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Initial Growth and Survival of Bluegills and Black Bullheads Stocked With Largemouth Bass in South Dakota Ponds

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INITIAL GROWTH AND SURVIVAL OF BLUEGILLS AND BLACK BULLHEADS STOCKED WITH LARGEMOUTH BASS IN SOUTH DAKOTA PONDS

BY

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INITIAL GROWTH AND SURVIVAL OF

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IN SOUTH DAKOTA 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.

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INITIAL GROWTH AND SURVIVAL OF BLUEGILLS AND BLACK BULLHEADS STOCKED WITH LARGEMOUTH BASS IN SOUTH DAKOTA PONDS

Abstract

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Initial growth and survival rates were estimated for bluegills (Lepomis macrochirus) and black bullheads (Ictalurus melas) stocked simultaneously with largemouth bass (Micropterus salmoides) in ponds throughout South Dakota. Mean first year survival for bluegills and black bullheads stocked in eastern South Dakota ponds was 28.6% and 67.7%, respectively. Differences in first year bluegill growth throughout the state were not detected. Total lengths for bluegills averaged 52.4 mm after one growing season statewide and 137.1 mm after two growing seasons in southeastern South Dakota ponds. Significant ($P < .05$) geographical differences in first year growth of black bullheads were detected with mean lengths ranging from 67.7 mm in northwest ponds to 116.6 mm in southeast ponds. The average total length for black bullheads after two growing seasons in southeastern South Dakota ponds was 215.2 mm. The combined effects of pH, turbidity, and bicarbonate alkalinity accounted for 67.5% of the variation in first year bluegill growth. The pond parameters total number of growing days, fish present prior to stocking, and pond surface area when combined accounted for 73.9% of the variation in first year black bullhead

growth. Differences in bluegill relative weight values were not detected throughout South Dakota; the average for the state was 105.2. Mean black bullhead condition factors (K) for fish with total lengths between 128 and 191 mm were 1.85 and 1.45 for pre- and post-spawning periods, respectively. Bullheads probably spawned between 29 May and 26 June 1980.

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INTRODUCTION

Within South Dakota approximately 45,300 ponds 0.4 to 4.0 ha (1 to 10 acres) in size have been constructed since 1935 (personal communication: Soil Conservation Service). For effective utilization of this pond fishery potential the need exists for development of optimum stocking strategies maximizing fish production. The largemouth bass (*Micropterus salmoides*) is often stocked in South Dakota ponds; therefore characteristics associated with panfish species stocked in combination with largemouth bass need to be investigated.

Largemouth bass and bluegill (*Lepomis macrochirus*) have been the most successful pondfish species combination stocked in several areas of the United States (Regier 1962; Bennett 1970; Modde 1980). Swingle (1949) found that bluegills produced the highest bass production over a three year period in Alabama ponds. However, studies conducted in northern states such as Indiana (Krumholz 1950), Michigan (Ball and Tait 1952), New York (Regier 1963), and Illinois (Bennett 1970) have demonstrated that bluegills often overpopulate when stocked with largemouth bass. Shorter growing seasons in northern parts of the country result in bluegill reproduction one year earlier than bass when fishes are stocked simultaneously. The influx of large bluegill numbers one year prior to bass spawning results in lowered bass recruitment, a result of predation by yearling bluegills on bass fry and embryos. Low bass recruitment results in reduced predation on bluegills and eventual bluegill overcrowding and stunting (Bennett 1970; Eipper and Regier 1962). As an alternative, other forage species have been recommended for stocking with bass in geographical regions where differences in growing season, pond size, and angling pressure and preferences differ from those in the southeast (Swingle 1970).

The black bullhead (*Ictalurus melas*) has often been stocked in ponds because it reproduces successfully and is easily caught by inexperienced anglers with simple tackle (Moorman 1957). Bullheads were the fourth most often fished for, and the sixth most preferred fish species, by all anglers in South Dakota (Volk and Montgomery 1973). However, the stocking of bullheads with bass in ponds has been questioned because of the tendency for bullheads to overpopulate. Brown and Thoreson (1951) and Krumholz (1950) stated that black bullheads should not be stocked with bass in Montana and Indiana ponds, respectively, because of their reproductive potential. Contrary to this, Moorman (1957), stated that bullheads become overcrowded and stunted only when bass predation is insufficient to control excess recruitment. By stocking adult bullheads (1250/ha) and adult bass (300/ha) excess bullhead recruitment was controlled in Kansas ponds (Rickett 1976).

In South Dakota little information is available regarding pond stocking combinations. This study was conducted to determine initial growth and survival of bluegills and black bullheads when stocked in combination with largemouth bass in South Dakota ponds. Results will be useful in determining the bass-panfish combination which provides sustained quality angling.

METHODS

Study Area

The entire state of South Dakota was the study area. To allow for both climatological and physiographical comparisons in pond fisheries, the state was divided into four quadrants. Eastern and western quadrants were separated by the Missouri River, whereas latitude 44° 21' delineated the northern and southern quadrants (Figure 1). Descriptions of the topography, soils, and climate of South Dakota are presented in Westin and Malo (1978).

Design

Two fish combinations, largemouth bass-bluegill and largemouth bass-black bullhead, were stocked within four randomly selected ponds per quadrant, except in the southeastern quadrant (IV) where the bass-bluegill combination was stocked within eight randomly selected ponds. Four of the eight bass-bluegill ponds stocked in quadrant IV were orginally thought to be stocked with a bass-hybrid sunfish-green sunfish x bluegill (*Lepomis cyanellus* x *Lepomis macrochirus*)-fathead minnow (*Pimephales promelas*) combination; however, all sunfish were found to be bluegills. Study ponds selected were obtained from South Dakota Department of Game, Fish and Parks pond stocking applications or from direct contact with pond owners. The following criteria were used in selecting study ponds:

1) Water depth at least 3.05 - 3.66 m (10 - 12 ft)
2) Surface area 0.4 - 2.2 ha (1 - 5 acres)
3) Absence of fish in ponds prior to stocking.

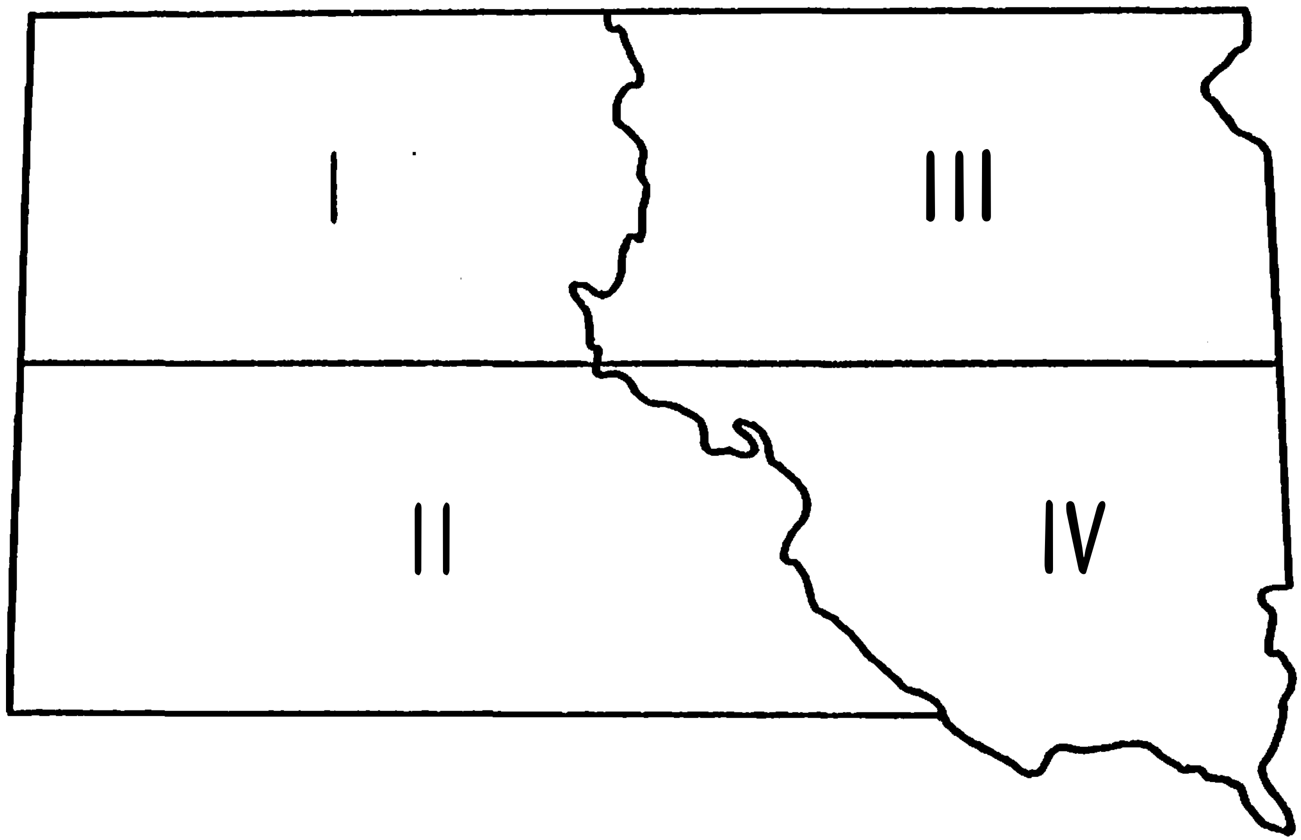

Figure 1. Map of South Dakota illustrating quadrant boundaries for the study of bluegills (*Lepomis macrochirus*) and black bullheads (*Ictalurus melas*) during 1979 and 1980.

