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MEMORANDUM

To: Royce Huber, Mark Lindvall, and Wayne Stancill
From: Dave Willis and Craig Paukert
Date: February 11, 2000

Re: Federal Aid Completion Report and New Federal Aid Proposal

Good day to everyone. Please find two enclosures with this cover letter.

First, enclosed is a copy of the completion report for the 2-year Federal Aid in Sport Fish Restoration project "Factors Affecting Panfish Populations in Sandhill Lakes." The report includes lakes both on and outside of the Valentine National Wildlife Refuge. There will be numerous, more specific products developed from this information (e.g., journal publications) and we will provide you with reprints of those articles as well.

Second, we have also enclosed the federal aid proposal for the next proposed aspect of research for panfish in Sandhill lakes. We realize that some of you have seen this proposal, and others have not. We apologize for any misunderstandings, and hope that inclusion of the new proposal with mailing of the completion report will result in everyone being "on the same page." We are excited about the new research, and are certain that you will find the results quite useful.

Thank you, once again, for your continued assistance in all aspects of this research. We sincerely appreciate all of your help over the last 2 years, and hope we can maintain our good working relationship.

Please contact us if you have additional questions.

cc: Rick Holland

SOUTH DAKOTA STATE UNIVERSITY
DEPARTMENT OF WILDLIFE AND FISHERIES SCIENCES

AND

STATE OF NEBRASKA
GAME AND PARKS COMMISSION
FISHERIES DIVISION

Federal Aid in Sport Restoration

Dingell - Johnson Project
F-118-R

Final Report

Study I

Factors Affecting Panfish Populations in Sandhill Lakes

Job I

Factors Affecting Panfish Populations in Sandhill Lakes

1 March 1998 through 28 February 2000

COMPLETION REPORT

State: Nebraska | Project No: F-118-R
Study Number: I | Segment Number: I

Project Title: Sandhill Lakes Fisheries Management Project

Period Covered: 1 March 1998 through 28 February 2000

Study Title and Objectives:

Factors Affecting Panfish Populations in Sandhill Lakes

1. Determine the physical, chemical, and biological factors that are related to bluegill, black crappie, and yellow perch recruitment, growth, and mortality in Sandhill Lakes.

Introduction: While Sandhill lakes produce quality fishing for a number of species, most anglers fish these lakes to catch large yellow perch *Perca flavescens*, bluegill *Lepomis macrochirus* and black crappie *Pomoxis nigromaculatus*. At this time, factors responsible for the production of high quality yellow perch, bluegill and black crappie populations in Sandhill lakes are unclear. Recently the Nebraska Game and Parks Commission (NGPC) purchased three Sandhill lakes and more purchases are being considered. Thus, there is a need to determine which Sandhill lakes are most likely to produce high-quality panfish.

(1) Job Objective I-1:

Determine the physical, chemical, and biological factors that are related to bluegill, black crappie, and yellow perch recruitment, growth, and mortality in Sandhill Lakes.

(a) Activity.

Fish Population Assessments

Largemouth bass *Micropterus salmoides* and common carp *Cyprinus carpio* were sampled by electrofishing, and all other fish species were sampled by trap netting during May through June of 1998 and 1999. Fifteen Sandhill lakes were sampled each year. An attempt was made to electrofish 12 stations along the shoreline or vegetation edge for 10 min each at each lake. Pulsed-DC current with 3-6 A and 200-250 V was used to attract fish toward the electrodes and minimize tissue damage. Catch per unit effort (CPUE) by boat electrofishing was expressed as the number of stock-length fish collected per hour of energized field time. Each lake was sampled with overnight sets of double-throated trap (i.e., modified fyke) nets with 16-mm bar measure mesh, 1.1- by 1.5-m frames, and 22-m leads. Catch per unit effort in trap nets was expressed as the number of stock-length fish captured per net night. Total sampling effort was 10 trap net nights in lakes <50 ha and 20 trap net nights in lakes ≥50 ha.

Scales or spines were taken from bluegills, black crappies, yellow perch, largemouth bass, northern pike *Esox lucius*, and black bullheads *Ameiurus melas* for age and growth analyses. During each sampling period, scales or spines were collected from up to 10 individuals per species per centimeter length group and these fish were weighed to the nearest gram and measured for total length (TL) to the nearest millimeter. All additional fish collected were tallied by centimeter length groups by species.

Fish condition was quantified using relative weight (*Wr*) and standard weight equations summarized by Anderson and Neumann (1996). Mean *Wr* values were calculated for the five-cell length category model for various species (Gabelhouse 1984a). We omitted length groups that contained less than three fish.

Size structure of the fish populations was visually assessed using length frequency histograms, and quantified using stock density indices (Gabelhouse 1984a; Anderson and Neumann 1996). Confidence intervals (95%) were calculated for stock density indices using calculations derived from Gustafson (1988). Stock density indices were calculated only when at least 20 stock-length fish were collected.

Recruitment was quantified using the recruitment variability index (RVI; Guy and Willis 1995). This index used the rationale of a catch curve (Ricker 1975) to quantify fluctuations in year-class strength. The RVI ranged from -1 to 1, with populations having more stable (consistent) recruitment being closer to 1. Very inconsistent recruitment would result in an RVI value close to -1. For this analysis, we used only ages that were fully recruited to the gear (i.e., age 2 and older), only used populations that had a minimum of three year classes present, and did not use populations where the number of missing year classes equaled or exceeded the number of year classes present (Guy and Willis 1995).

