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# Evaluation of Structure and Growth of Bluegills and Black Bullheads Stocked With Largemouth Bass in South Dakota Farm Ponds

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# EVALUATION OF STRUCTURE AND GROWTH OF BLUEGILLS AND BLACK BULLHEADS STOCKED WITH LARGEMOUTH BASS IN SOUTH DAKOTA FARM PONDS

BY

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EVALUATION OF STRUCTURE AND GROWTH OF
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IN SOUTH DAKOTA FARM PONDS

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.

Thesis Advisor

Wildlife and Fisheries
Sciences

EVALUATION OF STRUCTURE AND GROWTH OF

BLUEGILLS AND BLACK BULLHEADS STOCKED WITH LARGEMOUTH BASS

IN SOUTH DAKOTA PONDS


Abstract

CHARLES E. MORRIS

A two-year study estimated standing stock, growth, condition, survival rates, and population structure of bluegills (Lepomis macrochirus) and black bullheads (Ictalurus melas) stocked in South Dakota farm ponds with largemouth bass (Micropterus salmoides). Bluegills and black bullheads reproduced during the second growing season and by the end of the study three year-classes of fishes were present in most ponds. Mean back-calculated bluegill total lengths at annuli 1-3 were 58, 125, and 153 mm, respectively. Mean back-calculated black bullhead total lengths at annuli 1-3 were 82, 182, and 240 mm, respectively. A significant north vs south difference ($P \leq 0.05$) in third-year bullhead total lengths was detected. Bullheads in southern ponds averaged 262 mm; northern pond bullheads averaged 220 mm. No significant differences ($p \geq 0.05$) in total lengths were found for the 1980 and 1981 year-classes of bullheads in the same comparison. Bluegill standing stock estimates ranged from 22-64 kg/hectare (20-57 lbs/acre) and averaged 41 kg/hectare (37 lbs/acre). Standing stock estimates for black bullheads ranged from 145-398 kg/hectare (129-354 lbs/acre) and averaged 273 kg/hectare (243 lbs/acre). Bluegill and black bullhead survival for the first two years in eastern South Dakota ponds was 31.0% and 30.2%, respectively. Survival from 1980-1981 was

83.9% for bluegills and 69.1% for bullheads. Mean relative weight of bluegills (122) indicated above average condition for fish in South Dakota ponds. Black bullheads had a relative weight of 99. No significant geographical differences ($P \geq 0.05$) were detected in bluegill or black bullhead relative weights. Proportional Stock Density (PSD) values for bluegill ranged from 36-79%. Bluegill Young-Adult Ratio (YAR) values for the two ponds were 2.2 and 2.0. Black bullhead PSD values ranged from 9-80%. YAR values of black bullheads ranged from 0.3-290.0. Both Bluegill and black bullhead PSD values indicated a large number of quality size fish with few stock size fish. PSD values of 20-60% for bluegill are considered optimal when management of ponds is for both largemouth bass and bluegills. Bluegill YAR values were within the optimal range (1-10) while bullhead YAR values were extremely high. Discriminate analysis was used for predicting physical and chemical parameters influencing survival of individual fish populations. Five parameters were selected (area, maximum depth, conductivity, turbidity, and carbonates) and ponds were analyzed by individual species and all species combined. When all species were analyzed, pond depth was the most important parameter ($P \leq 0.05$).

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# INTRODUCTION

Within South Dakota approximately 100,000 farm and ranch ponds have been constructed with the assistance of the Soil Conservation Service (personal communication Soil Conservation Service). To maximize the utilization of this pond fishery, initial stocking strategies are critical in providing a desirable pond fishery in the shortest time possible based on physical and fiscal limitations (Dillard and Novinger 1975). However, the optimal combination of fish species to stock in warmwater ponds varies geographically due to slower annual growth rates in northern states and differences in management strategies and capabilities (Modde 1980).

The largemouth bass (*Micropterus salmoides*), has been the principal predator and premium game fish stocked in North American warmwater ponds. The largemouth bass can be stocked alone or in combination with a forage species. Bennett (1970) suggested a largemouth bass only stocking in Illinois ponds. This stocking produced a good bass fishery without the complication of controlling forage species. Bennett believed that when bass were stocked alone, their own young, crayfish, and large aquatic insects provide sufficient food for bass growth and reproduction. This stocking must include several year-classes to prevent the development of a dominant year-class that might later become stunted.

Swingle (1949) considered the "bass alone stocking method" as an inefficient use of the food available for fish production in ponds.

This stocking produced only about one-third the harvestable biomass that the largemouth bass-bluegill (Lepomis macrochirus) combination could produce. Forage fish stocked with bass could increase the annual crop of fish and provide another fish for the angler. The most widely used stocking combination in small private warmwater ponds is the largemouth bass-bluegill combination (Modde 1980). This combination has often resulted in overpopulation and stunted bluegills in Indiana (Krumholz 1950), Michigan (Ball and Tait 1952), Illinois (Bennett 1970), and New York (Regier 1963). Bennett (1952) believed that bluegills became overpopulated because bass did not become sexually mature in Illinois until two-years of age, while bluegills matured and spawned when one-year old. A shorter growing season in northern states and variations in survival and spawning success have been suggested as contributors to this problem. Bluegill appear to have low vulnerability to largemouth bass (Lewis and Helms 1964), so if alternative prey is available, bass may not control bluegill populations. Regier (1963) believed bluegills should not be stocked unless the pond owner has a sincere interest in fishing for bluegills as well as bass.

The black bullhead (Ictalurus melas) has been stocked in many ponds because of its ability to reproduce in ponds and supply a fish of sporting quality (Rickett 1976). The largemouth bass-black bullhead combination has been questioned in Illinois (Lopinot 1972) and Oklahoma (Houser and Collins 1962) because of the tendency for bullheads to overpopulate. However, Moorman (1957) stated that bullheads become overcrowded and stunted only when bass predation was insufficient to control excess recruitment.

Ball (1952) stated that when sport fishing for large fish was of major interest to the landowner, the largemouth bass-golden shiner (Notemigonus crysoleucas) combination appeared to be superior. Golden shiners have a high reproductive capacity and are capable of growing too large for bass to consume. This combination resulted in increased bass survival in Ontario ponds (Johnson and McCrimmon 1967) and increased growth and standing stock of largemouth bass in New York ponds (Regier 1963). Pond fish stocking experiments in Alabama (Swingle 1946) and New York (Forney 1957) resulted in the golden shiner failing to survive in ponds four to five years after stocking.

The use of the fathead minnow (Pimephales promelas) as a companion fish for largemouth bass has been reported by Ball and Ford (1953) and Lewis and Heidinger (1978). These authors stated that fathead minnows provided excellent forage in the initial stocking of bass, but were soon eliminated by bass predation.

The objectives of this study were to determine the structure and growth of bluegill and black bullhead populations stocked in combination with largemouth bass. An additional objective was to determine which of four forage species (bluegill, black bullhead, golden shiner, and fathead minnow) stocked would maintain adequate prey stocks within size ranges most vulnerable to the largemouth bass. This study concludes the last two years of a four year study initiated in 1979.

# METHODS AND PROCEDURES

## Study Area

Study ponds utilized in this investigation were located throughout the state of South Dakota (Shelley 1981). To allow for physiographical and climatological gradients the state was divided into four quadrants, divided east-west by the Missouri River and north-south by latitude 44° 21' (Fig. 1).

The study area has a continental-type climate characterized by cold winters and hot summers. Temperatures of 33 C (100 F), or higher can be recorded during the summer while below zero temperatures occur frequently during the winter. Ice and snow cover usually lasts from November through March with ice reaching thicknesses of up to 100 cm and snow cover of 30-40 cm or more. Annual precipitation decreases from about 64 cm in the southeast to less than 23 cm in the northwest (Spuhler et al. 1971).

The study area is characterized by rolling grasslands intermixed with agricultural crop land. Eastern and western South Dakota differences in soils are caused by climate, vegetation, and geological history. Predominant vegetation types vary from tall grass prairie in the east to mid and short grass prairie in the west. A description of soil types is presented in Westin and Malo (1978).

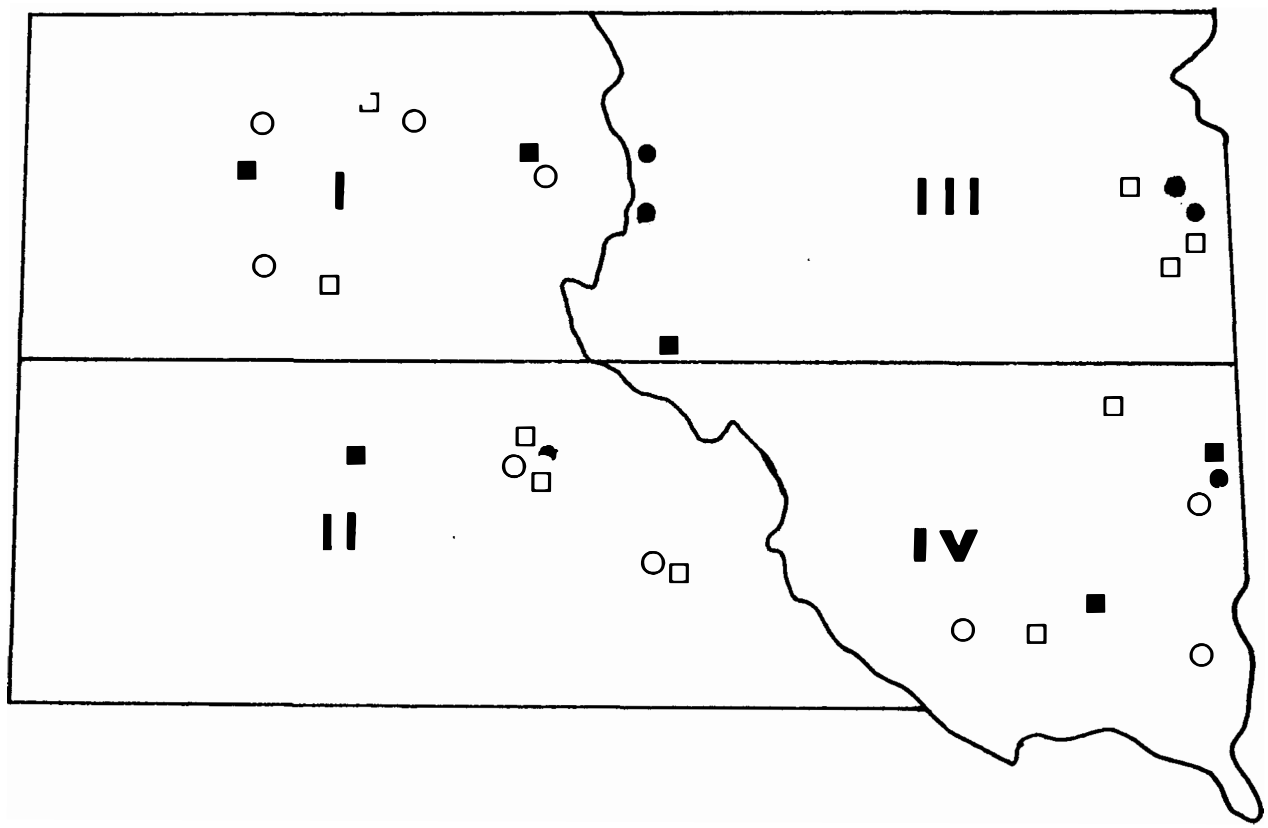


Figure 1. State of South Dakota showing locations of black bullheads (*Ictalurus melas*) (represented by squares) and bluegills (*Lepomis macrochirus*) (represented by circles) study ponds. Light circles or squares show initially stocked ponds and darkened ponds had a fish population in 1982.