The three species were stocked in the following sequence during the summer of 1979:

1) Largemouth bass (mean total length, TL 36.7 mm) were stocked 247/ha (100/acre) between 9-18 July.
2) Black bullheads (mean TL 34.1 mm) were stocked 988/ha (400/acre) between 24-28 July.
3) Bluegills were stocked 1236/ha (500/acre) on 15 August (mean TL 22.0 and 26.8 mm) and again between 22-24 August (mean TL 30.7 mm).

Field and Laboratory Techniques

Fish collections were made with an electro-shocker (230 volt A.C. generator), seines, and trap nets. Bullheads were collected with a 45.7 m x 2.4 m - 4.9 m (19.0 mm mesh) bag seine whereas bluegills were collected with a 25.9 m x 1.8 m (3.2 mm mesh) bag seine.

Spring populations were estimated for black bullheads in three ponds and bluegills in four ponds from the eastern quadrants (III and IV) between 7 May and 11 June 1980. The larger seine (45.7 m) was used to mark and recapture bullhead populations. Bullheads were marked by punching a hole in the upper lobe of their caudal fin with a small paper punch. Both the smaller seine (25.9 m) and electro-shocker were used to mark and recapture bluegills. Bluegills were marked by clipping a small portion of their upper caudal fin. Black bullhead spines, bluegill scales, and length-weight data for both species were collected from all study ponds between 8 May and 29 September 1980. Lengths of fishes from study ponds in the southeastern quadrant (IV) sampled between 11 and 29 September were used as an estimate of age II growth.

The left pectoral spine of bullheads was removed for growth analysis (Sneed 1951; Schoffman 1954; Marzolf 1955). To remove dead skin, bullhead spines were soaked in a 6% sodium hypochlorite solution. A dental separating disc fastened to a Dremel moto-tool mounted on a sliding platform was used to section spines. 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 spine along the longest radius.

Bluegill scales were removed from the lateral region near the tip of the pectoral fin (Everhart et al. 1975). A roller press was used to make acetate slide impressions of bluegill scales (Smith 1954). These impressions were read on an Eberbach scale reader. Measurements from the focus to annulus one and to the scale edge were recorded from the projected image.

Physical, chemical, and biological data were collected from each pond to determine their influence on growth. Data for all parameters, except growing days and fish present prior to stocking, were collected during the summer of 1980. Water hardness, turbidity, and alkalinity were measured using Hach kit procedures. Pond pH was estimated using wide and narrow range Hach pH wheels. Surface water temperature, salinity, and conductivity were measured using a Yellow Springs Instruments S-C-T meter. Pond surface area estimates were determined using a Gurney Explorers Alidade, stadia-rod, and planimeter. Mean daily air temperature data recorded at climatological stations near each pond were used to estimate growing days per pond. The number of post-stocking days in which the mean air temperature exceeded 10 C were totaled. Days were counted until the fall temperature dropped below 10 C for a period of 14 days. Black bullheads have been reported to actively feed at water temperatures above 10 C (Campbell and Branson 1978). Data on growing days were not computed for bluegills because these fish were stocked at three different mean total lengths (22.0, 26.8, and 30.7 mm). The presence of fish within study ponds prior to stocking was determined by seining the pond shorelines. Pond maximum depth was estimated using a weighted line graduated to the nearest tenth of a meter.

Analysis

Spring 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 recaptured marks in the sample.

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

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

was used to estimate population variance (Appendix Table 1). First year survival rates were calculated by dividing spring population estimates by the initial number stocked.

Black bullhead lengths at annulus one were back-calculated 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 bluegills at annulus one were back-calculated using the corrected Lee equation:

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

where:

L_n = back-calculated length at annulus

Sn = scale annulus length

Sc = scale radius length

Lc = length of fish at capture

a = correction factor (y-intercept).

A standard value of 20.0 mm (Carlander personal communication) was substituted for the y-intercept. A mean length at annulus one per pond was calculated for bluegills and black bullheads. Pond means were then averaged per quadrant. One-way analysis of variance tests for first year growth of both species were computed among quadrants. A Duncan's Multiple Range Test was used to determine where mean differences occurred.

Bullhead condition factors per fish were calculated using the equation:

$$K = W\ 10^5\ /\ L^3 \quad \text{(Carlander 1977)}$$

where:

K = condition factor

W = weight (g)

L = total length (mm).

Black bullhead mean condition factors (K) were calculated for fish within 15 mm length-groups during each of five 2-week periods from May to 7 August 1980. A two-way analysis of variance was computed for four bullhead length-groups. Treatments consisted of length-groups and sampling intervals. A least significant difference (LSD) mean comparison test was used to determine where differences occurred.

Bluegill condition values were calculated using the relative weight equation:

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

where:

W_r = relative weight

W = actual weight at sampling (g)

W_s = standard weight for fish of the same length.

Standard weights were obtained from the standard weight table found in Legler (1977). Relative weight is an index that allows for length-weight comparisons between individuals of different lengths within a species. If the relative weight value is greater than 100, a fish is in better condition than 75% of the fish of similar lengths recorded by Carlander (1977). Relative weight means were calculated per pond and averaged for quadrants. A one-way analysis of variance test for bluegill mean relative weights was computed among quadrants. Bluegill condition was not calculated for the Amdahl pond because of inaccurate weights due to small fish size at time of sampling.

Stepwise multiple regression was employed to determine which physical, chemical, or biological parameters (Table 1) had the greatest influence upon first year growth of black bullheads and bluegills. Bluegills in the Borah pond were not included in the multiple regression because this pond exhibited water loss due to atypical seepage. Linear correlations were also computed between the independent variables and first year growth of both species. Multiple regression, linear correlation, and analysis of variance tests were all computed using the SAS program package at the South Dakota State University Computer Center.

Table 1. Chemical, physical, and biological parameters estimated for South Dakota ponds during 1979 and 1980 which were used in bluegill (Lepomis macrochirus) and black bullhead (Ictalurus melas) first year growth multiple regression tests.

PARAMETERS
Fish Present Prior to Stocking
pH
Turbidity
Growing Days[1]
Hardness
Surface Area
Salinity
Total Alkalinity
Bicarbonate Alkalinity
Carbonate Alkalinity
Hydroxide Alkalinity
Conductivity
Pond Depth[2]

[1] Not included in the bluegill multiple regression.

[2] Not included in the bullhead multiple regression.

RESULTS

First Year Survival

Bluegill survival rates calculated for four eastern South Dakota ponds ranged from 5.8 to 68.8% with a mean of 28.6% (Table 2). Black bullhead initial survival estimated for three eastern South Dakota ponds ranged from 61.8 to 70.7% with a mean of 67.7% (Table 2).

First and Second Year Growth

Fish collections were obtained from 15 of the 16 originally stocked bullhead ponds and 14 of the 20 bluegill ponds (Figure 2). Winterkill, unwanted predator fish introductions, and inability to capture fish accounted for the missing data.

Mean black bullhead total length after the first growing season per quadrant ranged between 67.7 and 116.6 mm (Figure 3). Black bullheads stocked within the two northern quadrants (I and III) had the lowest mean first year growth. Standard deviations for pond means per quadrant ranged from 6.7 to 39.2. Mean bullhead length per pond ranged between 48.2 and 145.5 mm (Appendix Table 2).