Biological Assessments

Phytoplankton community biomass was measured in late June and early July 1998 and 1999 at each of the 30 lakes by chlorophyll *a* extraction using 90% alkalized acetone from filtered water samples. Samples were taken at each of four offshore sampling stations. Duplicate 100- to 300- mL aliquots from the integrated water samples were filtered through glass-fiber filters and extracted by methods described by Lind (1985).

The zooplankton community was sampled during late June and early July using a 2-m integrated tube sampler filtered through a 65-μm mesh net. Samples were collected at four offshore sampling stations, and then preserved in a 10% buffered formalin solution. In the laboratory, zooplankton were identified to genus and enumerated. A maximum of 120 individuals of each genus was measured.

Benthos were collected in late June and early July using an Ekman dredge. Composite samples, each consisting of three bottom grabs, were taken at each of four offshore sampling stations. Composite samples were hand seived in the field to condense the volume of each sample, then preserved using a 5% formalin solution. Macroinvertebrates were identified to the lowest necessary taxon and enumerated using a dissecting microscope in the laboratory.

Physical and Chemical Assessments

Physical and chemical parameters were measured during late June and early July at each of four offshore sampling stations in each lake. Water temperature and dissolved oxygen profiles were taken using electronic probes at each sampling station starting at the surface and at 0.5-m depth intervals to the bottom. Secchi disk transparency was measured to the nearest cm. Water samples were collected at the four sampling stations to determine alkalinity, total phosphorus and total dissolved solids.

Topographical maps and aerial photographs were used to calculate the shoreline development index (SDI; Lind 1985) for each lake. Alkalinity, total phosphorus and turbidity analyses were completed with Hach kits. Total dissolved solids and conductivity were determined with an electronic meter.

Vegetation and substrate were quantified on all 30 lakes in July 1999. Five to seven evenly spaced transects across each lake were established. At 50- to 200- m intervals along each transect, vegetation and substrate were classified. Vegetation was classified as either emergent, submergent, or floating at a 1-m^2 grid along side of the boat. Within each vegetation class, vegetation density was classified as either sparse (stems >16 cm apart on average), moderate (stems 5-15 cm apart on average), or dense (stems <5 cm apart on average). Substrate was classified (nearest 10%) as either sand, muck, gravel, cobble, or other (detritus, woody debris, clay) using an Ekman dredge. Percent coverage of vegetation or substrate classes was calculated as the number of sites of that class divided by the total number of sites in that lake.

Mean depth and maximum depth were calculated using measurements (nearest 0.1 m) taken at each of the above mentioned vegetation and substrate sites. Mean depth was calculated by dividing the sum of all the depth measurement for each lake by the numbers of sites on each lake.

Statistical analysis

Pearson correlation analysis was used to determine bivariate relationships among two variables or, when at least one of the variables was not normally distributed, a Spearman rank correlation was used. Multiple regression was used to determine what variables were important in predicting panfish size structure (proportional stock density; PSD), growth (mean length at age 3), and condition (mean *Wr* of stock- to quality- length fish). Mean length at age-3 was used as an index of growth in these models because this was the youngest age that would discriminate between fast and slow growing populations. Older ages were not used because ageing precision may be diminished for older ages when using scales. In all regression analyses, collinearity and influence diagnostics were used (Freund and Littel 1991). To compare variables in lakes with and without common carp, a t-test or, when the assumption of normality was not met, a Wilcoxon rank sum test was used with presence or absence of common carp as the class variable. To reduce the number of variables to interpret from the physicochemical data and vegetation and substrate, principal components analysis was used (Johnson 1998). Because sampling instability may arise when the sample size is less than three times the number of variables (Williams and Titus 1988), we attempted to reduce the number of variables by eliminating one of a set of two variables that were highly correlated with each other (e.g., we used either total dissolved solids or conductivity, not both). Correlations were then determined between fish population indices and the principal component scores.

(b) Target Date for Achievement:

Sampling and data collection for all 30 study lakes were completed in July 1999. All data analysis is complete.

(c) Date of Accomplishment:

Activities are proceeding on schedule.

(d) Significant Deviations:

None.

(e) Remarks:

Physicochemical and Biological Assessments

Physicochemical characteristics (Appendices 1-2). Thirty lakes were selected in Brown, Cherry, Garden, Grant, Holt, and Rock counties in Nebraska. Water chemistry, physical lake features, vegetation and substrate, fish communities, and invertebrates are summarized in appendices beginning on page 73. Surface area of the study lakes ranged from 15 to 907 ha. Most lakes were shallow (maximum depth 1.5-4.0 m) and almost entirely littoral zone (mean depth 1.0 - 2.9 m). Secchi disk transparency was highly variable (14-258 cm) and most lakes had low to moderate productivity. Alkalinity was moderate to high, with five lakes having >200 mg/L total alkalinity.

Vegetation (Appendix 3). All lakes had at least 4.5% total vegetation coverage. However, 17 lakes had at least 50% total vegetation coverage. All vegetation types (submergent, emergent, and floating) were highly variable among lakes. However, dense submergent vegetation covered >25% of seven lakes. Floating vegetation was found in only three lakes (Dewey, Schoolhouse, West Long).