## Design

Study ponds consisted of newly constructed or older private impoundments selected from South Dakota Department of Game, Fish, and Parks pond stocking applications or from direct contact with pondowners. Ponds were selected based on the following criteria:

1. Water depth of at least 3.05 m (10 ft)
2. Surface area 0.4-2.2 hectares (1-5 acres)
3. Absence of fish in ponds prior to stocking

Four fish species were selected for stocking in combination with the largemouth bass (Shelley 1981; Stone 1981). A largemouth bass only combination was also evaluated. Four ponds of each combination were randomly stocked in each quadrant. In the southeastern quadrant a bass-bluegill-fathead minnow combination was stocked in 4 randomly selected ponds. A total of eighty ponds were stocked in 1979. The five species stocked were:

1. Largemouth bass (mean total length TL 36.7 mm) were stocked at 247/hectare (100/acre) between 9-18 July, 1979.
2. Black bullheads (mean TL 34.1 mm) were stocked at 988/hectare (400/acre) between 24-28 July, 1979.
3. Bluegills were stocked at 1236/hectare (500/acre) on 15 August, 1979 (mean TL 22.0 and 26.8 mm) and between 22-24 August, 1979 (mean TL 30.7 mm).
4. Golden shiners were stocked at 617/hectare (250/acre) during May and June, 1979.
5. Fathead minnows were stocked at 1235/hectare (500/acre) during May and June, 1979.

Field and Laboratory Techniques

Fish were sampled from ponds in the southeastern and southwestern quadrants in 1981 and all ponds in 1982. Fish were collected using seines and electroshocking gear. Physical and chemical data collected from each pond during the summer of 1980 by Shelley (1981) and Stone (1981) were used for analysis in this study (Appendix Table 1).

Spring populations of bluegills and black bullheads in the southeastern quadrant were estimated between 22 April and 12 June, 1981. Bluegills and bullheads were captured with a 45.7 m x 2.4 m (19.0 mm mesh) bag seine. Both species were marked by punching a hole in the upper lobe of the caudal fin and released. Black bullhead young-of-the-year were captured using a 25.9 m x 1.8 m (3.2 mm mesh) bag seine and marked by clipping the upper portion of the caudal fin with scissors. Bluegills were recaptured using an electroshocking unit whereas bullheads were recaptured with seines several days after initial capture.

Relative abundance of minnow species and young-of-the-year bass and bluegills were determined from shoreline seining using a 4.6 m x 1.8 m (3.2 mm mesh) minnow seine. Six seine hauls per pond were made at random intervals around each pond. One end of the seine was anchored at the bank and then pulled full length perpendicular to shore. The seine was then rotated in a sweeping arc to shore. In this manner, a quantitative estimate was made to compare the relative number of forage species. Sampling was done in the fall and results were recorded in number of fish/seine haul (f/sh).

The right pectoral spine of bullheads was removed for growth analysis (Sneed 1951; Schoffman 1954; Marzolf 1955). To remove dead tissue, spines were soaked in a 6% sodium hypochlorite solution (bleach). A dental separating disc attached to a Dremel moto-tool mounted on a sliding platform was used to section adult spines. Young-of-the-year bullhead spines were placed in a decalcification solution for 20 minutes and sectioned using a single-edge razor blade (Perry 1967). Spines were sectioned at the distal end of the basal groove (Sneed 1951). Sections were then placed on a glass slide in a drop of water and observed under a binocular microscope equipped with a micrometer. Annuli appeared as translucent rings alternating with opaque bands. Measurements were made from the center of the lumen along the longest radius.

Bluegill scales were removed from below the lateral region near the tip of the pectoral fin (Everhart et al. 1975). Scale impressions were made on 2.6 x 7.6 cm cellulose acetate strips using a roller press as described by Smith (1954). Impressions were read on a Bell and Howell SR-II microfiche reader. Scales were measured (to the nearest millimeter) from the focus to each annulus and to the anterior margin of the scale.

Analysis

Population estimates were determined using the Modified Peterson equation:

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

where:

$\hat{N}$ = estimated population size

M = number of fish marked

C = catch or sample taken for census

R = number of recaptures

Confidence intervals of 95% $(\hat{N} \pm 1.96\sqrt{\hat{VN}})$ were placed around each population estimate. The equation:

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

was used to determine the estimate of the population variance. Mean survival rates were calculated by dividing the 1981 population estimate by the number of stocked fish.

Back-calculation of black bullhead lengths were made using the Dahl-Lea equation:

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

where:

Ln = back-calculated length at annulus

Lc = length of fish at capture

Sn = spine annulus length

Sc = spine radius length

Length of bluegill at each annulus was back-calculated using the corrected Lee equation:

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

where:

$Ln$ = back-calculated length at annulus

$Sn$ = scale annulus length

$Sc$ = scale radius length

$Lc$ = length of fish at capture

$a$ = correction factor

A standard value of 20.0 mm (Carlander 1982) was employed as the correction factor and corresponds to the length of the fish at the moment the scale was first laid down. An analysis of variance using a nested classification was used to compare ponds in the southeastern vs southwestern quadrants of the state in 1981 and a north vs south comparison in 1982.

The condition of bluegills and black bullheads were determined using the Relative Weight ($W_r$) index:

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

where:

$W_r$ = relative weight

$W$ = actual weight at sampling (g)

$W_s$ = standard weight for fish of the same length

The standard weight equation for bluegills was found in Anderson (1980). The standard weight equation for black bullheads was calculated from length-weight information summarized by Carlander (1977). This information provides a 50% length and weight range for each 2.54 cm (1 in group) and represents the 25th, 50th, and 75th percentile of all reported values. Using linear regression and the mean value of each group (10 to 23 cm) the following standard weight equation was calculated:

$$\log W_s = -4.9064 + 3.3069 \log L$$

A standard weight and $W_r$ was calculated for each 2.54 cm and plotted to determine which equation provided the best straight line relationship. The 75th percentile equation was selected because little change in Wr occurred with an increase in length.

To assess population structure two indices, Proportional Stock Density (PSD) and Young-Adult Ratio (YAR) were used. Proportional Stock Density values were calculated using the equation:

$$PSD = \frac{\text{number} \geq \text{quality size} \times 100}{\text{number} \geq \text{stock size}} \quad \text{(Wege and Anderson 1978)}$$

The quality size value used for bluegills was 150 mm (6 in) and the bluegill stock size value was 80 mm (3 in). Black bullhead quality and stock size values were 230 mm (9 in) and 150 mm (6 in), respectively.

Bluegill and black bullhead Young-Adult Ratio values were calculated using the equation:

$$YAR = \frac{\text{number of young-of-the-year}}{\text{number of adults}} \quad \text{(Reynolds and Babb 1978)}$$

Standing stock for each age-class of bullheads and adult bluegills were estimated by multiplying the 1981 population estimate by the average weight (g) for each cohort in each pond. Weights of all age-classes for bullheads were totaled to determine the standing stock for that pond.

To evaluate pond variables influencing survival of fish in the ponds stepwise discriminant analysis was employed (Cooley and Lohnes 1971). The 43 ponds sampled were divided into two groups for analysis. Group 1 had a fish population present in 1982 while group 2 had no surviving fish. Five independent variables (area, maximum depth, turbidity, conductivity, and carbonates) were used in the analysis. Missing data resulted in the elimination of 37 ponds from the analysis.

# RESULTS

## Bluegill Populations

Growth of bluegills was calculated from 8 of 12 ponds in the southwestern and southeastern quadrants (II and IV) in 1981. Dry ponds or an insufficient sample resulted in the loss of four ponds (Appendix Table 2). Estimated bluegill total lengths in the southwestern quadrant averaged 47 mm (range 44-51 mm) at annulus 1 and 141 mm (range 122-155 mm) at annulus 2. Average weight at capture was 97 g (Appendix Table 3). In the southeastern quadrant total lengths averaged 48 mm (range 47-50 mm) at annulus 1 and 141 mm (range 130-151 mm) at annulus 2. Average weight at capture was 86 g. An analysis of variance using a nested classification of 1981 total lengths indicated no significant difference ($P \geq 0.05$) between the total lengths of bluegills from ponds in the southwestern and southeastern quadrants (Table 1). Mean back-calculated lengths for all bluegill ponds in 1981 were 48 mm at annulus 1 and 141 mm at annulus 2. Average weight at capture was 92 g (Table 2).

In 1982, fish collections were made from 5 of 20 bluegill ponds. No samples were collected from the remaining ponds due to winterkill caused by low water levels, pond drying, and/or the failure to capture fish (Appendix Table 2). Bluegills reproduced during the second growing season and three year-classes were collected in all but the Hauk pond. However, data on some year-classes is missing because of the failure of capture fish.