A one-way analysis of variance for first year growth of black bullheads among quadrants had an observed significance level of .067. Since this analysis was nearly significant at the .05 probability level a Duncan's Multiple Range Test was computed among quadrant means. This test indicated a significant ($P < .05$) difference between quadrant I and quadrants II and IV.

Table 2. Mean first year survival rates of bluegills (*Lepomis macrochirus*) and black bullheads (*Ictalurus melas*) calculated for eastern South Dakota ponds during 1979 and 1980.

POND	QUADRANT	SPECIES	% SURVIVAL
Amdahl	III	BG[1]	5.8
Hinricher #3	IV	BG	20.2
Borah	IV	BG	19.8
Bush	IV	BG	68.8
			$\bar{x}$ = 28.6
Johnson #2	III	BB[2]	70.7
Hinricher #2	IV	BB	61.8
Murphy	IV	BB	70.6
			$\bar{x}$ = 67.7

[1] Bluegill

[2] Black bullhead

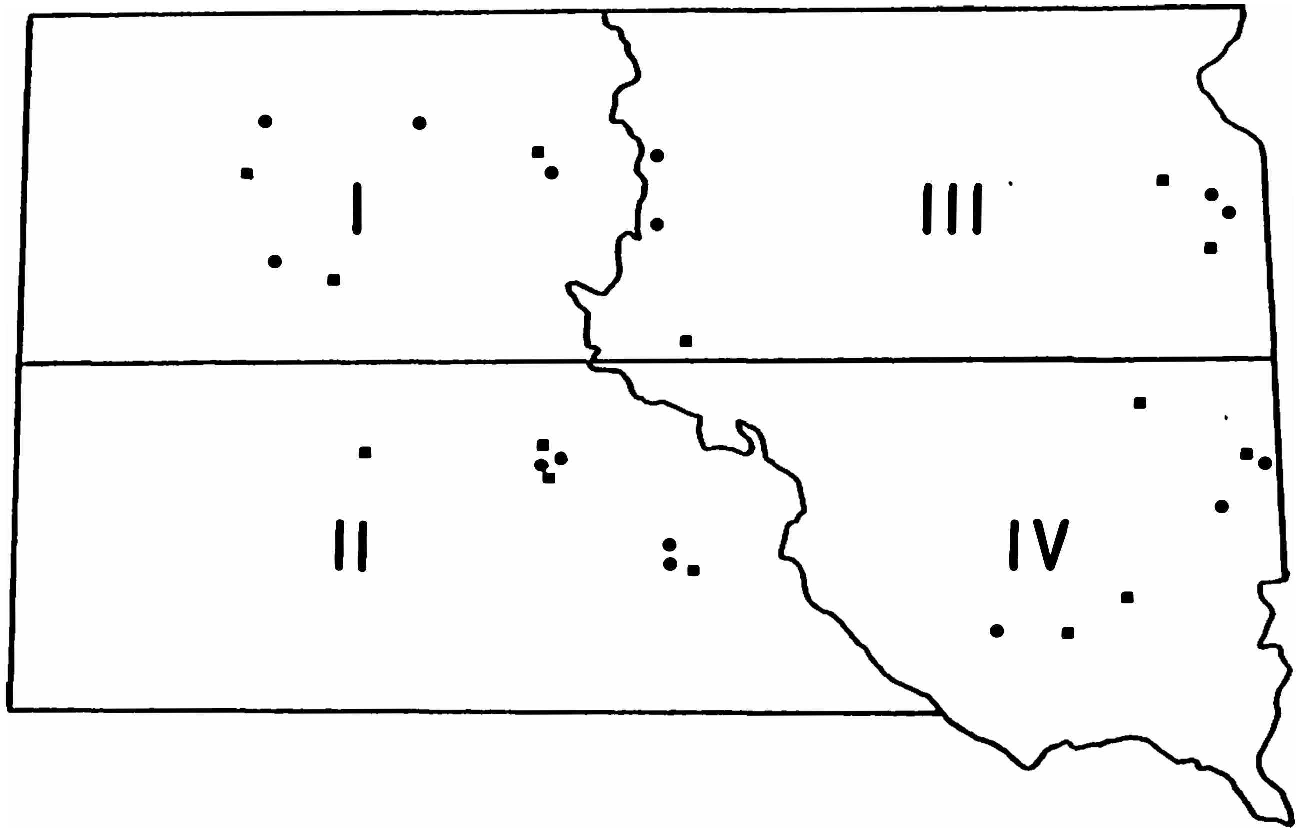

Figure 2. Locations of black bullhead (*Ictalurus melas*) (represented by circles) and bluegill (*Lepomis macrochirus*) (represented by squares) study ponds in South Dakota during 1980.

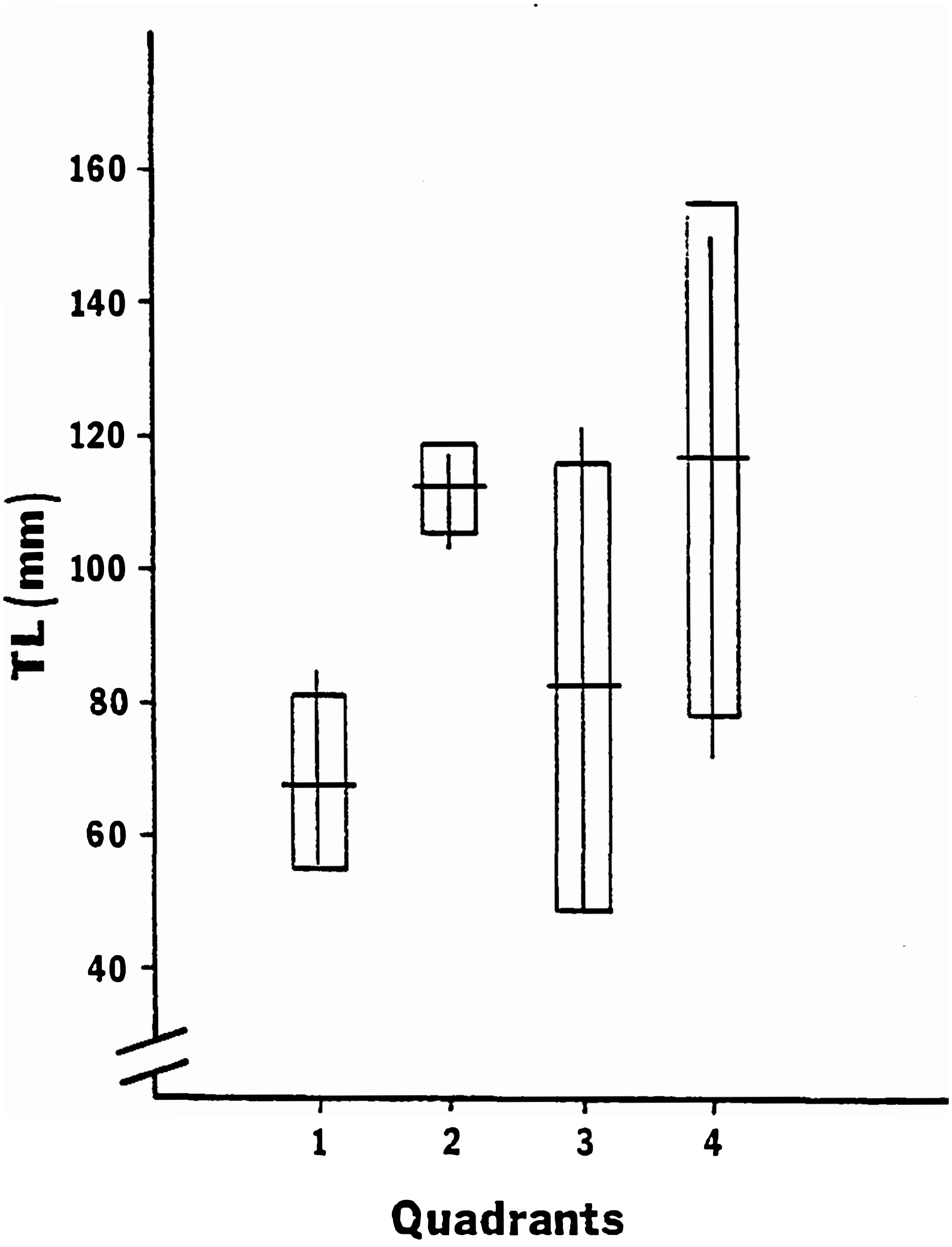

Figure 3. Ranges (vertical lines), standard deviations (rectangles), and means (horizontal lines) for total lengths (mm) associated with first year black bullhead <u>(Ictalurus melas)</u> growth per quadrant in South Dakota ponds during 1979.

