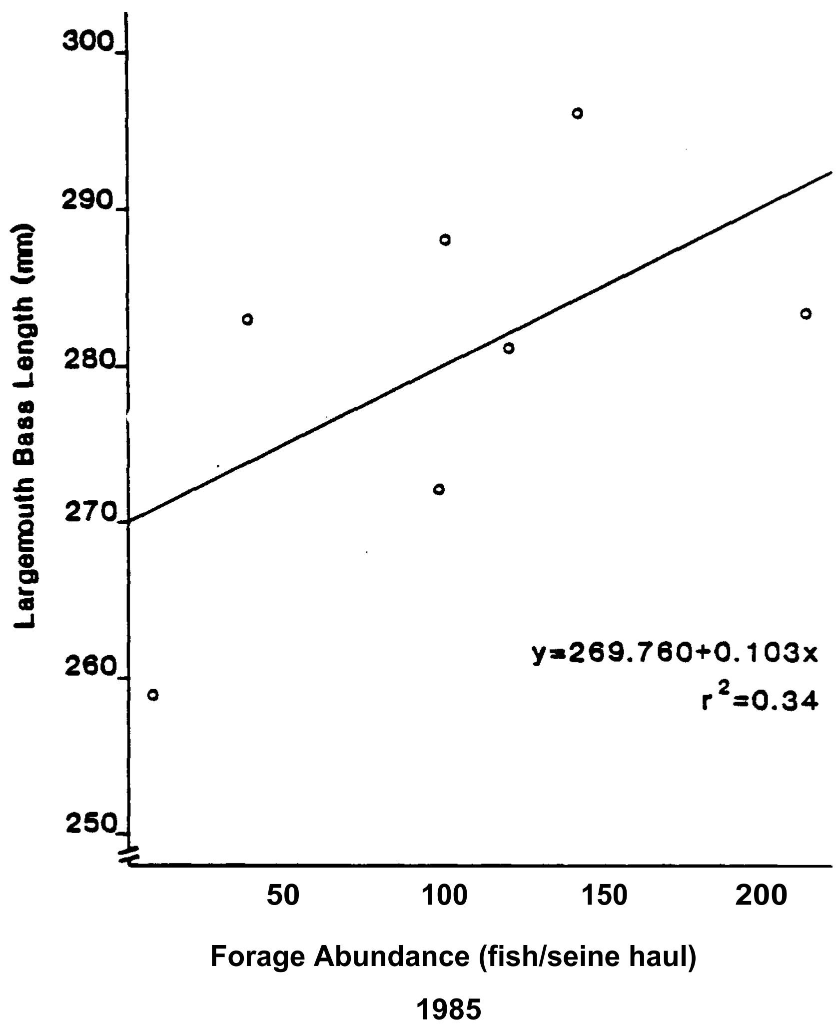


Figure 7.--Regression of age-I+ largemouth bass (*Micropterus salmoides*) length with total abundance of fathead minnows (*Pimephales promelas*) and age-0 and I bluegills (*Lepomis macrochirus*) as fish/seine haul in seven South Dakota ponds in 1985.

Discussion

Population Structure

The structure of a largemouth bass-bluegill population can be defined by three rate functions: growth, mortality, and reproduction (Reynolds and Babb 1978). Stone and Modde (1982) reported that largemouth bass growth decreased as latitude increased in South Dakota. Modde and Scalet (1985) further expanded the relationship of reduced largemouth bass growth relative to bluegill growth with latitude in the United States. Greater initial growth may explain why largemouth bass spawn at age I+ in Missouri (Novinger 1980) and Iowa (Hill 1980), but not in South Dakota. Simultaneously-stocked largemouth bass in southern South Dakota ponds in 1979 had greater second-year growth, 300 mm (Stone and Modde 1982), than those stocked by the split method in this study. In the present study, no significant ($P<.05$) differences were observed between largemouth bass growth in split and simultaneous stocking treatments; however, first-year growth among treatments was similar, whereas second-year growth was greater in split-stocking treatments.