The 1981 bluegill year-class (age-group I) had a mean back-calculated length at annulus 1 of 67 mm and an average weight at capture of 17 g (Table 3). The 1980 bluegill year-class (age-group II) had

Table 1. Back-calculated total lengths of bluegills (*Lepomis macrochirus*) showed no significant difference ($P \geq 0.05$) in a southwestern vs southeastern comparison, as determined by analysis of variance using a nested classification, 1981.

| SOURCE | d.f. | SS | MS | F |
|---|---|---|---|---|
| Treatment | 1 | 24.7250 | 24.7250 | 0.005 |
| Pond (Treatment) | 6 | 31713.5036 | 5285.5855 | 34.973** |
| Residual | 256 | 38689.8131 | 151.1321 | |

**Denotes significance ($P \leq 0.05$)

Table 2. Back-calculated total lengths (mm) at each annulus and relative weights ($W_r$) of bluegills (*Lepomis macrochirus*) stocked in South Dakota ponds, 1981.

| YEAR-CLASS | NUMBER OF FISH | MEAN (TL) AT CAPTURE | $W_r$ | ANNULUS 1 | ANNULUS 2 |
|---|---|---|---|---|---|
| 1979 | 264 | 153 | 121 | 48<br>(36-63)[1] | 141<br>(81-170) |
| | Weighted Mean | | | 48 | 141 |
| | Growth Increment | | | 48 | 94 |
| | Mean Weight | | | - | 92 |

Table 3. Back-calculated total lengths (mm) at each annulus and relative weights ($W_r$) of bluegills (*Lepomis macrochirus*) stocked in South Dakota ponds, 1982.

| YEAR-CLASS | NUMBER OF FISH | MEAN (TL) AT CAPTURE | $W_r$ | ANNULUS 1 | ANNULUS 2 | ANNULUS 3 |
|---|---|---|---|---|---|---|
| 1981 | 110 | 89 | 105 | 67<br>(33-104)[1] | | |
| 1980 | 4 | 110 | 114 | 71<br>(67-76) | 96<br>(88-106) | |
| 1979 | 65 | 122 | 122 | 43<br>(35-58) | 127<br>(74-156) | 153<br>(109-173) |
| | Weighted Mean | | | 58 | 125 | 153 |
| | Growth Increment | | | 58 | 81 | 28 |
| | Mean Weight | | | 17 | 29 | 124 |

[1]Range in millimeters

back-calculated lengths at annulus 1 and 2 of 71 and 96 mm, respectively, with an average weight at capture of 29 g. Stocked bluegills (age-group III) had mean back-calculated lengths at annuli 1-3 of 43, 127, and 153 mm, respectively, with an average weight at capture of 124 g (Table 3). Bluegill estimated mean back-calculated lengths at annuli 1-3 was 58, 125, and 153 mm, respectively. No comparison of total lengths could be made using 1982 data because of the small sample size.

Mean relative weights were calculated for bluegills in 1981 and 1982. In 1981, mean $W_r$ values averaged 117 in quadrant II and 127 in quadrant IV, with an overall average of 121 (Appendix Table 3). In 1982, $W_r$ values for age-groups I-III were 105, 114, and 122, respectively (Fig. 2).

In 1981, population estimates were calculated for stocked bluegills from the southeastern quadrant and ranged from 3-383 (Appendix Table 4). Bluegill survival rates for the first two years (1979-1981) ranged from 0.7-58.0% with a mean of 31.0% (Table 4). Survival from 1980-1981 ranged from 11.5-92.8% with a mean of 83.9%. Estimated standing stock for bluegills ranged from 22-64 kg/hectare (20-57 lbs/acre) and averaged 41 kg/hectare (37 lbs/acre) (Appendix Table 4). The Amdahl pond was not included due to the small sample size.

Proportional Stock Density (PSD) was calculated for the Edgecomb, Hauk, and Hinricker #3 ponds. PSD values for the three ponds were 79, 75, and 36%, respectively (Table 5). Young-Adult Ratios (YAR) for the Edgecomb and Hinricker #3 ponds were 2.2 and 2.0.

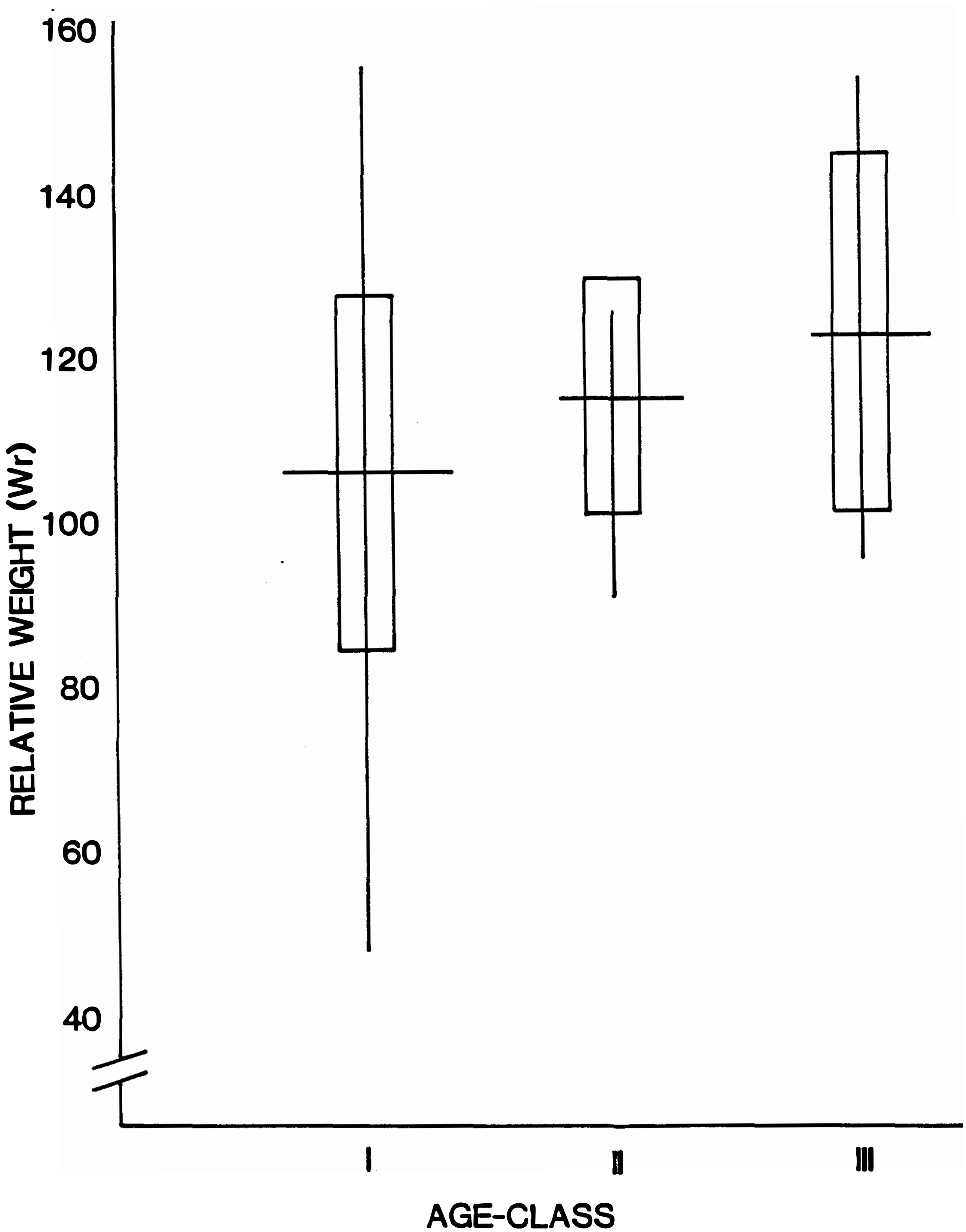


Figure 2. Ranges (vertical lines), standard deviations (rectangles), and means (horizontal lines) for bluegill (Lepomis macrochirus) relative weights ($W_r$) in South Dakota ponds, 1982.

Table 4. Survival rates of bluegills (*Lepomis macrochirus*) and black bullheads (*Ictalurus melas*) after two years (1979-1981), and survival from 1980-1981, sampled in eastern South Dakota ponds, 1981.

| POND OWNER | SPECIES | QUADRANT | SURVIVAL (%) 1979-1981 | SURVIVAL (%) 1980-1981 |
|---|---|---|---|---|
| Amdahl | BG[1] | III | 0.7 | 11.5 |
| Bush | BG | IV | 19.3 | 92.8 |
| Edgecomb | BG | IV | 46.1 | ---- |
| Hinricker #3 | BG | IV | 58.0 | 84.3 |
| | | | Mean = 31.0 | Mean = 83.9 |
| Hanson | BB[2] | III | 4.6 | ---- |
| Hinricker #2 | BB | IV | 56.4 | 91.4 |
| Johnson #2 | BB | III | 24.7 | 35.0 |
| Murphy | BB | IV | 48.0 | 67.8 |
| | | | Mean = 30.2 | Mean = 69.1 |

[1]Bluegills

[2]Black bullheads

Table 5. Proportional stock density (PSD) and young-adult ratio (YAR) for bluegills (*Lepomis macrochirus*) and black bullheads (*Ictalurus melas*) sampled in South Dakota ponds, 1982.

| POND OWNER | SPECIES | PSD | YAR |
|---|---|---|---|
| Edgecomb | BG[1] | 79 | 2.2 |
| Hauk | BG | 75 | - |
| Hinricker #3 | BG | 36 | 2.0 |
| Cronin | BB[2] | 68 | 12.0 |
| Hanson | BB | - | 290.0 |
| Hinricker #2 | BB | 78 | - |
| Hoff | BB | 9 | - |
| Merkel #2 | BB | 27 | 0.3 |
| Olson #3 | BB | 30 | 1.5 |
| Willinski | BB | 80 | - |

[1]Bluegills

[2]Black bullheads

Black Bullhead Populations

Growth was calculated from six of eight ponds in the southwestern and southeastern quadrants in 1981. Dry ponds or the failure to capture fish resulted in the loss of two ponds (Appendix Table 2). Black bullheads reproduced during the second growing season and two year-classes were present in most ponds. In the southwestern quadrant, collection of age-group I bullheads was made in one pond (Olson #3) and average total length at annulus 1 was 77 mm with an average weight at capture of 13 g (Appendix Table 5). Total lengths for age-group II bullheads averaged 93 mm (range 84-105) at annulus 1 and 237 mm (range 201-256 mm) at annulus 2 with an average weight at capture of 232 g. In the southeastern quadrant, age-group I bullhead total length at annulus 1 was 64 mm (range 43-77 mm) with an average weight at capture of 13 g. Total lengths of age-group II fish averaged 89 mm (range 81-96 mm) at annulus 1 and 241 mm (range 235-245 mm) at annulus 2. Average weight at capture was 221 g. Mean back-calculated total lengths in 1981 were 82 mm at annulus 1 and 239 mm at annulus 2 (Table 6). Average weight at capture of age-groups I-II was 13 and 131 g, respectively.