Multiple regression between pond parameters and first year black bullhead growth indicated that three variables exhibited a significant ($P < .05$) relationship. The combined effects of three parameters, total number of growing days, fish present prior to stocking, and surface area accounted for 73.9% of the variation in first year black bullhead growth (Table 3). A linear correlation indicated that both growing days and surface area had a positive effect on growth while fish present prior to stocking had a negative effect (Appendix Table 3).

Black bullhead mean total lengths after two years ranged from 173.3 to 238.1 mm in southeastern South Dakota ponds (quadrant IV) (Appendix Table 4). The average total length for bullheads within quadrant IV ponds was 215.2 mm.

Mean bluegill total length after the first growing season per quadrant ranged from 48.5 to 58.5 mm with a statewide average of 52.4 mm (Figure 4). Standard deviations for pond means per quadrant ranged from 3.0 to 17.3. Mean bluegill length per pond ranged between 44.6 and 78.5 mm (Appendix Table 5).

A one-way analysis of variance for mean first year growth of bluegills among quadrants was not significant ($P > .05$). The analysis indicated no difference in mean growth for bluegills sampled statewide.

The stepwise multiple regression between pond parameters and first year bluegill growth indicated that three variables exhibited a significant ($P < .05$) relationship. The combined effects of three parameters, pH, turbidity, and bicarbonate alkalinity, accounted for 67.5% of the variation in first year bluegill growth (Table 4).

Table 3. Biological and physical variables significantly ($P < .05$) related to first year growth of black bullheads (*Ictalurus melas*) in South Dakota ponds, during 1979, as determined by stepwise multiple regression.

INDEPENDENT VARIABLES [a]	R^2 [b]	ΣR^2 [c]
Growing Days	.338	.338
Fish Present Prior To Stocking	.269	.607
Surface Area	.132	.739

[a] Variables are listed in order to entrance into the analysis.

[b] Variance explained by this variable.

[c] Accumulated variation in growth explained.

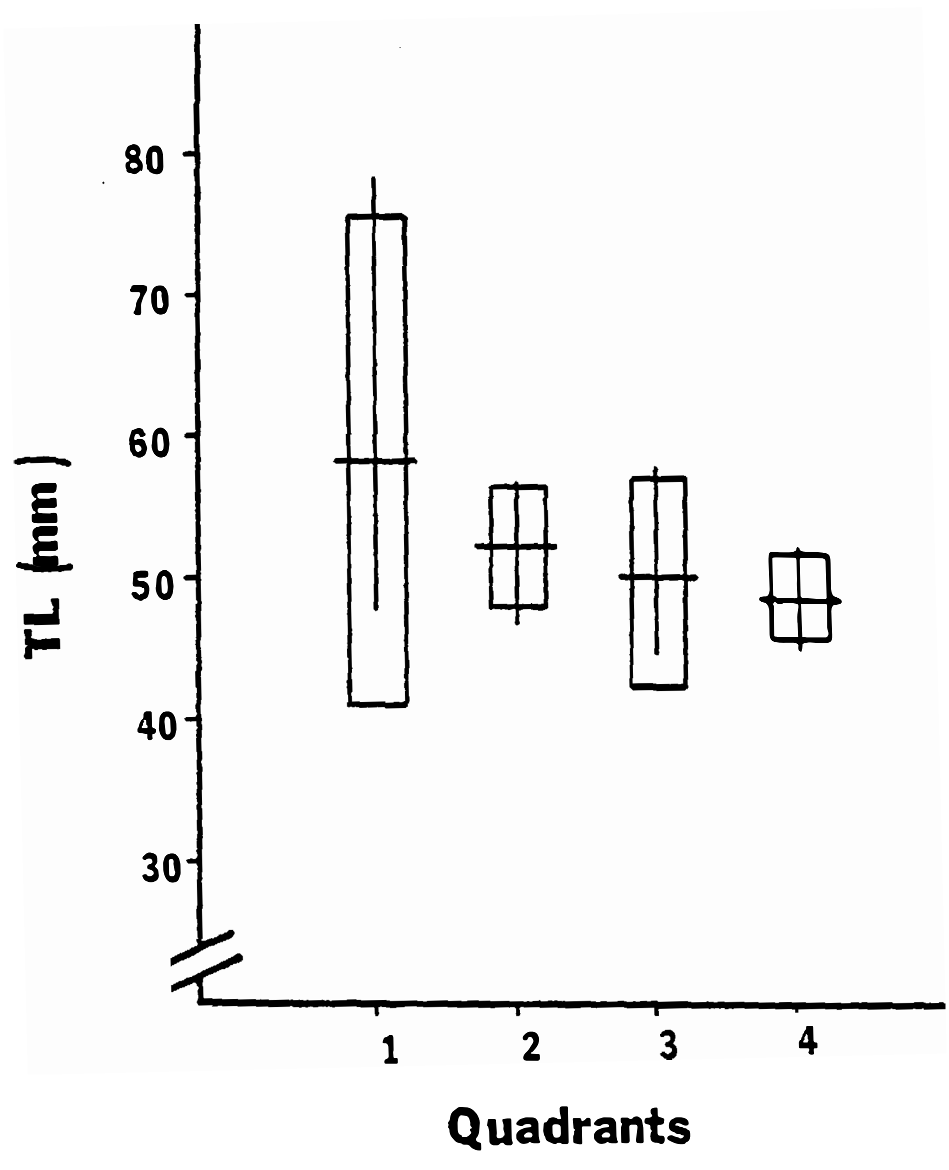

Figure 4. Ranges (vertical lines), standard deviations (rectangles), and means (horizontal lines) for total lengths (mm) associated with first year bluegill (*Lepomis macrochirus*) growth per quadrant in South Dakota ponds during 1979.

Table 4. Chemical and physical variables significantly ($P < .05$) related to first year growth of bluegills (*Lepomis macrochirus*) in South Dakota ponds, during 1979, as determined by stepwise multiple regression.

INDEPENDENT VARIABLES [a]	R^2 [b]	ΣR^2 [c]
pH	.151	.151
Turbidity	.131	.332
Bicarbonate Alkalinity	.343	.675

[a] Variables are listed in order to entrance into the analysis.

[b] Variance explained by this variable.

[c] Accumulated variation in growth explained.

Linear correlation indicated that both pH and turbidity had a negative effect on growth while bicarbonate alkalinity had a positive effect (Appendix Table 6).

Bluegill mean total lengths after two growing seasons ranged from 127.9 to 146.9 mm within southeastern South Dakota ponds (quadrant IV) (Appendix Table 4). The average total length for bluegills within quadrant IV ponds was 137.1 mm.

Condition

An increase in black bullhead condition was observed during May and declined sharply between 29 May and 26 June (Figure 5). Bullhead condition appeared to remain relatively stable from 26 June through 7 August. A two-way analysis of variance for mean bullhead condition indicated a significant interaction between sampling intervals and length-groups. Because of the interaction, length-groups were evaluated separately. Adjacent means per length-group were compared between sampling intervals using a Least Significant Difference (LSD) mean comparison test. Results indicated a significant difference in condition ($P < .001$) within all four length-groups between 29 May and 26 June. Results also indicated a significant difference ($P < .001$) within length-groups 128-143 mm and 144-159 mm between early and late May.