Poor first-year survival of largemouth bass (24.5%), half that reported in previous stocking studies in South Dakota, Iowa, and Missouri, may have been related to stocking size. Largemouth bass were stocked at 24.7 mm in this study, 36.7 mm in a previous South Dakota study (Stone and Modde 1982), 40.0 mm in Iowa (Hill 1980), and 48.3 mm in Missouri (Novinger 1980). Gutreuter and Anderson (1985) found that greater percentages of larger largemouth bass in a spawned cohort survived to stock size and the same may be true of a stocked cohort.

Because of the tendency toward reduced growth of largemouth bass relative to bluegills in northern latitudes, it is necessary to seek means of increasing growth of initially-stocked largemouth bass. One means of increasing growth is by maximizing prey abundance. Greater abundance of prey per predator (Hackney 1979), due to decreased intraspecific competition, may be achieved by reducing stocking densities. Hill (1980) and Novinger (1980) reported increased growth and successful age-I+ largemouth bass spawning at reduced densities of 173 and 124 fish/hectare. Initial growth of largemouth bass was greatest in the reduced-density treatment, although this difference was not significant (P).05). Largemouth bass densities of 60 and 51/hectare in high and low-density, split-stocking treatments, respectively, indicated reduced density differences between the two split-stocking treatments after one year, due to greater mortality in the high-density treatment. However, relative densities of 8 and 6 largemouth bass/electrofishing hour for high and low-density split treatments, respectively, indicated initial stocking ratios were maintained.

Foraging Efficiency

Initial largemouth bass growth may also be increased by maximizing foraging efficiency. Foraging is influenced by three characteristics of a prey population: behavior, body size, and abundance (Keast 1985). When largemouth bass were initially stocked in July, 1984, the split-stocking treatment ponds contained fathead minnows and age-0 bluegills, while the simultaneous-stocking treatment ponds contained only fathead minnows. Although both bluegills and fathead minnows were accessible, the soft-rayed, rounded-fusiform body of fathead minnows may have been handled more easily by largemouth bass than the spiny-rayed, gibbose form of bluegills (Keast and Webb 1966, Holden 1983, Savino et al. 1985). Fathead minnows were utilized as temporary forage for largemouth bass fry stocked in small Texas impoundments (Noble 1981). Snow (1961) reported that largemouth bass fingerlings grew larger on and selected for fathead minnows over bluegill fry. After modelling expected growth based on foraging efficiency, Savino et al. (1985) predicted that largemouth bass derive greater growth rates foraging on fathead minnows than on bluegills. Stone and Modde (1982) reported significantly (P(.05) greater growth of age-0 largemouth bass in South Dakota ponds stocked with fathead minnows. Relative abundance of fathead minnows in 1985, 54 fish/seine haul, was less than one third that in 1984, 176 fish/seine haul, suggesting predation by initially-stocked largemouth bass. Morris (1985) reported that fathead minnow populations in South Dakota ponds were virtually eliminated by largemouth bass in three years.

Keast and Eadie (1985) observed that age-I+ largemouth bass (approximately 50 mm at annulus I) preferred bluegills to fathead minnows. In 1985, both age-0 and I bluegills were present in the split-stocking treatments, while prey in the simultaneous-stocking treatment consisted of initially-stocked, age-I bluegills and fathead minnows. In this respect, forage was probably not limiting during the first year of largemouth bass growth among treatments, when fathead minnows were abundant. However, in 1985 fathead minnows were less available to age-I+ largemouth bass.

Documentation of prey size preference by largemouth bass is conflicting. Ivlev (1961), Timmons and Pawaputanon (1980), and Holden (1983) reported that predators prefer prey of the largest accessible size, corresponding to age-I bluegills in 1985 in split-stocking treatments. However, Cochran and Adelman (1982) concluded that the optimal prey size for age-I and II (212-276 mm) largemouth bass, based on handling time and energy gain determined by Werner (1977),_ corresponded to smaller age-0 bluegills. A predator can concentrate its attack on one prey type only after prey density has reached a threshold level (Curio 1976). Relative abundance of age-I bluegills in 1985 declined from 15 to 7 and 15 to 11 fish/seine haul for high and low-density, split-stocking treatments, respectively, although means were not significantly (P).05) different by sampling session. Relative densities of only 0.1 age-I bluegill/seine haul in the simultaneous-stocking treatment indicated a lack of larger prey. Relative abundance of age-0 bluegills in 1984 and 1985, 41 and 43 fish/seine haul, respectively, in the split-stocking treatments, indicated consistant reproduction. Although the minimum bluegill density providing optimum foraging conditions was not known, densities of age-0 and I bluegills were substantially greater in split than simultaneous-stocking treatments.