In 1982, fish collections were made from 8 of 16 ponds. No samples were collected from eight ponds due to winterkill, dry ponds, and/or the failure to capture fish (Appendix Table 2). A northern vs southern comparison of mean total lengths at each age-class is presented in Figure 3. Bullhead total lengths (age-group III) in the north (264 mm) averaged 44 mm more than mean total lengths of fish in the south (220 mm).

Table 6. Back-calculated total lengths (mm) at each annulus and relative weights ($W_r$) of black bullheads (<u>Ictalurus melas</u>) stocked in South Dakota ponds, 1981.

| YEAR-CLASS | NUMBER OF FISH | MEAN (TL) AT CAPTURE | $W_r$ | ANNULUS 1 | 2 |
|---|---|---|---|---|---|
| 1980 | 118 | 91 | 101 | 66<br>(52-92)[1] | |
| 1979 | 202 | 244 | 96 | 90<br>(42-176) | 239<br>(180-292) |
| | Weighted Mean | | | 82 | 239 |
| | Growth Increment | | | 82 | 157 |
| | Mean Weight | | | 13 | 231 |

Table 7. Back-calculated total lengths (mm) at each annulus and relative weights ($W_r$) of black bullheads (<u>Ictalurus</u> <u>melas</u>) stocked in South Dakota ponds, 1982.

| YEAR-CLASS | NUMBER OF FISH | MEAN (TL) AT CAPTURE | $W_r$ | ANNULUS 1 | 2 | 3 |
|---|---|---|---|---|---|---|
| 1981 | 55 | 77 | 89 | 68<br>(49-94)[1] | | |
| 1980 | 61 | 156 | 100 | 72<br>(46-112) | 139<br>(116-178) | |
| 1979 | 163 | 242 | 99 | 95<br>(72-165) | 198<br>(117-276) | 240<br>(185-298) |
| | Weighted Mean | | | 82 | 182 | 240 |
| | Growth Increment | | | 82 | 93 | 58 |
| | Mean Weight | | | 7 | 60 | 232 |

[1]Range in millimeters

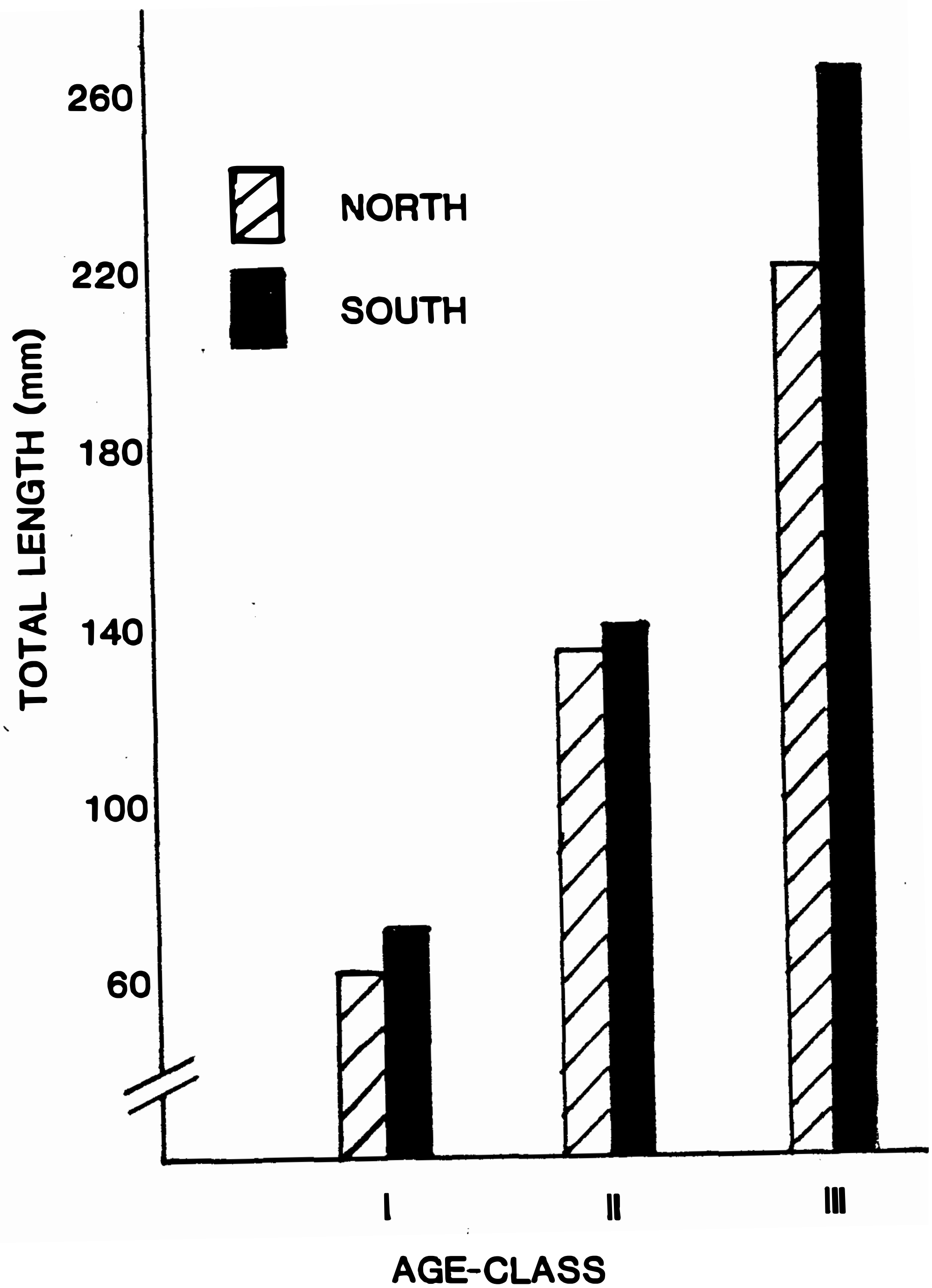


Figure 3. Comparison of mean total lengths of black bullheads (*Ictalurus melas*), ages I-III, from north and south quadrants, 1982.

An analysis of variance using a nested classification indicated a significant difference ($P \leq 0.05$) in total lengths of age-group III bullheads (Table 8). No significant difference ($P \geq 0.05$) in total lengths was detected in age-groups I or II in the same comparison. Bullhead estimated mean back-calculated total lengths at annuli 1-3 were 82, 182, and 240 mm, respectively (Table 7). Average weights at capture of age-groups I-III were 7, 60, and 232 g, respectively.

Relative weights were calculated for bullheads in 1981 and 1982. In 1981, age-group I bullheads average $W_r$ in quadrants II and IV ranged from 78-106 with an overall average of 101 (Appendix Table 5). The $W_r$ of age-group II bullheads ranged from 89-102 and averaged 96. An analysis of variance using a nested classification indicated no significant differences ($P \geq 0.05$) of Wr in a quadrant II vs IV comparison (Table 8). Mean $W_r$ values in May of age-group I and age-group II fish in the southeastern quadrant were 104 and 95. In September, fish were collected in the same ponds and $W_r$ values for age-groups I-II were 80 and 93, respectively. In 1982, statewide average $W_r$ values for bullheads age-groups I-III were 89, 100, and 99, respectively (Fig. 4).

Black bullhead population estimates were made on four ponds in the southeastern quadrant (IV) for two year-classes of fish in 1981. Population estimates for stocked bullheads (age-group II) ranged from 39-350 (Appendix Table 3). Population estimates of 2,099-25,049 were recorded for age-group I fish. Bullhead survival rates for the first two years (1979-1981) ranged from 4.6-56.4% with a mean of 30.2%

Table 8. Relative weights ($W_r$) of black bullheads (*Ictalurus melas*) sampled in 1981 indicated no significant difference ($P \geq 0.05$) in a southwestern vs southeastern comparison, as determined by analysis of variance using a nested classification. A significant difference ($P \leq 0.05$) of black bullheads total lengths was shown in a north vs south comparison, 1982.

| SOURCE | d.f. | SS | MS | F |
|---|---|---|---|---|
| 1981 | | | | |
| Treatment | 1 | 0.0034 | 0.0034 | 0.05 |
| Pond (Treatment) | 4 | 0.2674 | 0.0668 | 33.93** |
| Residual | 203 | 2.2262 | 0.0109 | |
| 1982 | | | | |
| Treatment | 1 | 21833.3672 | 21833.3672 | 7.43** |
| Pond (Treatment) | 5 | 14702.6138 | 2940.5226 | 9.96** |
| Residual | 156 | 46048.3744 | 295.1819 | |