Bluegill average relative weight per quadrant ranged from 101.6 to 110.5 with a statewide average of 105.2 (Figure 6). Standard deviations for means per quadrant ranged from 4.2 to 8.0. Mean relative weight per pond ranged between 93.3 and 122.1 (Appendix Table 5). The one-way analysis of variance for relative weight means among quadrants

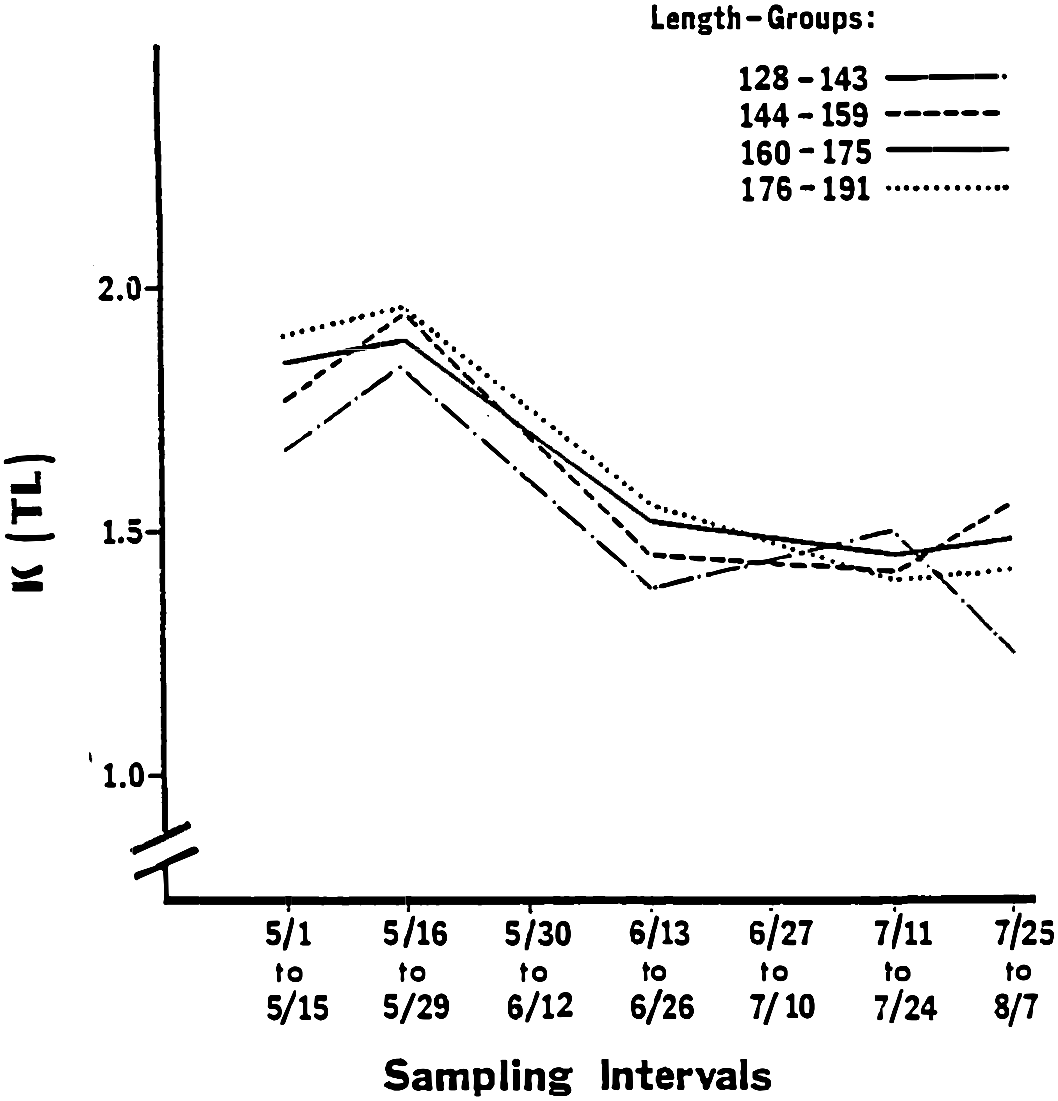

Figure 5. Mean condition factors K (TL) for black bullhead (Ictalurus melas) length-groups calculated throughout the 1980 summer in South Dakota ponds.

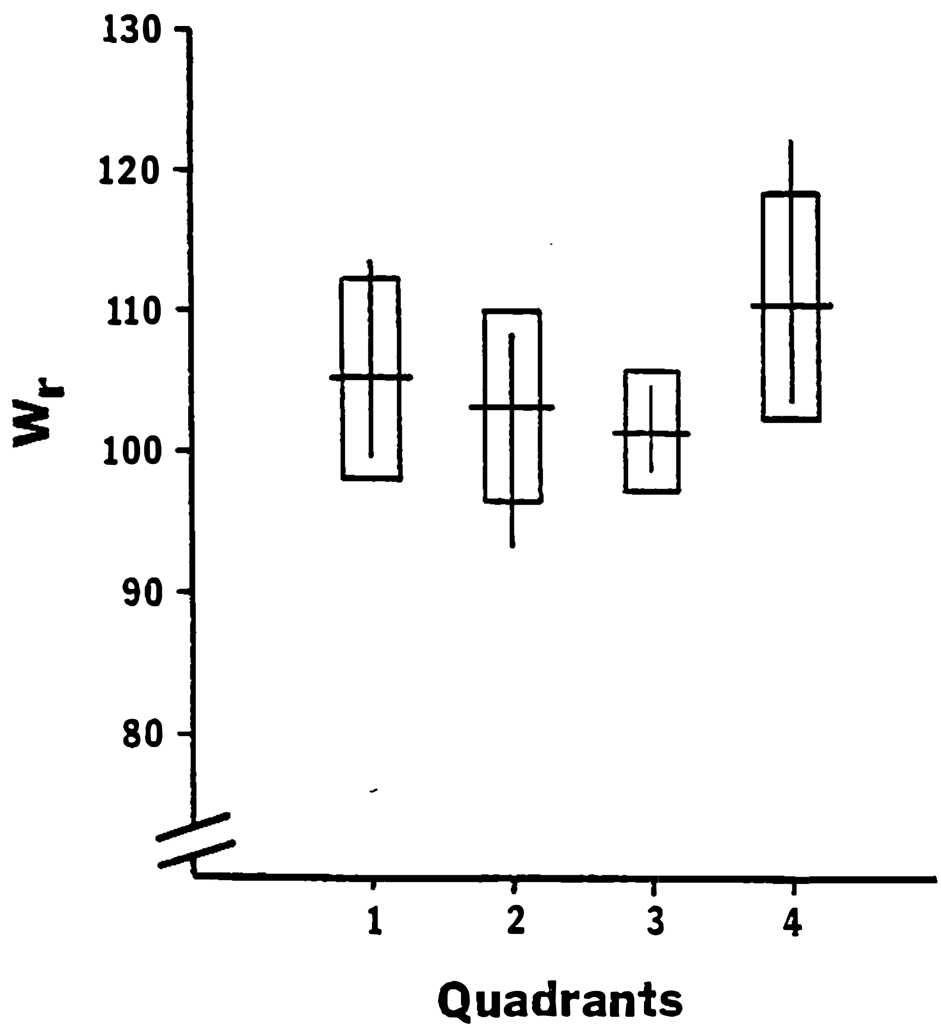

Figure 6. Mean relative weight condition (horizontal lines) and standard deviation (rectangles)-range (vertical lines) data for bluegills (*Lepomis macrochirus*) per quadrant in South Dakota ponds during 1980.

was not significant ($P > .05$). The analysis indicated no difference in mean relative weights for bluegills sampled statewide during the second growing season.

DISCUSSION

Mean first year survival for black bullheads in the present study (67.7%) was higher than expected. Moorman (1957) stated that bullheads usually become overcrowded and stunted when bass predation is insufficient to control their recruitment. Large numbers of bullheads may adversely affect largemouth bass growth and recruitments. Thus stocking rates play an important role in the success of this combination. High first year survival of bullheads combined with their reported tendency to overpopulate indicated that the stocking rate of 988/ha was too high. Bullhead fingerlings stocked at 247/ha, the rate recommended for channel catfish (Ictalurus punctatus) by most midwestern states (Modde 1980), would have a lesser tendency to overpopulate when stocked simultaneously with largemouth bass. Another possible alternative to lower bullhead reproduction and reduce the chance of overpopulation is to stock a small number of spent adult bullheads simultaneously with fingerling largemouth bass.

Mean first year survival for bluegills stocked in South Dakota (28.6%) was comparable with survival reported from Iowa and Missouri. Hill (1980) in Iowa observed a mean first year survival of 27.0% for bluegills split stocked (2471/ha) with bass in five privately owned ponds. Bluegills stocked (1236/ha) simultaneously with bass in six drainable Missouri ponds exhibited 44.0% survival between October 1974 and October 1975 (Novinger 1980). The higher reported bluegill percent survival in Missouri is possibly due to the fact that these fish were stocked in drainable more controlled ponds.