Fish Population Sampling

Black Bullhead (Appendices 5-7). A total of 14,148 black bullheads were collected by trap nets in 25 of the 30 study lakes. Of the 25 lakes, six had CPUE rates that exceeded 50 stock-length fish/net night. Proportional stock density ranged from 0 to 100. Only one lake had an RSD-M value >0 (Hackberry Lake, RSD-M = 10). A total of 582 black bullheads were aged from spines; maximum age was 8 (Willow and Marsh lakes). Black bullheads in Clear (Brown County), Hackberry, and Schoolhouse lakes reached 300 mm by age 4.

Black crappie (Appendices 8-11). A total of 737 black crappies were collected in trap nets in 12 of the 30 study lakes. Catch per unit effort was variable, ranging from 0.05 to 21.7 stock-length fish/net night. Five lakes (Big Alkali, Island, Medicine, Shell, and Twin) had memorable-length (30 cm) and longer fish, while Big Alkali was the only lake with trophy-length (38 cm) and longer fish. Relative stock density of memorable-length fish ranged from 0 (Cozad, Hagan, Schoolhouse, Tower) to 81 (Twin). Relative weight for all populations and length groups was moderate to high (range in mean *Wr* for various length groups was 82-123). However, longer fish generally had lower condition. A total of 308 black crappies were aged from eight lakes. Maximum age was 11 (Medicine Lake). The Hagan Lake sample was dominated by almost exclusively age-1 fish, indicating either highly erratic recruitment or a newly introduced population.

Bluegill (Appendices 12-15). Twenty-two of the 30 lakes sampled contained bluegills; we collected 12,906 bluegills in trap nets. Catch per unit effort ranged from 0.05 stock-length fish/net night (Big Alkali) to 232.5 stock-length fish/net night (Cozad). Of the seven lakes producing memorable-length and longer fish, Pelican Lake had the highest CPUE (7.4 memorable-length fish/net night). Condition indices were usually high (mean *Wr*>100) in most lakes and length groups. Only two lakes (Cottonwood and Shell) had any length group with a mean *Wr* below 100. Proportional stock density values were also generally high (16-99), with eight lakes having PSD values between 60 and 80. Scales were aged for 1,366 bluegills in 20 lakes. Maximum age was 13 (Cottonwood Lake); however, most lakes (17) contained age-7 and older fish. Thirteen bluegill populations attained a mean length of at least 180 mm by age 4. In contrast, Cottonwood Lake bluegill growth was very slow, where they reached 180 mm at age 11.

Common carp (Appendices 16-17). A total of 258 common carp were collected by electrofishing in nine study lakes. Catch per unit effort for stock-length and longer ranged from 0/hr (Cameron Lake, where common carp were collected in trap nets) to 77.1/hr (Home Valley). However, fewer than five common carp were collected in four of the nine lakes. Stock density indices were all high, with four lakes having common carp PSD values of 100. However, only Clear and Dewey lakes contained trophy-length (84 cm) and longer fish. Condition of common carp was generally low to moderate (mean *Wr* range in various length groups was 68-120).

Green Sunfish Lepomis cyanellus (Appendices 18-19). A total of 6,810 green sunfish were collected in 10 lakes using trap nets. However, 85% of the fish (5,794) were collected in Hagan Lake. Catch per unit effort for stock-length fish ranged from 0.2/trap net night (Cozad Lake) to 1,448.5/trap net night (Hagan Lake). Nine of the 10 lakes had CPUE values <20 fish/trap net night. Hagan Lake was the only lake where we collected preferred-length (i.e., ≥200 mm) fish. No memorable-length (i.e., ≥250 mm) fish were collected in any of the study lakes. Stock density indices were generally low, with all lakes having green sunfish PSD values of 35 or less. Relative stock density of preferred-length fish was 0 in all lakes. Condition was usually high, with all but two lakes (Lackaff West and Round) having mean *Wr* for all length groups ≥100.

Largemouth bass (Appendices 20-22). A total of 2,604 largemouth bass were collected by electrofishing in 22 of the 30 study lakes. However, no stock-length fish were collected in Hagan Lake. Few memorable-length (51 cm) were collected in any lake. Relative stock density of memorable-length fish was 0 in all waters except Clear Lake (Brown County; RSD-M=1), Duck (RSD-M=2), Goose (RSD-M=3), Medicine (RSD-M=1), and West Long (RSD-M=2). Condition was moderate to high in all populations and length groups. The lowest mean *Wr* value was 95 for Cozad and Alkali lake stock- to quality-length fish; the highest was 127 for Dewey, Pelican, and Twin lake preferred- to memorable-length fish. Scales were aged from 1,275 largemouth bass from 19 lakes. Maximum age was 13 (Medicine Lake) years; fourteen of the 19 population samples contained fish at least 9 years of age.

Northern pike (Appendices 23-25). Trap netting collected 324 northern pike in 16 of the study lakes. In four of the 16 lakes, we collected fewer than 10 northern pike (Clear on the Valentine National Wildlife Refuge (VNWR), Cottonwood, Marsh, and West Long). Catch per unit effort for stock-length fish was low, ranging from 0.1 to 2.6. Proportional stock density vales were high (>42) for all lakes. However, RSD-M values were 0 in all lakes except Dewey, (RSD-M=14), Hackberry (RSD-M=15), Shell (RSD-M=3) and Twin Lake (RSD-M=9). Condition was generally low, with the range of mean *Wr* values for all lakes and length groups being 68-102. Scales were aged for 255 northern pike from 11 lakes. Maximum age was 10 (Dewey Lake), and seven of the 11 lakes contained northern pike at least 6 years old.