**Denotes significance ($P \leq 0.05$)

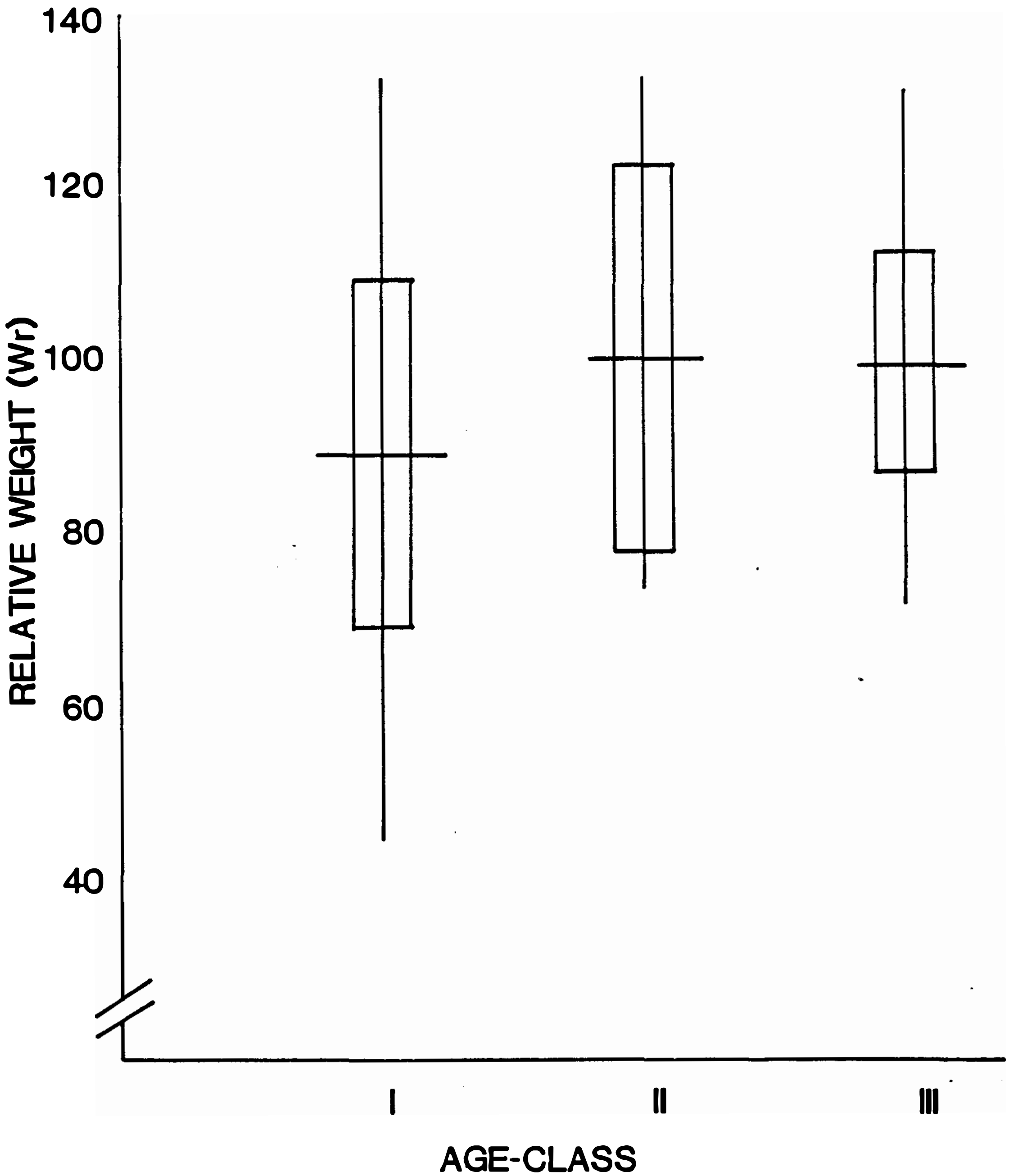


Figure 4. Ranges (vertical lines), standard deviations (rectangles), and means (horizontal lines) of black bullheads (Ictalurus melas) relative weights ($W_r$) in South Dakota ponds during the spring, 1982.

(Table 4). Survival from 1980-1981 ranged from 35.0-91.4% with a mean of 69.1%.

The estimated standing stock for age-group I bullheads ranged from 87-276 kg/hectare (78-245 lbs/acre) and averaged 167 kg/hectare (149 lbs/acre) (Appendix Table 4). Standing stock estimates from age-group II fish ranged from 58-138 kg/hectare (51-123 lbs/acre) and averaged 106 kg/hectare (94 lbs/acre). The Hanson pond was not included due to the small sample size. Total standing stock for the three ponds ranged from 145-398 kg/hectare (129-354 lbs/acre) and averaged 273 kg/hectare (243 lbs/acre).

Proportional Stock Density of bullheads in 1982 ranged from 9-80% (Table 5). Young-Adult Ratios calculated in 1982 ranged from 0.3-290.0 with an average of 76.0. YAR was calculated using 1981 population estimates for the Hinricker #2, Johnson #2, and Murphy ponds. YAR values for the three ponds were 12, 25, and 130, respectively.

Factors Affecting Pond Failure

Based upon five pond variables (area, maximum depth, turbidity, conductivity, carbonates), discriminant analysis was successful in separating ponds that contained surviving fish from those that had complete fish mortality. Maximum depth and specific conductance were the two most important variables ($P \leq 0.05$) in separating the bluegill ponds. These two variables explained 70% of the variation while all five variables accounted for 76% of the variation in the model. One hundred percent (13 of 13) of the bluegill ponds were correctly classified by the analysis. Pond group means for each variable are shown in Appendix Table 6.

Results of the analysis were less predictive with largemouth bass only and black bullhead ponds. Sixty-eight percent (13 of 19) of the largemouth bass only ponds were correctly classified with turbidity explaining only 12% of the variation in the model. Carbonates explained 20% of the variation in the bullhead model and correctly classified 92% (11 of 12) of the ponds.

When all 43 ponds were analyzed using the five variables, pond depth explained the greatest variation in the model. Sixty-eight percent (30 of 43) of the ponds were correctly classified. Pond group means for each variable are shown in Appendix Table 6. Ponds with insufficient physical and chemical data were excluded from the analysis.

## Forage Availability

Three fish species were captured by shoreline seining. Bluegills were the most numerous species capture in September followed by golden shiners and largemouth bass (Table 9). Fathead minnows were not captured while making seine hauls in 1982 but were originally stocked in two ponds sampled. Only ponds with largemouth bass and fathead minnows present were included in Table 9. Bluegills produced the greatest amount of forage, 147.6 fish/seine haul (f/sh), followed by golden shiners (51.4 f/sh) and fathead minnows (0.0 f/sh). The mean number of largemouth bass was greater in the largemouth bass only ponds (35.7 f/sh) than ponds stocked with another species. Mean largemouth bass numbers were lowest (7.6 f/sh) in the largemouth bass-black bullhead ponds. The mean total length of young bass (76.5 mm) was

Table 9. Seining catch rates (fish/seine haul) of largemouth bass (*Micropterus salmoides*) and forage species in September, 1981 (LMB = largemouth bass, *Micropterus salmoides*; GS = golden shiner, *Notemigonus crysoleucas*; BB = black bullhead, *Ictalurus melas*; BG = bluegill, *Lepomis macrochirus*; FHM = fathead minnow, *Pimephales promelas*).

| SPECIES | NUMBER OF PONDS | MEAN BASS (f/sh)[1] | MEAN FORAGE (f/sh) | MEAN TL BASS |
|---|---|---|---|---|
| LMB-ONLY | 2 | 35.7<br>( 1-71)[2] | 0.0 | 76.5<br>(58-95) |
| LMB-GS | 3 | 13.6<br>(65-78) | 51.4<br>(5-87) | 72.0<br>(65-78) |
| LMB-BG | 2 | 10.4<br>( 7-15) | 147.6<br>(83-212) | 57.0<br>(50-64) |
| LMB-BB | 1 | 7.6 | 0.0 | 80.0 |
| LMB-FHM | 2 | 10.4<br>( 7-15) | 0.0 | 57.0<br>(50-64) |

[1]Fish/seine haul

[2]Range (f/sh)

higher in the largemouth bass only ponds than the ponds stocked with a forage species with the exception of one black bullhead pond.

# DISCUSSION

Growth rates of bluegills recorded during the present study were comparable with regional studies previously reported from established populations (Fig. 5). Growth rates after three years were higher when compared to lakes in Iowa (DiCostanzo 1957) and southern South Dakota lakes (Boussu 1959), but slower than those reported by Hart (1979) for Kansas ponds. No difference in bluegill growth was found between ponds in eastern and western South Dakota. Carlander (1977) found decreasing bluegill growth with increasing latitude. Therefore, it appears that geomorphological influences in South Dakota are less important than length of the growing season.

Growth rates of bullheads from the present study were also comparable to regional studies (Fig. 6). First year growth rates for black bullheads in South Dakota ponds were lower when compared to South Dakota lakes (Boussu 1959), North Dakota lakes (Owen and Wahtola 1970), and Oklahoma ponds (Houser and Collins 1962) but obtained higher growth rates after three years. Higher growth rates of originally stocked fish is typically observed in new impoundments (Bennett 1970). Slower growth of subsequent year-classes was probably due to greater intraspecific competition resulting from higher densities. Shelley (1981) found significant differences in age-group 0 bullheads from northern and southern South Dakota ponds which he attributed to differences in the length of the growing season. Because latitudinal differences in bullhead growth were observed among the 1979 year-class but not in younger year-classes, it appears that increased recruitment during the