Mean lengths of 116.2 and 215.2 mm for black bullhead first and second year growth in southeast South Dakota ponds were higher than most growth rates for existing bullhead populations reported in the literature (Figure 7). The mean black bullhead total length of 215.2 mm for two years' growth in South Dakota ponds was a minimum estimate. For this study, growth of bullheads and bluegills after two growing seasons was determined from lengths of fishes collected in mid-September, prior to annulus formation. Black bullheads sampled from existing populations within Oklahoma ponds had mean back-calculated lengths at annuli one and two of 96.5 and 170.2 mm (Houser and Collins 1962). Moen (1959) reported that bullheads transferred from a crowded population showed excellent growth under uncrowded conditions. Slow growth within Oklahoma ponds was probably due to overcrowding. Mean lengths of 109.2 and 167.6 mm were calculated for first and second year bullheads sampled from Lake Ashtabula, North Dakota (Owen and Wahtola 1970). Bullheads in southern South Dakota lakes had mean back-calculated lengths at annuli one and two of 119.4 and 190.5 mm (Boussu 1959). Rapid growth rates observed in southeastern South Dakota ponds were probably due to low population densities and an initially unexploited food supply.

Lengths of bullheads in early May from two southeastern South Dakota ponds were equivalent to the minimum harvestable size, (152.4 mm) for bullheads (Moorman 1957). Thus, there exists a potential for the development of a bullhead fishery after one growing season in southern South Dakota. By reducing the stocking rates, even faster growth may be possible.

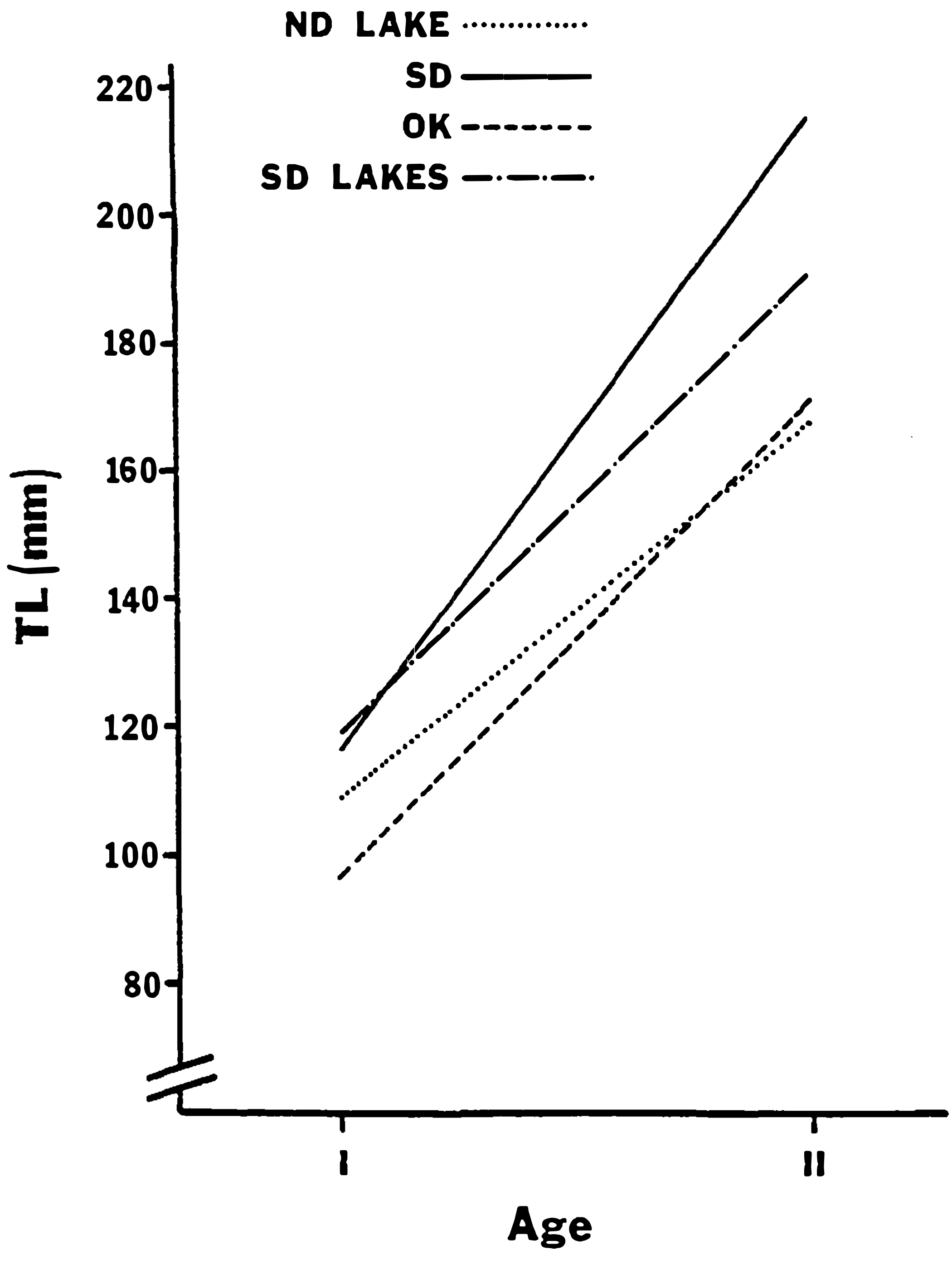

Figure 7. Comparison of mean first and second year growth of black bullheads (*Ictalurus melas*) during 1979 and 1980 in southeastern South Dakota ponds with growth in southern South Dakota lakes (Boussu 1959), Oklahoma ponds (Houser and Collins 1962), and Lake Ashtabula, North Dakota (Owen and Wahtola 1970).

No differences were detected in bluegill first year growth among quadrants of the state. Carlander (1977) observed a decreasing trend in bluegill growth rates with increasing latitude. The absence of latitudinal differences in growth of bluegills in South Dakota ponds may be due to the short number of growing days following stocking dates (15-24 August 1979).

The mean values of 52.4 and 137.1 mm for first and second year growth of bluegills in South Dakota ponds were compared with growth data from similar studies conducted in Missouri and Iowa (Figure 8). Hill (1977) reported that bluegills stocked in Iowa ponds exhibited a mean length of 38.0 mm after the first year and 132.0 mm after the second year of growth. Stocked bluegill in Missouri ponds were 41.0 mm at annulus one and 122.0 mm at annulus two (Novinger 1980). Growth during the second growing season for bluegills stocked in Missouri ponds paralleled that observed in South Dakota; however, bluegills stocked in Iowa exhibited a slightly higher rate. Mean lengths after the first year were lower in Missouri and Iowa. This difference can be explained by stocking dates. Bluegills were stocked in South Dakota ponds during late August, whereas the other two states stocked bluegills in October.

The significant difference in first year black bullhead growth between the northwest quadrant (I) and south quadrants (II and IV) can be explained primarily by differences in growing season. The highest growth observed in the southeast and the lowest in the northwest coincided with climatological trends within the state. Westin and Malo (1978) observed a decreasing trend in the length of growing season from the southeast to northwest South Dakota. No significant ($P > .05$)