Pumpkinseed Lepomis gibbosus (Appendices 26-27). A total of 310 pumpkinseed were collected in eight of the 30 lakes. Catch per unit effort for stock-length was low, ranging from 0.55 - 4.50/trap net night. We sampled no quality-length (i.e., ≥150 mm) fish in Clear Lake on the VNWR and Shell Lake. Proportional stock density ranged from 0 (Clear and Shell lakes) to 69 (Medicine Lake). Relative stock density of preferred length fish was 0 in all lakes. Condition was usually high, with all but Shell Lake population samples having mean *Wr* for all length groups >100.

Yellow perch (Appendices 28-31). A total of 8,250 yellow perch were collected from 29 study lakes. No yellow perch were collected from Shoup Lake. Catch per unit effort was highly variable, ranging from 0.05 fish/trap net night (Big Alkali Lake) to 120.8 fish/net (Hagan Lake). Eleven of the lakes had RSD-M values >0, with Marsh Lake (VNWR) having the highest value (RSD-M=31). Scales were aged for 1,644 yellow perch from 24 lakes. Growth was variable, with mean back-calculated length at age 2 ranging from 104 to 186 mm, and mean length at age 6 ranging from 194 to 306 mm. Maximum age was 12 (Marsh Lake), and 21 of 24 population samples contained fish at least age 7.

Invertebrate sampling

Zooplankton- (Appendix 32). Total zooplankton relative abundance ranged from 78 organisms/L (Alkali Lake) to 2,466 organisms/L (Twin Lake). *Bosmina* were found in 26 of the 30 lakes and relative abundance ranged from 1/L (Alkali Lake) to 630/L (Goose Lake). *Daphnia* were found in 22 lakes. Of these, nine lakes had >50 *Daphnia*/L. Copepod nauplii were collected in all lakes, while *Keratella* and *Cyclops* were found in 29 lakes.

Benthos (Appendix 33). Benthic invertebrate relative abundance was extremely variable, ranging from 62 organisms/m^2 to 54,275 organisms/m^2. Chironomids were found in all lakes, and relative abundance ranged from 14/m^2 (Defair Lake) to 2,493/m^2 (Goose Lake). Seventeen lakes had >500 chironomids/m^2. Gastropod relative abundance also varied substantially. Shell Lake had the highest relative abundance (54,112/m^2); however, Alkali, Cottonwood, Defair, Goose, Marsh, Marsh (VNWR), Schoolhouse, and Willow lakes all had >1,000 gastropods/m^2.

Panfish Relationships

Bluegill

Few relationships were found between bluegill population parameters and physicochemical variables. However, shoreline development index was positively associated with mean *Wr* of stock- to quality-length bluegill (r=0.58 P=0.01; Figure 1) . Lakes with a more irregular shoreline had higher bluegill condition. Multiple regression revealed that bluegill mean length at age 3 increased with higher shoreline development index (SDI) and chlorophyll *a* concentration [bluegill mean length at age 3 = 79.60 +30.24(SDI) - 1.43(chlorophyll *a*); P=0.017]. However, this model did not have high predictive power (R^2=0.36). Bluegill PSD increased with increasing total alkalinity and decreasing mean lake depth [bluegill PSD = 64.95 - 16.88(mean lake depth) + 0.15 (total alkalinity); R^2=0.41, P=0.004]. The third eigenvector of the physicochemical principal components analysis revealed that mean lake depth and lake size were associated (Table 1), and bluegill PSD increased with principal component 3 (r=0.52 P=0.02; Figure 2). Bluegill PSD tended to be higher in smaller, more shallow lakes.

Bluegill PSD was positively related to bluegill mean length at age 3 (r=0.70 P<0.01; Figure 3), indicating that size structure and growth were correlated. There was no inverse relationship between CPUE or relative weight and bluegill PSD, suggesting no density dependence for condition and size structure among all populations. However, in smaller lakes (i.e., <50 ha) mean length at age 2 was lower when bluegill relative abundance was high (r=-0.82 P=0.02; Figure 4). In larger lakes, (i.e., ≥50 ha) this relationship was not evident (r=-0.22 P=0.46; Figure 4).

Relations between bluegill and the two primary predators in these lakes, largemouth bass and northern pike, indicated that largemouth bass was most likely the primary predator even when the two predators coexisted with bluegills. Largemouth bass and bluegill PSD were inversely related (r=-0.49 P=0.03; Figure 5), and bluegill PSD increased with higher largemouth bass CPUE (r=0.52 P=0.02; Figure 6). Largemouth bass may influence bluegill size structure by preying on the smaller bluegill in these lakes. Few relationships were evident between bluegill and northern pike.

However, bluegill PSD was positively related to mean *Wr* for quality- to preferred-length northern pike (r=0.87 P=0.003; Figure 7).