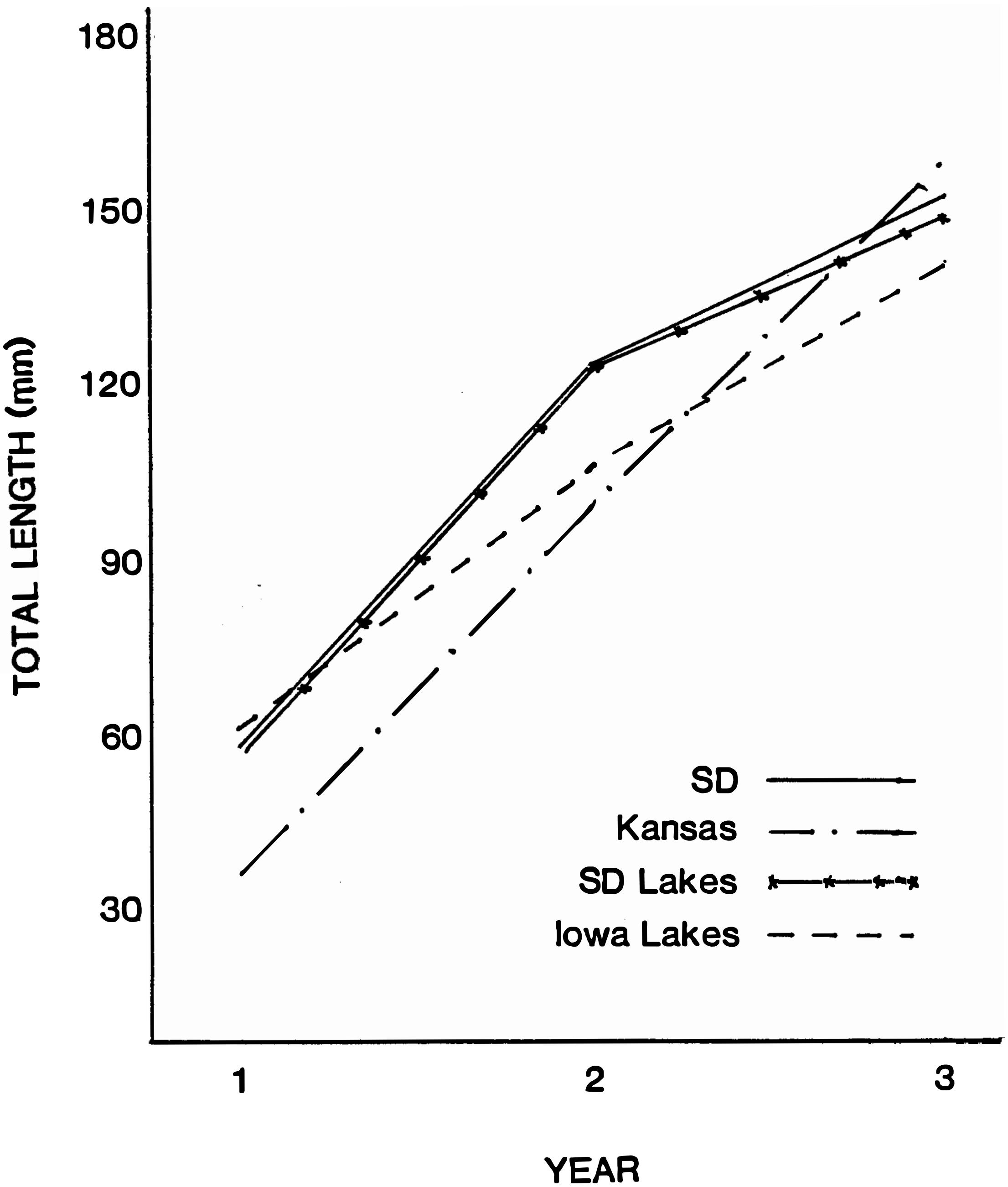


Figure 5. Comparison of back-calculated total lengths (mm) of bluegills (Lepomis macrochirus) in South Dakota study ponds with Iowa lakes, South Dakota lakes, and Kansas ponds.

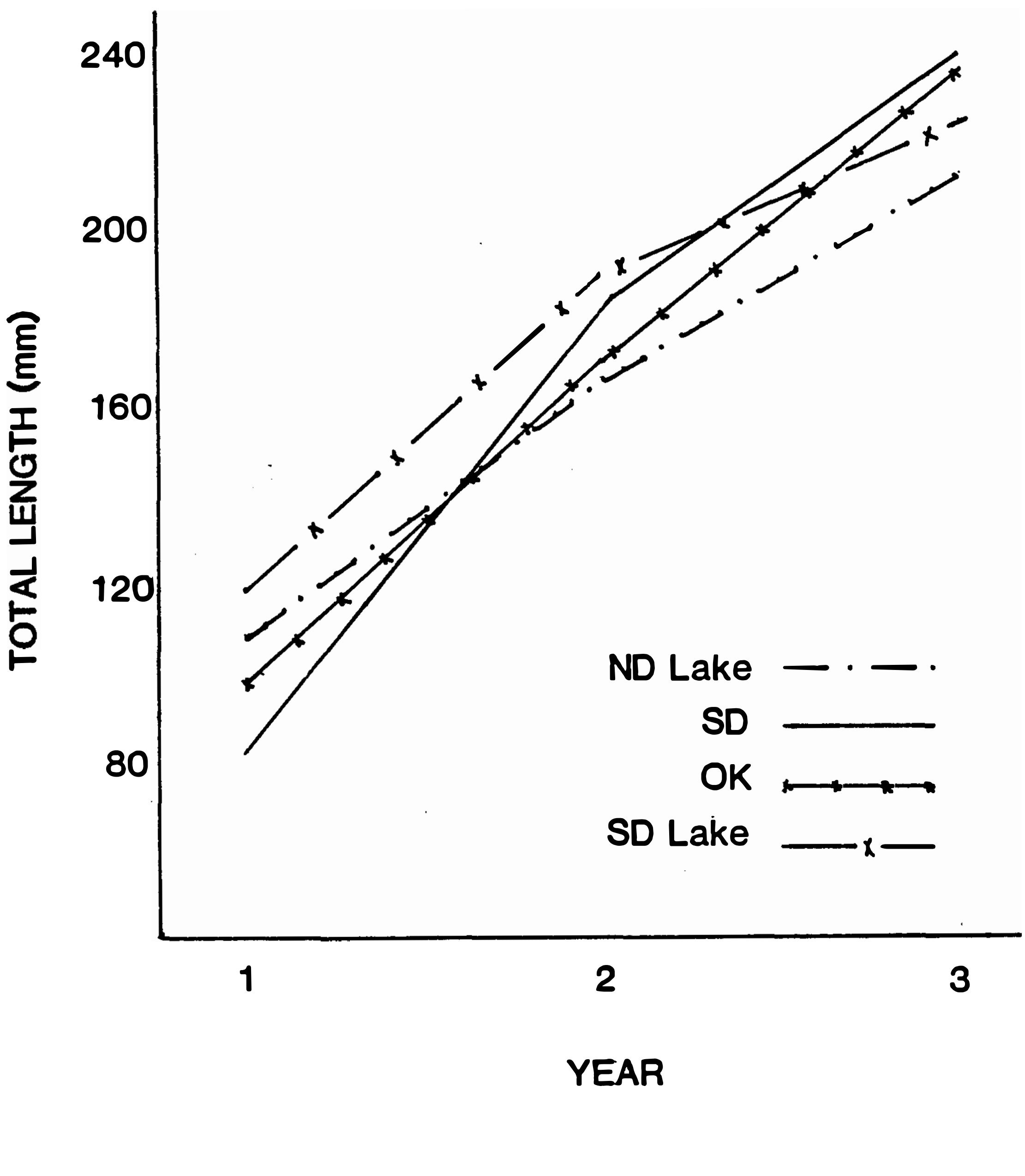


Figure 6. Comparison of back-calculated total lengths (mm) of black bullheads (Ictalurus melas) in South Dakota study ponds, with South Dakota lakes, Oklahoma ponds, and North Dakota lakes.

latter two years decreased growth rates and reduced the variation associated with latitude.

Condition ($W_r$) of all three year-classes of bluegills was above the satisfactory level of 90-100 described by Wege and Anderson (1978), and exceeded the mean of 84 reported by Novinger (1980) for bluegills from Missouri ponds. Low densities of all year-classes allowed for fast growing bluegills with high $W_r$. Relative weights for the 1979 and 1980 year-classes of bullheads were within the satisfactory range but the 1981 year-class was somewhat low with a mean of 89. A $W_r$ below the satisfactory level is an indication of possible increased competition for food and reduced growth. In May 1981, the $W_r$ of age-groups I and II were higher than that recorded in September, due to an increase in gonadal weight prior to spawning (Campbell and Branson 1978).

Survival of bluegills after two years (31.0%) was close to the 37.0% reported from Missouri (Novinger 1980) but less than the 55.6% reported from Iowa (Hill 1980). Several factors contributed to the low survival of stocked bluegills. Largemouth bass were stocked in July and bluegills in late August allowing the bass to obtain a larger size and probably resulted in some predation of bluegill. In the Edgecomb pond predation by and competition with bullheads, present prior to stocking, may have occurred. Also, drought conditions occurred in South Dakota during the study (1979-1982) resulting in greatly reduced water levels in most ponds and undoubtedly caused fish mortality. Discriminant analysis indicated specific conductance and maximum depth of ponds were the major variables influencing survival of bluegills. Ponds that had surviving fish after three years had a mean depth of 3.6 m while failing ponds had an average maximum depth of only 1.9 m. Higher specific conductance of ponds was also associated with higher survival of bluegill.

Black bullhead survival for the first two years of this study (30.2%) was lower than expected; Shelley (1981) reported a first year survival of 67.7%. Higher first year survival was probably due to low bass densities. Largemouth bass survival in bullhead ponds averaged only 9.7% (Beck personal communication). Bullhead ponds were also characterized by higher turbidity. Buck (1956) found that turbidity limited bass production and growth. Discriminant analysis indicated turbidity as the major variable influencing bass survival which Hastings and Cross (1962) also indicated was the most important factor affecting the survival of sport fishes. Turbidity appeared to be a more important influence on the survival of bass than on either bluegills or bullheads in this study. Higher carbonate levels and surface area of ponds were the most important variables influencing survival of bullheads in study ponds. Maximum depth was the most important factor influencing survival of all species and has been reported by several investigators as a major factor affecting pond success (Hastings and Cross 1962; Lopinot 1972; Peeters 1978).

Mean standing stock of bluegills during the present study (41 kg/hectare) was below that reported in other ponds in South Dakota and Illinois. Thorn (1969) reported a bluegill standing stock of 134 kg/hectare in Blue Cloud Abbey pond in South Dakota. Lopinot (1972) stated that approximately 225-449 kg/hectare was the carrying capacity for bluegills in Illinois ponds. Bluegill densities in study ponds were low in relation to the capacity of the ponds and indicate that populations were still expanding after three years. This conclusion is further supported by the high $W_r$ of bluegills.

The mean standing stock of adult bullheads from study ponds (106 kg/hectare) was higher than that reported from other ponds in South Dakota. Thorn (1969) reported standing stocks of 34-84 kg/hectare in two South Dakota ponds. Total standing stock of adult and yearling bullheads in this study (273 kg/hectare) was comparable to Iowa ponds. Standing stocks in Iowa ponds ranged from 8-733 kg/hectare and averaged 144 kg/hectare (Carlander and Moorman 1956). Standing stocks in Iowa over 200 kg/hectare did not have bass in the population to control recruitment. Standing stocks of both species in this study were probably underestimated since 1979 and 1980 higher surface area estimates were used in the calculation.

Bullhead standing stock in study ponds indicated large numbers of harvestable fish and large numbers of stunted yearlings. Since growth and $W_r$ of stocked bullheads was satisfactory at a standing stock of 106 kg/hectare this is believed to be at least a minimum estimate of the carrying capacity of ponds during drought conditions.

Proportional Stock Density in two bluegill ponds were higher than the 20-60% range recommended by Novinger and Legler (1978). Stocked bluegills reached quality size in the Edgecomb pond in three years but few age-group II bluegill reached stock size during the same period. In the Hauk pond, growth rates were slower and PSD values were calculated based on age-group III bluegill that were either quality size or stock size. No reproduction of bluegills occurred in the Hauk pond probably because of high turbidity and destruction of spawning beds by cattle. High PSD values were characterized by populations with high $W_r$ and low biomass. The PSD value in the Hinricker #3 pond of 36% was a result of winterkill prior to spawning and not because of adequate recruitment of stock size bluegill.