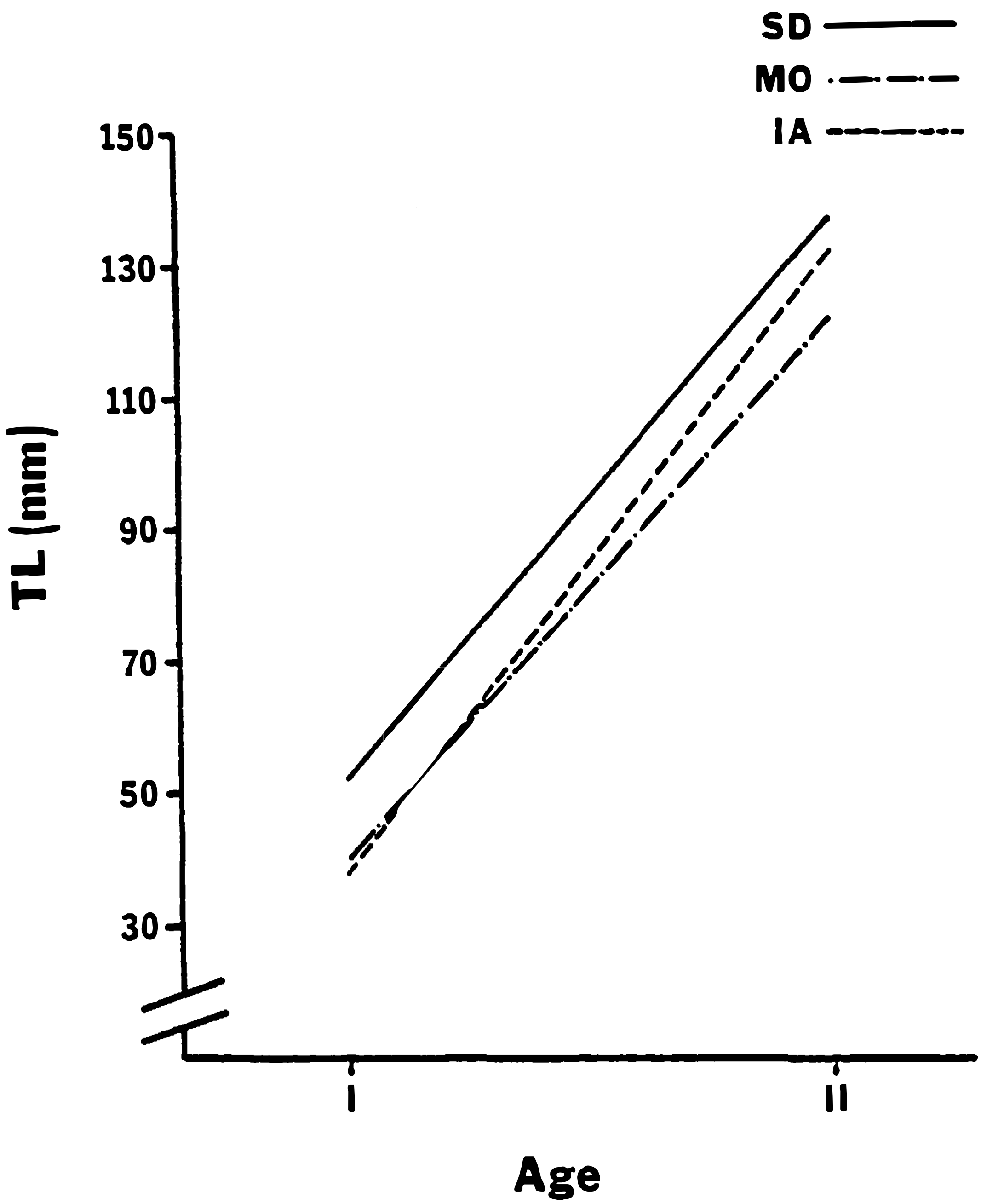

Figure 8. Mean first and second year growth of bluegills (Lepomis macrochirus) during 1979 and 1980 in South Dakota ponds compared with growth in Missouri (Novinger 1980) and Iowa (Hill 1977) ponds.

differences in mean bullhead first year growth between the northeast quadrant (III) and south quadrants (II and IV) were detected. This can be explained by the fact that two of the four bullhead ponds in quadrant III exhibited a high number of growing days equivalent to those observed in the southeast quadrant (IV) (Appendix Table 7). The presence of fish prior to stocking had a negative effect on growth and accounted for a significant ($P < .05$) proportion of the variation in bullhead first year growth when combined with the effects of growing days and surface area. The negative impact probably resulted from competition for a reduced food supply within ponds containing existing populations of fish.

Combined, the parameters, pH, turbidity, and bicarbonate alkalinity accounted for a significant ($P < .05$) proportion of the variation in bluegill first year growth. Turbidity and pH negatively affected growth while bicarbonate alkalinity had a positive effect. Swingle (1961 cited in Boyd 1979) stated that the desirable pH range for fish production is between 6.5 and 9.0. Sampled pH values ranged from 7.8 to 9.1 in bluegill ponds (Appendix Table 7). Observed pH values which exceeded 9.0 could explain the negative effect pH had on bluegill growth. Buck (1956) and Hastings and Cross (1962) observed a negative relationship between turbidity and bluegill growth. Carlander (1955) reported a positive correlation between carbonate content of water and standing crop of fish within midwestern warmwater lakes.

The initial rise in black bullhead condition between 1 and 29 May and subsequent decline between 29 May and 26 June can be attributed to differences between pre-spawning and post-spawning gonadal development. Mean condition for all four length-groups increased from 1.80 to 1.91

during May. Campbell and Branson (1978) reported a substantial increase in gonadal weight to body weight ratios for female black bullheads during the pre-spawing period in Kentucky lakes. They reported that gonads were at their lowest absolute weight during the post-spawning period. A similar decrease in condition was observed in the present study where mean condition factors decreased from 1.85 in May to 1.45 between 13 June and 7 August. Bullhead spawning in the present study probably occurred sometime between 29 May and 26 June. Boussu (1959) stated that the peak spawning period for black bullheads in southern South Dakota lakes apparently extends from the latter part of May through mid-June. This period coincides with the drop in condition and assumed spawning period for black bullheads in South Dakota ponds.

The mean pre- and post-spawning bullhead condition factors from this study were higher than most K factors for similar length black bullheads reported in the literature. Boussu (1959) recorded a mean condition of 1.43 for black bullheads in southern South Dakota lakes, and in Iowa ponds, a mean K factor of 1.25 was recorded by Carlander (1969). Higher bullhead condition factors for newly stocked ponds, compared to those obtained from existing populations, is expected because of low population numbers and an initially unexploited food supply.

Bluegills stocked in South Dakota ponds were also in good condition after one year. The mean relative weight for bluegills in South Dakota ponds of 105.2, indicates that these fish were in better condition than 75% of the bluegills of similar lengths reported by Carlander (1977).

Differences in bluegill relative weight values due to spawning were not detected; however, young-of-the-year bluegills were observed in at least one southeastern pond (i.e. Bush pond). Age I bluegill spawning occurred in 100% of the Iowa study ponds by mid-July or early August (Hill 1977). Mean total lengths for age I bluegills in South Dakota ponds were similar to or greater than those reported by Hill (1977).

SUMMARY AND CONCLUSIONS

1) Mean black bullhead and bluegill first year survival estimates for eastern South Dakota ponds were 67.7% and 26.8%, respectively.

2) High bullhead survival during the first year indicates that either the stocking rate should be reduced to approximately 247/ha, or a small number of spent adult bullheads should be stocked simultaneously with fingerling largemouth bass.

3) Black bullhead mean first year growth significantly differed between the northwest quadrant (I) and southern quadrants (II and IV), whereas no significant differences in bluegill mean first year growth were detected throughout the state.

4) Within southern South Dakota ponds there exists a potential for a bullhead panfish fishery after one growing season.

5) The combined effects of pH, turbidity, and bicarbonate alkalinity were important to bluegill first year growth, whereas growing days, fish present prior to stocking, and surface area were important to black bullhead first year growth.

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APPENDIX

Appendix Table 1. Modified Peterson population estimates and confidence intervals for bluegills (*Lepomis macrochirus*) and black bullheads (*Ictalurus melas*) sampled from eastern South Dakota ponds during the spring, 1980.

POND	QUADRANT	SPECIES	MARKING DATES	CUMULATIVE NUMBER MARKED	RECAPTURE DATES	TOTAL CATCH DURING RECAPTURE	NUMBER OF RECAPTURES	POPULATION ESTIMATE	CONFIDENCE INTERVAL (95%)
Amdahl	III	BG[1]	6/3	10	6/9	6	2	26	6-46
Rozah	IV	BG	6/10	83	6/11	67	31	179	134-224
Bush	IV	BG	5/14 and 5/19	29	5/27	12	1	195	(-8)-398
Hartleber #3	IV	BG	5/30 and 6/2	128	6/6	31	11	364	196-492
Johnson #2	III	BB[2]	5/21	164	6/3	185	127	240	216-264
Hartleber #2	IV	BB	5/7 and 5/8	229	5/30	54	32	381	301-465
Murphy	IV	BB	5/12	272	5/27	217	209	281	275-291

[1] Bluegill

[2] Black bullhead

Appendix Table 2. Black bullhead (*Ictalurus melas*) mean total lengths (mm) at annulus one for South Dakota ponds during 1979.

POND	QUADRANT	DATE SAMPLED (1980)	SAMPLE SIZE	MEAN LENGTH (mm)
Hoff	I	7/16	35	85.7
Merkel	I	7/19	4	67.9
Scofield #3	I	7/15	29	55.9
Shambo #1	I	7/17	13	61.2
				$\bar{x}$ = 67.7
Calhoon #4	II	6/22	12	117.8
Olson #1	II	6/26	7	112.0
Olson #3	II	6/24	30	102.9
Wilinski	II	6/23	22	116.2
				$\bar{x}$ = 112.2
Allerding	III	7/29	29	60.8
Croin	III	7/29	3	48.2
Hansen	III	5/22	41	98.2
Johnson #2	III	5/21	30	121.6
				$\bar{x}$ = 82.2
Grosz	IV	9/25	27	72.0
Hinricher #2	IV	5/8	24	145.5
Murphy	IV	5/12	35	132.5
				$\bar{x}$ = 116.6

Appendix Table 3. Linear correlation coefficients between black bullhead (*Ictalurus melas*) mean total lengths at annulus one and South Dakota pond parameters estimated during 1979 and 1980.