Few relationships were found between bluegill population characteristics and benthic invertebrate abundance. However, there was a positive association between mean *Wr* of stock- to quality-length bluegills and dipteran abundance (r=0.50 P=0.02; Figure 8). This was the only indication that bluegill may be preying on benthic invertebrates. However, bluegill do appear to be preying on zooplankton. Mean *Wr* of stock- to quality-length bluegills increased with increased *Daphnia* abundance (r=0.54 P=0.03; Figure 9). In addition, high bluegill mean length at age 2 was associated with high *Daphnia* mean length (r=0.51 P=0.03; Figure 9). *Daphnia* are most likely an important food source for bluegill.

Few bivariate relationships existed between bluegill population characteristics and the proportion of the area covered with vegetation. However, mean *Wr* of preferred- to memorable-length bluegills and mean length at age 4 both increased at more sparse levels of vegetation (r's $\geq$0.46, P's $\leq$0.06; Figure 10). In addition CPUE of bluegill decreased when there was a high proportion of sand substrate (r=0.66, P=0.01; Figure 11). High bluegill relative abundance only occurred when there was a low proportion of sand substrate. Principal components analysis also revealed that high condition, growth, and size structure of bluegill was associated with low submergent vegetation coverage (Figure 12). Therefore, there is an indication that increased vegetation within a lake may lead to lower quality (i.e., low growth, condition, and size structure) bluegill populations.

Bluegill recruitment was relatively consistent. The mean RVI was 0.44 with a range from -0.38 to 0.86. However, only two lakes (Schoolhouse and Willow) had RVI values below zero. There were very few missing year classes for bluegill popaultion samples from Sandhill lakes that we sampled.

Yellow Perch

There were few relationships suggesting that yellow perch population quality in the Nebraska Sandhills is related to productivity. Mean *Wr* of stock- to quality-length yellow perch decreased with increasing turbidity (r=0.47, P=0.02; Figure 13). Yellow perch PSD increased with increasing alkalinity and decreased mean lake depth [yellow perch PSD = 56.41 - 20.43(mean lake depth) + 0.16(total alkalinity); R^2=0.33, P=0.004]. Shallow lakes with higher alkalinity were more likely to have high yellow perch size structure. Yellow perch mean length at age 3 was positively related to the physicochemical principal component 2 (r=0.46, P=0.03; Figure 14). Principal component 2 was a gradient of productivity, where more productive lakes scored higher on principal component 2 (Table 1). Yellow perch thus exhibited somewhat faster growth in more productive lakes.

Similar to bluegill, yellow perch exhibited no negative relationship between CPUE and size structure and *Wr* for all population samples combined. In smaller (<50 ha) lakes, yellow perch CPUE was inversely related to yellow perch mean length at age 3 (r=-0.65, P=0.04; Figure 15). In the larger lakes (≥50 ha) this relationship appeared dome-shaped (r=0.77, P=0.001; Figure 15). In larger lakes, faster growth may occur at intermediate densities. Yellow perch RSD-P increased with increasing mean length at age 3 (r=0.51, P=0.01; Figure 16). Populations of yellow perch that had high size structure generally exhibited faster growth.

Largemouth bass apparently help structure yellow perch populations. High largemouth bass CPUE was positively related to yellow perch PSD ($r=0.82$, $P<0.001$; Figure 17). In addition, yellow perch CPUE and largemouth bass PSD were inversely related ($r=-0.59$, $P=0.007$; Figure 18). Abundant largemouth bass apparently control yellow perch by preying on smaller perch. Very few relationships existed between yellow perch and northern pike. However, an increased abundance of yellow perch was associated with increased mean *Wr* of stock- to quality-length northern pike ($r=0.71$, $P=0.009$; Figure 19), suggesting that 35- to 53-cm northern pike may prey on yellow perch.

Daphnia and *Bosmina* appear to be important food sources for yellow perch. Daphnia mean length was positively related to yellow perch mean length at age 3 ($r=0.63$, $P=0.01$; Figure 20). In, addition there was a negative relationship between yellow perch PSD and *Bosmina* abundance ($r=-0.53$, $P=0.01$; Figure 21), and between yellow perch mean *Wr* for preferred- to memorable- length fish and *Bosmina* mean length ($r=-0.83$, $P=0.02$; Figure 21). However, there were no significant relationships between benthic invertebrate abundance and yellow perch population characteristics.

No significant bivariate relationships were evident between yellow perch population characteristics and the proportion of vegetation covering the lake area. However, principal components analysis revealed that high yellow perch size structure was associated with a low coverage of submergent vegetation (Figure 22). In contrast, there were some lakes that had high submergent vegetation coverage and high yellow perch condition and growth. Therefore, there is some indication that a high proportion of submergent vegetation was related to low yellow perch size structure.

Yellow perch recruitment was quite consistent, with RVI values ranging from 0.32 to 0.96. No lakes had negative RVI values, which would suggest that recruitment was relatively stable in all 24 population samples for which RVI was calculated. Although year-class strength varied within lakes, there were few missing yellow perch year classes in any of the Sandhill lake samples.