Murdoch et al. (1975) reported that fish switch feeding preference in response to changes in prey density and species. The effects of maximizing prey abundance may be most apparent the second year after largemouth bass stocking, when switching to total piscivory occurs (Keast and Eadie 1985). Prey were more abundant in the split-stocking treatment ponds because two spawned age-classes of bluegills were present. Although Ivlev (1961) reported no linear dependence between prey density and consumption, decreased predator search time suggests greater foraging efficiency (Schoener 1971). Data from only seven ponds may have been insufficient to establish a significant (P.05) linear relationship between second-year largemouth bass growth and combined prey abundance. However, the regression line suggested that as prey density increased, largemouth bass growth increased.

Predator-Prey Balance

A second requirement of a successful largemouth bass-bluegill stocking program is a balanced predator-prey relationship. Bluegills mature earlier than largemouth bass, resulting in relatively greater recruitment of the former. This problem is aggravated at northern latitudes by decreased maximum size of largemouth bass (Modde and Scalet 1985). Consequently, each bluegill year-class is accessible to largemouth bass predation for a shorter period. An appropriate management strategy would be to maximize the interval of time that each bluegill year-class is accessible to predation.

Split stocking provided age-0 bluegill prey for age-0 largemouth bass. In contrast, simultaneous stocking usually provides age-0 bluegill prey for age-I largemouth bass (Shelley and Modde 1982). Even if age-0 bluegills were supplemental to fathead minnows as prey, age-0 largemouth bass may provide more effective predation (Davies et al. 1982) than age-I largemouth bass (>176 mm), capable of ingesting much larger prey. Although age-0 and I bluegills were abundant in split-stocking treatments, due to two year-classes spawned in the pond, both classes remained accessible to largemouth bass predation. Therefore, balance may be better achieved, not by reducing the absolute abundance of prey, but rather by synchronization of predator and prey reproduction.

When age-I+ largemouth bass do not reproduce, the second year-class of bluegills spawned in the pond are free of age-0 largemouth bass predation. This deficiency could be addressed by a supplemental stocking of fingerling largemouth bass during the second year. Noble (1981) recommended supplemental stocking while Emig (1966) questioned its effectiveness. Davies et al. (1979) reported that supplemental fingerling stocking improved the population structure of largemouth bass in Alabama lakes. Young (1987) found that survival of supplementally-stocked largemouth bass appeared to be inversely related to adult largemouth bass density.

Recruitment of bluegills, measured by Young-Adult Ratios, was 28.1 in 1984 and 38.2 in 1985. A higher bluegill YAR in 1985 may have been a consequence of the missing age-0 largemouth bass year-class. However, a high YAR indicated high densities of small bluegills required for good largemouth bass growth (Novinger and Legler 1978).

Young-Adult Ratios varied considerably among split-stocking treatments by year. Either higher bluegill survival in the low-density, split-stocking treatment (34.9%) in 1984 resulted in increased spawning or largemouth bass predation was greater in the high-density, split-stocking treatment. Abundant age-I bluegills in the low-density, split-stocking treatment (90 fish/shocking hour), may have suppressed reproduction of adult bluegills in 1985. A relative abundance of 40 age-I bluegills/shocking hour suppressed adult bluegill reproduction in Missouri ponds (Novinger 1980).

The split-stocking method did not result in significantly ($P<.05$) greater largemouth bass growth rates than simultaneous-stocking treatments in this or previous studies in South Dakota. However, greater prey density in split-stocking treatments may influence largemouth bass growth rates as the pond fishery reaches carrying capacity. Differential growth between stocking chronologies was suggested by greater largemouth bass mean length the second year after stocking. In addition, synchronization of predator-prey size achieved initially by the split-stocking method and extended a second year by supplemental stocking of largemouth bass, may control bluegill recruitment until largemouth bass reproduction produces successive year-classes.