RANK	PARAMETERS	CORRELATION COEFFICIENT
1	Growing Days	.581*
2	Turbidity	-.489
3	Fish Present Prior to Stocking	-.472
4	Hardness	.197
5	pH	-.130
6	Surface Area	.126
7	Salinity	-.117
8	Total Alkalinity	.111
9	Bicarbonate Alkalinity	.092
10	Hydroxide Alkalinity	-.067
11	Carbonate Alkalinity	.028
12	Conductivity	.021

* Significant ($P < .05$)

Appendix Table 4. Mean total length (mm) for bluegills (*Lepomis macrochirus*) and black bullheads (*Ictalurus melas*) after two growing seasons in southeastern South Dakota ponds during 1980.

POND	SPECIES	SAMPLE SIZE	DATE SAMPLED	MEAN TOTAL LENGTH (mm)
Borah	BG[1]	32	9/11	127.9
Bush	BG	33	9/24	145.9
Edgecomb	BG	30	9/19	146.6
Hinricher #3	BG	30	9/16 and 9/29	128.1
				$\bar{x}$ = 137.1
Grosz	BB[2]	27	9/25	173.3
Hinricher #2	BB	26	9/12	238.1
Murphy	BB	34	9/12	234.3
				$\bar{x}$ = 215.2

[1] Bluegill

[2] Black bullhead

Appendix Table 5. Mean bluegill (Lepomis macrochirus) total lengths (mm) at annulus one during 1979 and relative weight values during 1980 from South Dakota ponds.

POND	QUADRANT	DATE SAMPLED (1980)	SAMPLE SIZE	MEAN LENGTH (mm)	MEAN (W_r)
Imsland	I	7/15	30	48.1	102.9
Thompson #2	I	7/18	35	78.5	113.6
Van Den Berg	I	7/16	31	48.9	99.8
				$\bar{x}$ = 58.5	$\bar{x}$ = 105.4
Frantz #3	II	6/21	31	57.2	108.2
Hauk	II	6/27	29	46.9	93.3
Olson #4	II	6/25	31	51.7	106.9
Olson #6	II	6/25	30	53.7	105.2
				$\bar{x}$ = 52.4	$\bar{x}$ = 103.4
Amdahl[1]	III	6/3 and 6/9	10	58.2	----
Pollman	III	7/28	16	47.4	104.6
Sherman	III	7/29	16	44.6	98.6
				$\bar{x}$ = 50.1	$\bar{x}$ = 101.6
Borah	IV	9/11	30	44.9	108.7
Bush	IV	9/24	32	52.3	122.1
Edgecomb	IV	9/19	30	48.6	103.7
Hinricher #3	IV	9/16 and 9/29	30	48.1	107.7
				$\bar{x}$ = 48.5	$\bar{x}$ = 110.5

[1] Bluegill relative weight values were not calculated for the Amdahl pond because of inaccurate weights due to small fish size at time of sampling.

Appendix Table 6. Linear correlation coefficients between bluegill (*Lepomis macrochirus*) mean total lengths at annulus one and South Dakota pond parameters estimated during 1979 and 1980.

RANK	PARAMETERS	CORRELATION COEFFICIENTS
1	Fish Present Prior To Stocking	-.426
2	pH	-.389
3	Carbonate Alkalinity	-.311
4	Surface Area	-.296
5	Bicarbonate Alkalintiy	.197
6	Turbidity	-.188
7	Pond Depth	.164
8	Salinity	.089
9	Conductivity	.087
10	Hardness	.086
11	Total Akalinity	.060

Appendix Table 7. Biological, physical, and chemical data collected from South Dakota bluegill (*Lepomis macrochirus*) and black bullhead (*Ictalurus melas*) ponds during 1979 and 1980.

	Species	Number Stocked	Quadrant	Date Sampled (1980)	Pond Temp. (C)	pH	Salinity o/oo	Turbidity (JTU's)	Hardness (mg/l)	Total Alkalinity (mg/l)	Carbonate Alkalinity (mg/l)	Bicarbonate Alkalinity (mg/l)	Hydroxide Alkalinity (mg/l)	Conductivity (umhos)	Ortho-phosphate (mg/l)	Surface Area (ha)	Maximum Depth (m)	Fish Present[1]	Growing Days (1979)
Iseland	BG[2]	1750	I	7/15	23	7.8	0.0	265	50	120	0	120	0	210	.76	.33	1.68	0	-
Thompson #2	BG	1250	I	7/18	26	8.0	0.1	30	100	150	0	150	0	310	-	.33	2.9	0	-
Van Den Berg	BG	1500	I	7/16	22	8.4	0.0	30	70	200	0	200	0	345	.6	.13	0.91	0	-
Frantz #3	BG	1500	II	6/21	28	8.9	2.0	20	1400	60	60	0	0	3900	.45	1.11	5.49	0	-
Hauk	BG	2500	II	6/27	25	9.0	0.0	40	70	110	60	50	0	250	.5	1.13	4.27	1	-
Olson #4	BG	1000	II	6/25	25	9.0	1.0	15	140	70	20	50	0	1850	.4	.29	2.0	0	-
Olson #6	BG	1500	II	6/25	32	8.7	0.1	20	120	110	20	90	0	720	.36	.48	2.13	0	-
Amdahl	BG	450	III	5/22	26	8.1	0.0	15	140	160	0	160	0	330	.075	.37	3.04	0	-
Pullman	BG	3000	III	7/28	29	9.1	0.4	35	140	110	100	10	0	650	.14	3.03	3.05	0	-
Sherman	BG	1645	III	7/9	31	9.1	0.1	25	160	90	60	30	0	350	.45	1.33	2.1	1	-
Bush	BG	985	IV	5/14	18	8.7	1.0	40	580	220	40	80	0	1150	.5	.8	2.29	1	-
Edgecomb	BG	830	IV	5/12	14	8.0	0.5	25	613	210	0	210	0	1050	.3	.67	3.81	1	-
Hinricher #3	BG	500	IV	5/7	14	8.5	0.0	50	130	140	0	140	0	210	.15	.4	2.74	1	-
Huff	BB[3]	2000	I	7/16	26	9.4	0.5	0	220	80	40	0	40	1225	.65	.78	1.83	0	90
Merkel #2	BB	560	I	7/9	22	7.6	0.1	380	100	80	0	80	0	337	-	.36	1.52	0	92
Scofield #3	BB	800	I	7/15	23	8.2	0.1	330	80	190	0	190	0	406	.35	.34	3.2	0	93
Shambo #1	BB	2000	I	7/17	26	8.2	0.2	500	160	180	0	180	0	461	-	.93	0.46	1	90
Calhoun #5	BB	1412	II	6/22	26	9.2	0.4	14	150	70	60	10	0	980	.45	1.43	4.0	0	94
Olson #1	BB	1200	II	6/26	24	8.8	1.2	15	500	50	10	40	0	2172	.45	.95	2.13	0	93
Olson #3	BB	1000	II	6/24	29	8.4	0.1	80	120	140	0	140	0	322	.4	.46	--	0	93
Wellinski	BB	524	II	6/24	26	7.9	0.0	150	110	170	0	170	0	281	.75	.53	--	0	94
Allerding	BB	240	III	7/29	27	9.1	0.1	40	90	90	60	30	0	267	.2	.2	1.52	0	92
Croin	BB	800	III	7/29	26	8.5	0.8	30	290	140	0	140	0	1201	.18	.81	4.88	1	92
Hansen	BB	840	III	5/22	18	8.2	0.2	20	350	360	0	360	0	678	.2	1.61	3.66	1	98
Johnson #2	BB	340	III	5/21	21	8.9	0.0	45	120	100	30	70	0	275	.6	.34	--	0	98
Grosz	BB	800	IV	9/25	15	8.8	0.0	30	230	180	0	180	0	529	.0	.81	4.57	1	98
Hinricher #2	BB	620	IV	5/7	15	7.8	0.0	15	230	200	0	200	0	443	.17	.63	4.27	0	97
Murphy	BB	400	IV	5/12	14	7.9	0.1	20	215	240	0	240	0	446	.25	.49	2.13	0	98

[1] (1) If fish were present prior to stocking, (0) if fish were absent prior to stocking

[2] Bluegill

[3] Black bullhead