Poor recruitment of stock size bluegill was probably caused by water level decreases in ponds due to drought conditions. Bluegills reproduced during the first summer (1980) and produced many young-of-the-year by September but heavy mortality must have occurred after September since very few age-group II fish were sampled the following spring. Decreased water levels would cause crowding of bass and bluegill into smaller areas and make small bluegills more vulnerable to predation.

Bullhead populations had a wide range of PSD values (9-80). Fifty percent (three of six) of the ponds had PSD values above the 20-60% range recommended for bluegill by Novinger and Legler (1978). In 1982 the high average YAR value indicated that bass numbers were too low to control recruitment of bullheads. However, two of four ponds had YAR values within the optimal range. Low YAR values or bullheads failing to reproduce was probably caused by destruction of nests by cattle and competition during low water levels. YAR values determined in 1981 from the Hinricker #3, Johnson #2, and Murphy ponds were all above the optimal range. Failure to capture fish and the incidence of winterkill eliminated these ponds from sampling in 1982.

Evaluation of forage species abundance in 1981 seine hauls indicated that bluegills produced the most forage (147.6 f/sh) for bass. Since bullheads could not be adequately sampled by shoreline seining their availability as forage could not be determined by this method. Bluegills provided abundant forage, but young-of-the-year bass recruitment and mean total lengths of bass were lower in bluegill ponds. No fathead minnows were present or collected in ponds that contained bass but were collected in large numbers where 100% bass mortality occurred. Fathead minnows were eliminated by bass within three years, however, Stone (1981) reported even though fathead minnows may be eliminated in ponds they provide excellent forage for bass during the first few years after stocking. Large bullhead populations appear to reduce bass recruitment since the mean number of bass (f/sh) was lower in bass-bullhead ponds. Bullheads produced the greatest quantity of forage (based on population estimates) but reduced survival and recruitment of bass. Rickett (1976) stated that bullheads provide excellent forage if ponds were clear and free of vegetation to allow predation. Golden shiners provided abundant forage, higher recruitment of young-of-the-year bass, and resulted in comparable mean bass length.

# CONCLUSIONS AND RECOMMENDATIONS

1. Growth of bluegills and black bullheads was strongly influenced by population densities. Stocked bluegills reached quality size in three years and the 1980 and 1981 year-classes were fast growing with high $W_r$ when densities were low. Growth of stocked bullheads reached quality size in two growing seasons but bullheads spawned in the study ponds were stunted because of large populations. Higher bass densities must be achieved to control yearling densities and improve growth.
2. First year survival of 25 mm bluegills was low (28.6%) but increased to 83.9% from 1980-1981. Higher survival could be achieved by stocking 51 mm bluegills (1235/hectare). Increasing the stocking rate (2472/hectare) to increase densities will need further investigation. Black bullhead survival after two years (1979-1981) of 30.2% and high reproductive capacity resulted in large population densities. Reducing the stocking rate to 247/hectare and increasing predator densities is needed to control bullheads.
3. Drought conditions during the study reduced water levels and resulted in winterkill in many ponds. Minimum requirements for stocking fish in South Dakota ponds should include a pond depth of 3.6-4.7 m and a surface area of 0.4 hectares. The pond stocking program could be improved by performing pre-stocking checks on each pond which include determination of correct depth and area estimates.

4. The stocking of a forage species should be based on pondowner interests. A largemouth bass-black bullhead stocking is recommended only when the pondowner has a strong interest in fishing for both species. Stocking golden shiners (1236/hectare) should provide abundant forage for increased largemouth bass growth. Pond angling information should be provided to prevent overharvest of predator species and therefore the deterioration of quality fishing.

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Appendix Table 1. Physical and chemical data collected from ponds that contained a fish population (group 1) and ponds that were determined to have complete fish mortality (group 2) by the end of the study, 1982 (LMB = largemouth bass, Micropterus salmoides; GS = golden shiner, Notemigonus crysoleucas; BB = black bullhead, Ictalurus melas; BG = bluegill, Lepomis macrochirus; FHM = fathead minnow, Pimephales promelas).

| Species and Pond owner | Combination | Quadrant | Group | Area (ha) | Depth (meters) | Carbonates (mg/1) | Conductivity (umhos) | Turbidity (FTU) |
|---|---|---|---|---|---|---|---|---|
| Largemouth bass | | | | | | | | |
| Merkel #1 | GS | I | 2 | 0.7 | 4.3 | 40 | 265 | 10 |
| Scofield #1 | GS | I | 2 | 0.8 | 2.1 | 0 | 1000 | 70 |
| Scofield #2 | FHM | I | 1 | 0.9 | 2.1 | 0 | 1200 | 70 |
| Sternad | FHM | I | 2 | 0.4 | 2.6 | 0 | 160 | 85 |
| Buls | GS | II | 1 | 0.3 | 1.8 | 20 | 850 | 15 |
| Calhoon #3 | Only | II | 2 | 0.7 | 3.0 | 20 | 1800 | 10 |
| Olson #2 | GS | II | 2 | 3.9 | 3.7 | 60 | 720 | 35 |
| Olson #5 | Only | II | 1 | 1.0 | 3.0 | 20 | 2450 | 15 |
| Bamesperger | Only | III | 1 | 0.5 | 3.0 | 60 | 420 | 25 |
| Blue Cloud Abbey | GS | III | 1 | 1.9 | 5.0 | 0 | 560 | 45 |
| Knott | FHM | III | 1 | 0.6 | 1.8 | 0 | 220 | 30 |
| Ricker | Only | III | 2 | 0.6 | 3.2 | 0 | 200 | 55 |
| Armstrong #1 | GS | IV | 2 | 0.6 | 3.7 | 0 | 380 | 5 |
| Armstrong #2 | Only | IV | 1 | 0.5 | 3.4 | 0 | 420 | 10 |
| Baughman | GS | IV | 2 | 0.4 | 1.2 | 0 | 230 | 57 |
| Halstead | GS | IV | 2 | 1.0 | 3.8 | 0 | 380 | 36 |
| Hinricker #1 | Only | IV | 1 | 0.4 | 2.7 | 20 | 140 | 20 |
| McMurry | Only | IV | 2 | 0.5 | 2.0 | 0 | 220 | 39 |

Appendix Table 1. Continued.

| Species and Pond Owner | Quadrant | Group | Area (ha) | Depth (meters) | Carbonates (mg/l) | Conductivity (umhos) | Turbidity (FTU) |
|---|---|---|---|---|---|---|---|
| Bluegills | | | | | | | |
| Imsland | I | 2 | 0.3 | 1.7 | 0 | 210 | 265 |
| Thompson #2 | I | 1 | 0.3 | 3.0 | 0 | 310 | 30 |
| Van Den Berg | I | 2 | 0.2 | 1.0 | 0 | 345 | 30 |
| Frantz #3 | II | 1 | 1.1 | 6.1 | 60 | 3900 | 20 |
| Hauk | II | 1 | 1.1 | 4.3 | 60 | 250 | 40 |
| Olson #4 | II | 2 | 0.3 | 2.0 | 20 | 1850 | 15 |
| Olson #6 | II | 2 | 0.5 | 2.1 | 20 | 720 | 20 |
| Amdahl | III | 1 | 0.4 | 2.4 | 0 | 330 | 15 |
| Pollman | III | 1 | 3.0 | 3.1 | 100 | 650 | 35 |
| Sherman | III | 2 | 1.3 | 2.1 | 60 | 350 | 25 |
| Bush | IV | 2 | 0.8 | 2.3 | 0 | 1150 | 40 |
| Edgecomb | IV | 1 | 0.7 | 3.8 | 0 | 1050 | 25 |
| Hinricker #3 | IV | 1 | 0.4 | 2.7 | 40 | 210 | 50 |
| Bullheads | | | | | | | |
| Hoff | I | 1 | 0.8 | 1.8 | 40 | 1250 | 8 |
| Merkel #2 | I | 1 | 0.4 | 1.5 | 0 | 315 | 380 |
| Scofield #3 | I | 2 | 0.3 | 3.2 | 0 | 390 | 330 |
| Shambo | I | 2 | 0.9 | 0.5 | 0 | 460 | 500 |

Appendix Table 1. Continued.

| Species and Pond Owner | Quadrant | Group | Area (ha) | Depth (meters) | Carbonates (mg/1) | Conductivity (umhos) | Turbidity (FTU) |
|---|---|---|---|---|---|---|---|
| Calhoon #4 | II | 1 | 1.4 | 4.0 | 60 | 980 | 14 |
| Olson #1 | II | 2 | 1.0 | 2.1 | 10 | 2150 | 15 |
| Allerding | III | 1 | 0.2 | 1.5 | 40 | 267 | 40 |
| Cronin | III | 1 | 2.0 | 4.9 | 0 | 1225 | 30 |
| Hanson | III | 1 | 1.6 | 3.7 | 0 | 600 | 20 |
| Grosz | IV | 2 | 0.8 | 4.6 | 0 | 529 | 30 |
| Hinricker #2 | IV | 1 | 0.6 | 4.3 | 0 | 443 | 15 |
| Murphy | IV | 2 | 0.3 | 3.2 | 0 | 390 | 330 |

Appendix Table 2. Study ponds originally stocked with largemouth bass (*Micropterus salmoides*) and forage species but determined to have complete fish mortality by the end of the study, 1982 (LMB = largemouth bass; GS = golden shiner, *Notemigonus crysoleucas*; BB = black bullhead, *Ictalurus melas*; BG = bluegill, *Lepomis macrochirus*; FHM = fathead minnow, Pimephales promelas).

| POND OWNER | QUADRANT | COMBINATION | REASON FOR POND FAILURE |
|---|---|---|---|
| Bickel | I | FHM | No sample |
| Imsland | I | *BG | Pond dry |
| Merkel #1 | I | GS | No sample |
| Reich | I | Only | No sample |
| Scofield #1 | I | *GS | No sample |
| Scofield #3 | I | *BB | No 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 |
| Sternad | I | *FHM | No sample |
| Stradinger | I | Only | No sample |
| Thompson #1 | I | *Only | No sample |
| Van Den Berg | I | *BG | No sample |
| Voegele #1 | I | Only | Pond dry |
| Voegele #2 | I | GS | Pond dry |
| Calhoon #1 | II | FHM | Winterkill |
| Calhoon #2 | II | FHM | No sample |