Black crappie

Limited inferences can be drawn from the black crappie population characteristics because only 12 lakes contained black crappie. Black crappie PSD was inversely related to shoreline development index (r=-0.66, P=0.07; Figure 23). This relationship appeared to be sigmoidal, with high size structure of black crappies in lakes with more irregular shorelines. In addition, black crappie mean length at age 1 increased with mean lake depth (r=0.81, P=0.01; Figure 24). Black crappie size structure was related to measures of productivity. Multiple regression indicated that black crappie PSD increased with conductivity and decreased with trophic state index and mean lake depth [black crappie PSD = 154.28 - 73.51 (mean lake depth) - 3.25(chlorophyll *a* trophic state index) + 0.55(conductivity); R^2=0.957 P=0.001]. Shallow lakes with high conductivity and lower trophic state index values had higher black crappie size structure.

As with bluegill and yellow perch, there was no evidence that black crappie size structure and condition were density dependent. Black crappie size structure (i.e., PSD) was positively related to growth (i.e., mean length at age)(Table 2).

Unlike yellow perch and bluegill, black crappie PSD and largemouth bass CPUE were not related (r=0.43, P=0.34). Thus, there was no evidence that largemouth bass structured black crappie populations. In addition, there were only six lakes that contained both northern pike and black crappie, and no significant bivariate relations between these two species were found.

Smaller black crappie appear to prey on zooplankton and benthic invertebrates. Mean *Wr* of stock- to quality-length black crappies was positively related to chironomid abundance (r=0.72, P=0.04; Figure 25) and *Daphnia* abundance (r=0.89, P=0.02; Figure 25). Condition of small (i.e., stock to quality) black crappies increased when chironomids and *Daphnia* were abundant.

Lake vegetation coverage apparently influenced black crappie growth and size structure. When there was a high proportion of submergent vegetation within a lake, black crappie size structure was low (r=-0.75, P=0.03; Figure 26). In addition, growth was slower when there was a high proportion of submergent vegetation in a lake (r= -0.93, P=0.003; Figure 26).

We could only calculate recruitment variability values for six black crappie populations. However, mean RVI was 0.38. Only one population (Island Lake) had negative RVI value (-0.40). The remaining RVI values ranged from 0.29 (Twin) to 0.79 (Big Alkali). As with bluegill and yellow perch, few missing year classes were evident in any of the populations sampled.

Panfish interspecific relationships

Interspecific competition among bluegill and black crappie and yellow perch was not evident. High quality bluegill populations were associated with high quality yellow perch and black crappie populations. Bluegill PSD was positively related to yellow perch PSD (r=0.58, P=0.02) and black crappie PSD (r=0.77, P=0.08; Figure 27). In addition, mean

Wr of stock- to quality-length bluegill was associated with mean *Wr* of stock- to quality-length yellow perch (r=0.54, P=0.03) and black crappie mean *Wr* (r= 0.90, P=0.01; Figure 28). In general, when size structure and condition was high for one of the panfish species, it was high for all three.

Common carp effects

Common carp were found in 10 of the 30 lakes sampled. However, indices of relative abundance based on our electrofishing samples may not adequately reflect the abundance of common carp in these lakes. In one instance, we did not collect any common carp during electrofishing (the gear selected to be used to index common carp), but did collect them with trap nets. Therefore, we analyzed all common carp data as presence-absence of carp. A higher proportion of submergent vegetation was found in lakes without common carp compared to lakes with carp (P<0.001). Lakes with common carp had an average of 14% submergent vegetation whereas lakes without carp had an average of 60% vegetation coverage (Table 3). In addition, lakes without common carp had higher secchi depth readings ($\bar{x}$=150 cm) compared to lakes with carp ($\bar{x}$=68 cm; P=0.002). Similarly, turbidity was higher in lakes containing common carp (P=0.01). Although maximum lake depth was not different between lakes with and without common carp (P=0.148), mean depth was deeper in lakes containing carp (P=0.005). However, there was no difference in measures of productivity (i.e., alkalinity, phosphorus, chlorophyll *a*, conductivity, morphoedaphic index) in lakes with and without carp (P's>0.22) (Table 3).

The presence of common carp did not appear to directly affect panfish populations. There was no difference in CPUE; mean length at ages 1, 2, 3, and 4;

mean *Wr* of stock- to quality-length fish; and PSD for both bluegill and yellow perch sampled from lakes with and without common carp (P's>0.19). In addition there was also no difference in benthic invertebrate and zooplankton abundance (P's>0.33). In contrast, lakes with common carp had lower CPUE of largemouth bass ($\bar{x}$=27/hr) compared to lakes without carp ($\bar{x}$=82/hr; P=0.02). In lakes without common carp, largemouth bass CPUE was still positively related to bluegill PSD (r=0.60, P=0.025) and yellow perch PSD (r=0.69, P=0.009). However, in lakes with common carp present, largemouth bass CPUE was not related to bluegill PSD (r=0.09, P=0.871) or yellow perch PSD (r=0.70 P=0.188).

Black bullhead effects

Black bullheads were collected in 25 of the 30 study lakes. However, these fish did not appear to adversely affect the panfish populations. In contrast, yellow perch CPUE and black bullhead CPUE were positively related (r=0.70 P=0.001; Figure 29) as were mean *Wr* of stock- to quality-length black bullheads and yellow perch (r=0.60 P=0.017; Figure 30). Bluegill and black bullhead relationships were not highly correlated; however, there were no significant inverse relationships between bluegill and black bullhead population characteristics. Bluegill growth (i.e., mean length at age) was positively associated with black bullhead growth (i.e., mean length at age)(Table 4). Few relationships were evident between black bullhead and black crappie. Only nine lakes contained both of these species and most of the analyses could be assessed for fewer than six lakes. As with yellow perch and bluegill populations, there was no indication that black bullheads adversely affect black crappie abundance, size structure, condition, or growth.