Management Recommendations

1. Continue the largemouth bass stocking density of 247/hectare (100/acre) because survival was extremely variable. Reduced densities of largemouth bass, in ponds with low survival rates, may

not be sufficient to sustain angling and reproduction for five years, when recruitment to harvestable size occurs. There was no largemouth bass reproductive success in ponds stocked at the lower density of 173/hectare (70/acre). Supplemental stocking of largemouth bass at 371/hectare (150/acre) may replace the missing year-class caused by failure of age-I largemouth bass to spawn.

2. Establish a minimum stocking size for largemouth bass and bluegills (Graham 1973). Stone and Modde (1982) reported 49% survival of largemouth bass at a stocking size of 36.7 mm. A larger bluegill stocking size of 50 mm (2 in) did not increase survival in this study but did result in reproduction at age-I.
3. Stock fathead minnows prior to largemouth bass introduction. Largemouth bass stocked with fathead minnows in South Dakota ponds had better first-year growth (Stone and Modde 1982) than any other forage combination.
4. If vegetation is less than 30% of the pond volume (Modde 1986), initiate the split-stocking chronology. Either stock bluegill fingerlings the fall preceeding largemouth bass introduction, or adults in the spring. Either option should insure bluegill reproduction before largemouth bass introduction.

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Appendix 1.--Physical and chemical variables measured in 14 South Dakota ponds June, July, and August, 1984.

				High-density, split-stocking								
Schlobohm	.45	4.1	650	0	340	40	9.0	30	145	2.4	0.23	130
Brookings			780	0.3	320	35	8.3	0	170	0	0.14	150
			630	0	340	44	7.9	0	170	0	0	120
Perry #1	.59	4.0	1050	0.4	240	8	8.3	0	75	0.8	0.33	300
Lyman			1250	0.5	260	15	8.9	0	70	0.7	0.10	460
			1020	0.9	240	22	8.2	0	80	0.4	0.19	375
Beauchamp	.95	6.7	610	0	160	4	8.2	0	190	0.4	0.24	24
Gregory			450	0	120	10	8.8	20	110	1.6	0.25	29
			620	0.4	135	8	8.4	0	180	1.0	0.10	26
Joyce	.50	4.6	1350	0.5	390	30	8.4	0	100	0	0.14	280
Gregory			1160	0.7	440	30	8.5	0	110	0	0.13	345
			1280	1.1	450	30	8.4	0	140	0.3	0.09	340
Nix	.58	3.8	4450	2.2	1800	15	8.0	0	120	0.6	0.05	1875
Jones			4720	2.5	1950	7	8.4	0	100	0.4	0.49	3000
			4400	4.8	2150	18	7.8	0	115	0.7	0.22	2450
Mean	.61	4.6	1628	1.0	622	21	8.3	3	125	0.6	0.18	660
				Low-density, split-stocking								
Halstead	.93	4.3			155	110	7.1	0	150	0	0	17
Brookings					235	20	8.3	0	210	0.8	0.65	22
			530	0.3	260	32	7.9	0	250	0	0.06	18
Bronemann	.75	4.4	640	0	205	28	9.2	10	40	0	0.75	160
Hughes			770	0.2	220	34	8.7	20	30	0.6	0	220
			750	0.5	280.	32	8.4	0	75	0.1	0.08	240

Appendix 1.--(continued)

					Total hardness (mg/liter)			(mg/liter)	(mg/liter)			
Baker Jones	.72	4.9	3380	1.6	1350	8	8.8	20	65	0.7	0.19	1600
			3540	2.0	1600	15	8.2	0	70	1.9	0.61	1875
			3500	3.8	1400	14	8.0	0	98	0.8	0.07	1850
Perry #2 Lyman	.20	3.0	3200	2.0	850	4	9.7	40	20	0.5	0.23	1450
			3290	1.5	900	12	9.6	40	0	0.6	0.42	1700
			3000	3.0	1100	21	9.1	30	25	0.7	0.11	1425
Mean	.65	4.2	2260	1.5	713	28	8.6	13	86	0.6	0.26	881
					Simultaneous-stocking							
Wolfe Lyman	.56	3.7	350	0	110	47	8.4	0	150	0	0.08	13
			350	0	110	69	8.3	0	140	0	0.04	13
			310	0	120	53	8.5	0	155	0	0.54	18
Jandreau #1 Lyman	.58	4.9	850	0.2	230	10	9.5	26	34	0.5	0.18	270
			990	0.2	240	40	8.0	0	70	0	0.35	340
			1000	0.9	320	40	7.7	0	70	0	0.16	325
Jandreau #2 Lyman	.46	5.8	550	0	130	15	9.0	30	50	0.5	0.24	95
			430	0	120	18	8.7	0	70	0.8	0.10	93
			450	0.1	130	9	8.3	0	80	0.4	0.28	110
Brakke Lyman	.98	5.3	1250	0.3	350	10	8.5	0	50	0.4	0.26	530
			1450	0.6	370	48	8.9	0	50	0	0.43	485
			940	0.8	430	32	7.3	0	60	0	0.15	580
Moore Lyman	.89	5.2	600	0	120	30	9.3	40	75	0	0.16	145
			590	0	100	18	9.0	20	80	0.8	0.02	120
			620	0.3	115	20	8.4	0	125	0.4	0.24	120
Mean	.69	5.0	715	0.2	200	31	8.5	8	84	0.3	0.22	217