Appendix Table 2. (Continued)

| POND OWNER | QUADRANT | COMBINATION | REASON FOR POND FAILURE |
|---|---|---|---|
| Calhoon #3 | II | *Only | Winterkill |
| Chocholousek | II | Only | No sample |
| Frantz #1 | II | GS | No sample |
| Frantz #2 | II | GS | No sample |
| Kjerstad #1 | II | FHM | Pond dry |
| Kjerstad #2 | II | Only | Pond dry |
| Olson #1 | II | *BB | Pond dry |
| Olson #2 | II | *GS | No sample |
| Olson #4 | II | *BG | Winterkill |
| Olson #6 | II | *BG | Winterkill |
| Swanda | II | FHM | No sample |
| Amman #1 | III | GS | No sample |
| Amman #2 | III | GS | No sample |
| Amman #3 | III | GS | No sample |
| Breitag | III | Only | No sample |
| Johnson #1 | III | BG | No sample |
| Johnson #2 | III | BB | Winterkill |
| Nolte | III | FHM | No sample |
| Ricker | III | *Only | No sample |
| Schilder | III | Only | No sample |
| Sherman | III | *BG | No sample |

Appendix Table 2. (Continued)

| POND OWNER | QUADRANT | COMBINATION | REASON FOR POND FAILURE |
|---|---|---|---|
| Van Beek | III | FHM | No sample |
| Anderson | IV | BB | No sample |
| Armstrong #1 | IV | *GS | Winterkill |
| Baughman | IV | *GS | Winterkill |
| Borah | IV | BG | No sample |
| Bush | IV | *BG | Summerkill |
| Grosz | IV | *BB | Pond dry |
| Halstead | IV | *GS | Winterkill |
| Herren | IV | BG | No sample |
| Hemmingson | IV | BG | No sample |
| Koerner | IV | BG | No sample |
| McMurry | IV | *Only | No sample |
| Murphy | IV | *BB | Winterkill |
| Paulson | IV | BG | Pond dry |

*Ponds used in discriminant analysis (group 2)

Appendix Table 3. Estimated back-calculated total lengths (mm) at each annulus and relative weights ($W_r$) of bluegills (*Lepomis macrochirus*) for ponds in South Dakota sampled in 1981 and 1982.

| POND OWNER | AGE-CLASS | NUMBER OF FISH | $W_r$ | ANNULUS 1 | 2 | 3 |
|---|---|---|---|---|---|---|
| 1981 (SE) | | | | | | |
| Amdahl | II | 2 | 143 | 50 | 151(125)[1] | |
| Bush | II | 39 | 129 | 50 | 147( 97) | |
| Edgecomb | II | 36 | 121 | 47 | 145( 92) | |
| Hinricker #3 | II | 36 | 123 | 47 | 130( 66) | |
| 1981 (SW) | | | | | | |
| Frantz #3 | II | 39 | 113 | 51 | 155(124) | |
| Hauk | II | 43 | 129 | 44 | 122( 70) | |
| Olson #4 | II | 34 | 116 | 46 | 149(107) | |
| Olson #6 | II | 35 | 109 | 49 | 143( 88) | |
| 1982 (Statewide) | | | | | | |
| Edgecomb | I | 28 | 109 | 49( 6) | | |
| | II | 4 | 114 | 71 | 96( 29) | |
| | III | 35 | 116 | 43 | 137 | 155(122) |
| Hauk | III | 20 | 133 | 44 | 110 | 145(109) |
| Hinricker | I | 20 | 93 | 69( 9) | | |
| #3 | II | - | - | - | - | |
| | III | 10 | 124 | 48 | 124 | 159(163) |
| Pollman | I | 20 | 86 | 57( 7) | | |
| Thompson #2 | I | 42 | 117 | 82(33) | | |

[1]Average weight at capture in grams

Appendix Table 4. Bluegills (*Lepomis macrochirus*) and black bullheads (*Ictalurus melas*) population and standing stock estimates from eastern South Dakota ponds during the spring, 1981.

| Species and Pond Owner | Number Stocked | Date Marked | Cummulative Number Marked | Total Catch During Recapture | Number of Recaptures | Population Estimate | 95% Confidence Interval | Standing Stock (kg/ha) |
|---|---|---|---|---|---|---|---|---|
| Bluegill | | | | | | | | |
| Amdahl | 450 | 6/03 | 2 | 1 | 1 | 3 | | 0.95 |
| Bush | 985 | 4/22 | 78 | 38 | 16 | 181 | 118-243 | 21.90 |
| Edgecomb | 830 | 5/05 | 218 | 93 | 70 | 383 | 280-468 | 37.60 |
| Hinricker #3 | 500 | 4/28 | 215 | 38 | 21 | 290 | 256-323 | 63.70 |
| Black Bullhead (age-2) | | | | | | | | |
| Hanson | 840 | 5/18 | 2 | 12 | 0 | 39 | -12-91 | 0.25 |
| Hinricker #2 | 620 | 4/27 | 175 | 184 | 92 | 350 | 300-400 | 137.50 |
| Johnson #2 | 340 | 6/12 | 72 | 69 | 60 | 84 | 77-91 | 57.60 |
| Murphy | 400 | 5/21 | 186 | 163 | 159 | 192 | 187-197 | 122.00 |
| Black Bullhead (age-1) | | | | | | | | |
| Hinricker #2 | | 4/27 | 605 | 3287 | 470 | 4230 | 3877-4583 | 138.30 |
| Johnson #2 | | 6/12 | 320 | 1235 | 188 | 2099 | 1834-2374 | 87.00 |
| Murphy | | 5/21 | 1000 | 1050 | 41 | 25049 | 17713-32385 | 275.70 |

Appendix Table 5. Estimated back-calculated total lengths (mm) at each annulus and relative weights ($W_r$) of black bullheads (*Ictalurus melas*) for ponds in South Dakota sampled in 1981 and 1982.

| POND OWNER | AGE-CLASS | NUMBER OF FISH | $W_r$ | ANNULUS 1 | 2 | 3 |
|---|---|---|---|---|---|---|
| 1981 (SE) | | | | | | |
| Hinricker | I | 35 | 106 | 71(21) | | |
| #2 | II | 29 | 102 | 96 | 245(247) | |
| Johnson | I | 36 | 100 | 77(14) | | |
| #2 | II | 33 | 96 | 92 | 244(233) | |
| Murphy | I | 33 | 105 | 43( 3) | | |
| | II | 38 | 89 | 81 | 235(191) | |
| 1981 (SW) | | | | | | |
| Olson #1 | II | 36 | 96 | 105 | 254(277) | |
| Olson #3 | I | 14 | 78 | 77(13) | | |
| | II | 34 | 97 | 89 | 201(148) | |
| Willinski | II | 32 | 98 | | 256(302) | |
| 1982 (North) | | | | | | |
| Allerding | III | 2 | 106 | - | 199 | 248(265) |
| Cronin | I | 20 | 81 | 62( 4) | | |
| | II | 9 | 92 | 58 | 155( 58) | |
| | III | 39 | 101 | 70 | 161 | 231(217) |
| Hoff | III | 35 | 101 | - | 156 | 208(146) |
| Merkel #2 | I | 3 | 185 | 70(16) | | |
| | III | 11 | 108 | 73 | 152 | 206(158) |
| Hanson | I | 18 | 101 | 64( 4) | | |
| 1982 (South) | | | | | | |
| Hinricker | II | 14 | 88 | 93 | 141( 75) | |
| #2 | III | 36 | 83 | 106 | 249 | 259(233) |
| Olson #3 | I | 17 | 86 | 80(13) | | |
| | II | 34 | 99 | 68 | 140( 57) | |
| | III | 36 | 109 | 109 | 243 | 269(339) |
| Willinski | II | 1 | 114 | 51 | 149(140) | |
| | III | 4 | 92 | 70 | 197 | 265(330) |

1Average weight at capture in grams

Appendix Table 6. Major independent variables discriminating ponds that contained a fish population (group 1) and ponds that had complete mortality (group 2) after three years.

| GROUP | NUMBER OF PONDS | % CORRECTLY CLASSIFIED | MAJOR DISCR. VARIABLE a AND WILKS' LAMBDA ( ) b | | GROUP MEANS 1 | 2 |
|---|---|---|---|---|---|---|
| Largemouth bass | | | | | | |
| | | | Turbidity | (.8845) | 26 | 42 |
| 1 | 9 | 67 | Conductivity | (.8756) | 725 | 542 |
| | | | Area | (.8634) | 0.7 | 0.9 |
| 2 | 10 | 70 | Carbonates | (.8529) | 17.8 | 11.0 |
| | | | Depth | (.8384) | 3.0 | 2.8 |
| Bluegill | | | | | | |
| | | | *Depth | (.5204) | 3.6 | 1.9 |
| 1 | 7 | 100 | *Conductivity | (.2954) | 957 | 770 |
| | | | Turbidity | (.2687) | 65.8 | 30.7 |
| 2 | 6 | 100 | Carbonates | (.2633) | 37.1 | 16.7 |
| | | | Area | (.2584) | 1.0 | 0.6 |
| Black Bullhead | | | | | | |
| | | | Carbonates | (.8045) | 22.8 | 2.0 |
| 1 | 7 | 86 | Area | (.7060) | 1.0 | 0.7 |
| | | | Conductivity | (.6062) | 725 | 795 |
| 2 | 5 | 100 | Turbidity | (.5848) | 72.4 | 179 |
| | | | Depth | (.5846) | 3.1 | 2.5 |
| All Species | | | | | | |
| | | | *Depth | (.8899) | 3.2 | 2.4 |
| 1 | 23 | 65 | Carbonates | (.8368) | 25.2 | 10.5 |
| | | | Area | (.8123) | 0.9 | 0.8 |
| 2 | 21 | 71 | Conductivity | (.8105) | 796 | 688 |
| | | | Turbidity | (.8101) | 42 | 82 |

[a]Major independent discriminating variables are listed in the order of their ability to discriminate between groups. The ability of each variable is dependent on the ability of the variables listed prior to it.

[b]Inverse measure of the discriminatory power of the variables which had not yet been removed by the function.

*Significant at the 0.05 level of probability.