Discussion

Physicochemical effects- Panfish populations were not substantially related to the physicochemical variables measured. The only significant bivariate relationships has low correlation coefficients and most multiple regression models had low coefficients of determination. However, there was some indication that panfish growth and size structure increased with increasing productivity. Both yellow perch and bluegill size structure were higher in shallow lakes with higher alkalinity. However, black crappie populations did not show these trends, at least in the few populations in our study. In forested watersheds in Mississippi, bluegill abundance increased with conductivity and size structure increased with alkalinity (Jackson and Brown-Peterson 1995). Although limited information exists specifically indicating relationships between panfish size structure and productivity, alkalinity has been associated with high fish productivity and yield (Carlander 1955; Hayes and Anthony 1964). However, Hayes and Anthony (1964) determined that fish productivity increased with lake depth and decreased with alkalinity, which is in contrast to our Nebraska Sandhill lakes study. The difference may be attributed to the wide range of North American lakes they used compared to the limited range found in the Sandhill lakes.

In the Sandhill lakes, bluegill growth increased with increasing chlorophyll *a* concentrations, and yellow perch growth increased with increasing measures of productivity (i.e., chlorophyll *a* and phosphorus). Similarly, bluegill growth in Minnesota lakes was also faster in shallow, more alkaline lakes (Tomcko 1997). Black crappie first-year growth did increase in deeper Minnesota lakes as chlorophyll *a* concentrations increased up to 100 mg/L (McInerny and Cross 1999). However, growth was reduced in lakes with ≥100 mg/L of chlorophyll *a*. DiCenzo et al. (1995) also found faster growth of spotted bass *Micropterus punctulatus* in Alabama reservoirs with high chlorophyll *a*. In contrast, Theiling (1990) found no relationship between primary productivity and bluegill growth in Michigan natural lakes. In our study lakes, higher phytoplankton production most likely resulted in increased invertebrate production, which led to increased bluegill and yellow perch growth.

More irregular shorelines were related to high *Wr* values of smaller bluegills and a higher size structure of black crappie. Guy and Willis (1995) suggested that South Dakota waters with low shoreline development allowed wind and wave action to affect the black crappie reproductive process, destabilizing recruitment. In our study, recruitment was relatively consistent for all panfish species. In addition, no physicochemical variables were related to the recruitment variability index. Mitzner (1991) found that abundance of larval crappies (both species combined) was reduced in areas with increased turbidity in an Iowa reservoir. If higher shoreline development decreases the influence of wind and wave action, invertebrate abundance may be higher because of lower wind-caused turbidity. Therefore, bluegill and black crappie may be more efficient in foraging for zooplankton and thus increase their condition, growth, and size structure. Tomcko (1997) also found that shoreline development was related to bluegill populations in Minnesota lakes; growth increased with increasing shoreline development index and decreased with increasing secchi transparency.

There was no evidence of a density-dependent relationship with condition or size structure for any of the three panfish species. Even when bluegill, black crappie, and yellow perch CPUE indicated high abundance, the populations still often exhibited high size structure and condition. However, the nature of these relations was confounded by lake area. In lakes <50 ha, there was a density-dependent relationship evident for yellow perch and bluegill growth. However, this relationship was not as evident in larger lakes. In larger lakes, the environment may regulate panfish recruitment more than intraspecific competition. Novinger and Legler (1978) found an inverse relationship between bluegill biomass and PSD in Midwestern impoundments. However, these impoundments were all <2.4 ha. Hill and Willis (1993) found similar relationships with largemouth bass biomass and size structure in South Dakota impoundments. Other studies have suggested that growth was reduced with higher panfish density (black crappie: Guy and Willis 1995, McInerny and Cross 1999; bluegill: Weiner and Hanneman 1982). However, Tomcko (1997) did not find an inverse relationship in Minnesota bluegill populations.

Largemouth bass appear to be the key predator in these Sandhill lakes. Yellow perch and bluegill size structure increased with largemouth bass relative abundance. Similar relationships have been shown in Midwestern small impoundments (Novinger and Legler 1978; Guy and Willis 1990, 1991a). Largemouth bass feed on smaller bluegills and yellow perch, thus decreasing intraspecific competition and increasing panfish growth and population size structure. In contrast, black crappie size structure was not related to largemouth bass abundance in our study, at least in the few Sandhill study lakes that contained both species. However, other studies have shown that largemouth bass will effectively prey on small black crappies (Gabelhouse 1984b; Boxrucker 1987). In the Sandhills, every study lake that contained black crappie also contained yellow perch, and all but one lake that contained black crappie contained bluegill. Therefore, yellow perch and possibly bluegill may be selected for by largemouth bass over black crappie. Stronger relationships between yellow perch and largemouth bass suggest that the bass may select the more fusiform yellow perch over bluegill and black crappie.

Few relationships existed between northern pike and panfish. Although some studies have shown that northern pike consume panfish (Sammons et al. 1994; Gurtin et al. 1996), little evidence suggest that they are able to control overabundant panfish (Beyerle 1971). We did find that condition of larger (i.e., quality length) northern pike increased with high bluegill size structure. The mechanism for this relationship is unclear. However, it is possible that larger northern pike may be preying on small (i.e., stock- to quality- length) bluegills.