Appendix 2.--Nested factorial analysis of variance with treatment and session as main factors with ponds nested within treatments of 12 physical and water-quality variables in 14 South Dakota ponds measured June, July, and August 1984; area and depth measured once.

Source of variation	df	Mean square	F
Area			
Treatment	2	0.024	0.13 NS
Pond (Treatment)	11	0.179	
Depth			
Treatment	2	2.300	0.84 NS
Pond (Treatment)	11	2.752	
Conductivity			
Treatment	2	5,023,185.500	1.10 NS
Session	2	32,252.323	2.20 NS
Treatment X Session	4	2,135.556	0.15 [a] NS
Pond (Treatment)	11	4,573,006.200	
Session X Pond (Treatment)	20	14,656.222	
Salinity			
Treatment	2	2.703	0.92 [b] NS
Session	2	2.299	11.50 **
Treatment X Session	4	0.279	1.40 NS
Pond (Treatment)	11	2.945	
Session X Pond (Treatment)	20	0.200	
Total Hardness			
Treatment	2	1,060,585.300	1.13 N
Session	2	20,813.109	4.53 *
Treatment X Session	4	3,290.982	0.72 NS
Pond (Treatment)	11	937,336.910	
Session X Pond (Treatment)	22	4,594.659	
Turbidity			
Treatment	2	352.721	0.45 NS
Session	2	1.132	0.00 NS
Treatment X Session	4	342.582	1.37 NS
Pond (Treatment)	11	788.018	
Session X Pond (Treatment)	22	250.959	
PN			
Treatment	2	0.166	0.32 NS
Session	2	1.096	6.02 **
Treatment X Session	4	0.185	1.02 NS
Pond (Treatment)	11	0.517	
Session X Pond (Treatment)	22	0.182	

Appendix 2.--(continued)

Source of variation	df	Mean square	F
Carbonate Alkalinity			
Treatment	2	333.343	1.07 NS
Session	2	478.815	5.50 *
Treatment X Session	4	85.986	0.99 NS
Pond (Treatment)	11	311.661	
Session X Pond (Treatment)	22	87.024	
Bicarbonate Alkalinity			
Treatment	2	7,772.611	0.90 NS
Session	2	3,127.424	8.55 **
Treatment X Session	4	405.361	1.11 NS
Pond (Treatment)	11	8,660.653	
Session X Pond (Treatment)	22	365.880	
Nitrate			
Treatment	2	0.568	1.76 NS
Session	2	0.243	0.98 NS
Treatment X Session	4	0.271	1.09 NS
Pond (Treatment)	11	0.322	
Session X Pond (Treatment)	22	0.249	
Phosphate			
Treatment	2	0.0236	3.47 NS
Session	2	0.0490	1.14 NS
Treatment X Session	4	0.0540	1.26 NS
Pond (Treatment)	11	0.0068	
Session X Pond (Treatment)	22	0.0429	
Sulfate			
Treatment	2	1,576,368.400	0.87 NS
Session	2	68,868.985	2.92 NS
Treatment X Session	4	23,900.350	1.01 NS
Pond (Treatment)	11	1,808,022.500	
Session X Pond (Treatment)	22	23,575.709	

[b] No appropriate F-test.
Significantly different at the P<.01 level.
[c] Significantly different at the P<.05 level.

Appendix 3.--First-year survival rates and population estimates of largemouth bass (*Micropterus* salmoides) by stocking treatment in 13 South Dakota ponds surveyed in 985.

Pond owners	Number stocked	Total number marked	Total catch during recapture period	Number recaptured	Population estimate	95% confidence limits		Percent survival
			High-density, split-stocking					
Schlobohm	113	25	25	19	34	+7	(27-41)	30.1
Perry #1	147	0	0	0	0	0		0.0
Beauchamp	238	45	27	7	161	+89	(72-250)	67.6
Joyce	126	5	10	2	22	+18	(4-40)	17.5
Nix	146	2	1	0	6	+6	(0-12)	4.1
Mean								23.9
			Low-density, split-stocking					
Bronemann	131	1	0	0	2	0		1.5
Baker	127	11	8	4	22	+12	(10-34)	17.3
Perry #2	34	21	13	12	24	+3	(21-27)	70.6
Mean								29.8
			Simultaneous-stocking					
Wolfe	97	0	0	0	0	0		0.0
Jandreau #1	102	0	0	0	0	0		0.0
Jandreau #2	80	1	8	0	18	+24	(0-42)	22.5
Brakke	171	3	1	1	4	0		2.3
Moore	155	45	22	7	132	+70	(62-202)	85.2
Mean								22.0

Appendix 4.--Second-year survival rates and population estimates of bluegills (*Lepomis macrochirus*) by stocking treatment in eight South Dakota ponds surveyed in 1985.

Pond owners	Number stocked	Total number marked	Total catch during recapture period	Number recaptured	Population estimate	95% confidence limits		Percent survival
			High-density, split-stocking					
Schlobohm	600	16	11	5	34	+18	(16-52)	5.7
Perry #1	800	1	0	0	2	0		0.3
Beauchamp	1700	198	18	3	945	+736	(209-1681)	55.6
Joyce	875	11	1	0	24	+24	(0-48)	2.7
Nix	1400	34	7	1	140	+137	(3-277)	10.0
Mean								14.9
			Low-density, split-stocking					
Bronemann	875	1	0	0	2	0		0.2
Baker	1500	41	15	0	672	+902	(0-1574)	44.8
Perry #2	500	260	7	6	298	+73	(225-371)	59.6
Mean								34.9

Appendix 5.--Catch/unit effort (C/f) as fish shocked/hour for age-0 and I largemouth bass (*Micropterus salmoides*) and age-0, I, and II bluegills (*Lepomis macrochirus*) in 13 South Dakota ponds, fall 1984 and 1985.

	1984			1985			
	Largemouth bass		Bluegill	Largemouth bass	Bluegill		
Pond owners	Age-class						
	0	I	0	I	II	I	0
				High-density, split-stocking			
Schlobohm	16	0	0	20	0	49	424
Perry #1	0	0	8	0	0	87	0
Beauchamp	5	28	112	25	17	311	327
Joyce	19	16	8	12	1	42	132
Nix	1	4	25	0	10	89	224
Mean	8	10	31	11	6	116	221
				Low-density, split-stocking			
Bronemann	15	1	1	0	0	10	0
Baker	3	5	89	7	13	92[a]	
Perry #2	0	1	69	16	8	170	6
Mean	6	2	53	8	7	90	3
				Simultaneous-stocking			
Wolfe				0		0	
Jandreau #1				0		4	
Jandreau #2				10		9	
Brakke				0		4	
Moore				16		29	
Mean				5		9	

[a] Age-0 and I bluegills were combined.

Appendix 6.--Mean back-calculated total length of age-I largemouth bass (*Micropterus* salmoides) and length, weight, and Relative Weight (VC) of age-I+ largemouth bass in the fall of 1985 by stocking strategy in nine South Dakota ponds.

Pond owners	Age I N	Age I length (mm)	Age I+ N	Age I+ length (mm)	Age I+ Weight (g)	Relative Weight
			High-density, split-stocking			
Schlobohm	32	165	14	272	346	121
Beauchamp	30	180	27	296	429	115
Joyce	12	166	9	281	404	123
Nix	4	149				
Mean		165		283	393	120
SE		6.4		6.8		
			Low-density, split-stocking			
Baker	12	184	8	288	376	110
Perry #2	21	183	13	283	351	108
Mean		183		285	364	109
SE		0.5		2.1		
			Simultaneous-stocking			
Jandreau #2	9	172	8	283	393	121
Brakke	4	185				
Moore	38	172	22	259	276	113
Mean		176		271	335	117
SE		4.2		12.0		

Appendix 7.--Nested analysis of variance using treatment as the main factor with ponds nested within treatments of largemouth bass (*Micropterus* salmoides) first and second-year growth and Relative Weight (W_r) in nine South Dakota ponds in 1984 and 1985.

Source of variation	df	Variance component	Mean square	F
First-year growth				
Treatment	2	7.28	2092.962	1.21 NS[a]
Pond (Treatment)	6	65.29	1084.515	8.09 **[a]
Residual	153	134.11	134.106	
Second-year growth				
Treatment	2	53.18	4359.056	1.62 NS
Pond (Treatment)	4	153.68	2221.330	9.18 **
Residual	94	241.95	241.952	
Relative Weight				
Treatment	2	8.95	613.088	1.85 NS
Pond (Treatment)	4	16.19	282.586	3.82 **
Residual	94	74.05	74.0511	

[a] Significantly different at the P<.01 level.

Expected Mean Squares; Treatment fixed, Pond (Treatment) random.

First-year growth

Treatment $\sigma^2 + 24.34\,\sigma^2_{P(T)} + 50.830\,\sigma^2_T$

Pond (Treatment) $\sigma^2 + 14.56\,\sigma^2_{P(T)}$

Residual σ^2

Second-year growth and Relative Weight

Treatment $\sigma^2 + 15.89\,\sigma^2_{P(T)} + 31.49\,\sigma^2_T$

Pond (Treatment) $\sigma^2 + 12.88\,\sigma^2_{P(T)}$

Residual σ^2

Appendix 8.--Mean back-calculated total length of age-I and II bluegills (*Lepomis macrochirus*) and length, weight, and Relative Weight (W_r) of age-II+ bluegills in the fall of 1985 by stocking strategy to nine South Dakota ponds.

Pond owners	N	Age I length (mm)	Age II length (mm)	Age II+ N	Age II+ length (mm)	Age II+ Weight (g)	Age II+ Relative Weight
			High-density, split-stocking				
Schlobohm	23	48	121				
Beauchamp	30	56	116	18	152	68	93
Joyce	12	46	128	1	171	127	118
Nix	34	51	116	7	146	64	99
Mean		50	120		156	86	103
SE		2.2	3.0		7.5		
			Low-density, split-stocking				
Baker	40	52	111	15	150	69	98
Perry #2	30	53	136	7	145	58	93
Mean		52	123		148	64	96
SE		0.5	12.5		2.4		
			Simultaneous-stocking				
Jandreau #2	6	32	66				
Brakke	4	32	82				
Moore	39	32	82				
Mean		32 [a]	77				
SE		0	5.2				

[a] Mean stocking length.

Appendix 9.--Nested analysis of variance using treatment as a main factor with ponds nested within treatments of bluegill *(Lepomis macrochirus)* first, second, and third-year growth and Relative Weight (W_r) in six South Dakota ponds in 1985.

Source of variation	df	Variance component	Mean square	F
First-year growth				
Treatment	1	-4.11	46.541	0.12 NS[a]
Pond (Treatment)	4	10.89	319.124	10.16 **[a]
Residual	163	31.40	31.405	
Second-year growth				
Treatment	1	-41.85	328.596	0.09 NS
Pond (Treatment)	4	112.07	3098.949	22.63 **
Residual	163	136.91	136.907	
Third-year growth				
Treatment	1	-13.36	91.847	0.22 NS
Pond (Treatment)	3	26.91	241.082	4.70 **
Residual	43	51.28	51.275	
Relative Weight				
Treatment	1	-16.70	5.953	0.01 NS
Pond (Treatment)	3	23.43	256.579	2.81 NS
Residual	43	91.30	91.303	

[a] Significantly different at the P'.01 level.

Expected Mean Squares: Treatment fixed, Pond (Treatment) random.

First and second-year growth

Treatment $a^2 + 32.34a^2_{P(T)} + 23.83a^2_T$

Pond (Treatment) $a^2 + 26.43\,a^2_{P(T)}$

Residual a^2

Third-year growth and Relative Weight

Treatment $a^2 + 13.34\,a^2_{P(T)} + 23.83\,a^2_T$

Pond (Treatment) $a^2 + 7.05a^2_{P(T)}$

Residual a^2

Appendix 10.--Young-Adult Ratios (YAR) of bluegills (*Lepomis macrochirus*) in eight South Dakota ponds, fall 1984 and 1985.

Pond owners	1984 YAR age 0	1985 YAR age 0	1985 YAR age 0 and I
	High-density, split-stocking		
Beauchamp	4.1	19.7	38.4
Joyce	0.5	110.0	145.0
Nix	6.3	22.4	31.3
Mean	3.6	50.7	71.6
	Low-density, split-stocking		
Bronemann	1.0		
Baker	19.7	——[a]	6.9
Perry #2	137.0	0.7	21.0
Mean	52.6	0.7	14.0
Grand mean	28.1	38.2	

[a] Could not be calculated in 1985 because age-0 and I bluegill numbers were combined.

Appendix 11.--Nested factorial analysis of variance with treatment, session, and year as main factors with ponds nested within treatments of fathead minnow (*Pimephales promelas*) abundance in nine South Dakota ponds containing largemouth bass (*Micropterus salmoides*), 1984-1985.

Source of variation	df	Mean square	F
Treatment	2	5,488.411	0.06 NS
Session	1	19,166.014	1.42 NS
Treatment X Session	2	5,263.725	3.16 NS
Year	1	75,326.337	4.58 NS
Treatment X Year	2	27,768.528	1.69 NS
Session X Year	1	16,070.008	2.73 NS
Treatment X Session X Year	2	241.230	0.04 NS
Pond (Treatment)	7	41,658.707	2.53 NS
Session X Pond (Treatment)	7	3,283.816	0.56 [a] NS
Year X Pond (Treatment)	6	16,458.625	
Session X Year X Pond (Treatment)	6	5,890.831	

[a] No appropriate F-test.

Appendix 12.--Nestd factorial analysis of variance with treatment, session, and qualify' as main factors with ponds nested within treatment X qualify of fathead minnow (*Pimephales promelas*) abundance in 14 South Dakota ponds, 1984-1985.

Source of variation	df	Mean square	F
Treatment	2	3,278.592	0.22 NS
Session	2	920.741	13.37 NS
Treatment X Session	4	305.679	0.20 NS
Qualify	1	3.043	0.00 [b] NS
Treatment X Qualify	2	3,695.296	
Session X Qualify	2	68.852	0.06 NS
Treatment X Session X Qualify	4	1,515.306	1.32 NS
Ponds (Treatment X Qualify)	8	11,063.701	
Session X Pond (Treatment X Qualify)	15	1,145.655	

' Presence or absence of largemouth bass (*Micropterus salmoides*).
[b] No appropriate F-test.

Appendix 13.--Nested factorial analysis of variance with treatment, session, and year as main factors with ponds nested within treatments of age-0 bluegill (*Lepomis macrochirus*) abundance in nine South Dakota ponds containing largemouth bass (*Micropterus salmoides*), 1984-1985.

Source of variation	df	Mean square	F
Treatment	2	17,436.698	3.78 NS
Session	1	4,241.241	2.24 NS
Pond (Treatment)	7	4,616.761	2.44 N
Year X Pgnd (Treatment)	6	5,878.067	3.10 *
Residual	21	1,894.649	

[b] Significantly different at the P<.05 level.
Components with F<1.0 were pooled into a common error term.

Appendix 14.--Nested factorial analysis of variance with treatment and session as main factors with ponds nested within treatments of age-I bluegill (*Lepomis macrochirus*) abundance in nine South Dakota ponds containing largemouth bass (*Micropterus salmoides*) in 1985.

Source of variation	df	Mean square	F
Treatment	2	474.440	2.04 NS
Session	2	46.810	3.31 NS
Treatment X Session	4	16.462	1.17 NS[a]
Pond (Treatment)	6	232.133	16.43 **
Session X Pond (Treatment)	12	14.127	

[a] Significantly different at the P<.01 level.