Although there is some evidence that bluegills and black crappies consume benthic invertebrates, zooplankton appears to be important prey for panfish in these lakes. *Daphnia* and *Bosmina* are probably the primary invertebrates that panfish consume. In the Sandhill lakes, lakes with larger *Daphnia* had faster bluegill and yellow perch growth. This relation was also reported for bluegill in Michigan lakes (Theiling 1990). In our study, inverse relationships were evident between yellow perch size structure and *Bosmina* abundance, as well as yellow perch condition and *Bosmina* mean length. Fish communities, including panfish, can reduce abundance and decrease the size structure of the invertebrate community (Mills et al. 1987; Mills and Schiavone 1992). Bluegill growth in other Midwestern lakes has been inversely related to zooplankton abundance (Theiling 1990). In addition, larger bluegill (>203 mm) growth was higher in Michigan lakes with high densities of *Daphnia* as well as chironomids (Schneider 1999). Panfish may consume the largest invertebrates (Mittlebach 1988; Olson et al.1995), thus reducing the size structure of the invertebrates. Although Noble (1975) found that yellow perch may alter the *Daphnia* populations in New York lakes, he cautioned that invertebrate populations fluctuated more with environmental conditions than yellow perch populations. Keast and Fox (1992) found that bluegills in a mesotrophic Ontario lake consumed primarily zooplankton and some benthic invertebrates. In addition, Theiling (1990) did not find any relationships between bluegill growth and benthic invertebrates. However, Lott et al. (1996) found that fast-growing adult yellow perch were associated with a diet dominated by macroinvertebrates in eastern South Dakota glacial lakes. However, Lott et al. (1998) did report that yellow perch populations with high size structure were found in lakes with larger zooplankton. Yellow perch consumed almost exclusively benthic invertebrates (Keast and Fox 1992) in Lake Opinicon, Ontario, whereas black crappies consumed primarily *Chaoborus* and chironomids. In some Wisconsin lakes, bluegills were zooplanktivorus until about 200 mm total length, but they also consumed chironomids and gastropods (Engel 1987, 1988), and consumed age-0 fish when they attained 240 mm. Food habit studies of panfish may be valuable to corroborate our speculations on prey selectivity in Nebraska Sandhill lakes.

Common carp and vegetation effects-Common carp apparently did not directly affect the panfish populations in the Sandhill lakes. Panfish population characteristics were not significantly different in lakes with and without common carp. However, lakes with common carp had increased turbidity and reduced vegetation. Other studies have also suggested that common carp may reduce vegetation abundance (Crivelli 1983; Kolterman 1990). Invertebrate size structure and abundance were not altered by the presence of common carp in these Sandhill lakes. However, there was higher largemouth bass relative abundance in lakes without common carp. In these highly vegetated lakes, there was an adequate number of largemouth bass to control the panfish populations. In contrast, lakes with common carp had largemouth bass relative abundance that was too low to help structure panfish communities. Largemouth bass recruitment may increase with increased vegetation abundance (Durocher 1984; Guy and Willis 1991b). There was no relationship (linear or dome-shaped) evident between largemouth bass CPUE and submergent vegetation coverage in our study. However, it appears that common carp may decrease submergent vegetation abundance in these Sandhill lakes, thus reducing recruitment of largemouth bass to low enough numbers where they cannot control panfish.

Panfish, in particular bluegill and black crappie, respond to changes in vegetation coverage. Panfish quality (growth, condition, or size structure) in these Nebraska Sandhill lakes declined when there was more submergent vegetation within a lake. For bluegill, black crappie, and yellow perch, size structure was reduced when there was a high proportion of vegetation coverage in a lake. In addition, growth of bluegill and black crappie was lower in lakes with more vegetation. However, vegetation coverage had little effect on growth and condition of yellow perch and vegetation coverage in these lakes. The literature regarding the influence of vegetation coverage on panfish populations is quite mixed. Bluegill growth was reduced at high levels of macrophyte abundance in Michigan (Theiling 1990) and Wisconsin (Trebitz et al. 1997). However, removal of excessive macrophytes (e.g., >50%) also led to slower growth (Trebitz and Nibbelink 1996). Therefore, bluegill growth was best at moderate macrophyte coverage in these lakes. Crowder and Cooper (1982) also suggested that intermediate macrophytes densities were better for bluegill growth. In an experimental study in Wisconsin, removal of macrophytes increased bluegill growth (Olson et al. 1998).

Similar results were shown after chemical removal of vegetation in Minnesota lakes (Pothoven et al. 1999). Little information exists on growth-vegetation relationships for black crappies and yellow perch. In eastern South Dakota lakes, Lott (1991) found higher relative abundance and slower growth of yellow perch in lakes with submerged macrophytes compared to lakes without submerged macrophytes. Our results suggest that black crappies and yellow perch respond to vegetation coverage in a similar manner to bluegills, at least in Nebraska Sandhill lakes.

Although there is little evidence regarding the impact of vegetation on size structure and condition of panfish, size structure was reduced in Sandhill lakes that had a higher proportion of submergent vegetation. Hinch and Collins (1993) suggested that higher abundance of *Lepomis* species was associated with higher macrophyte coverage. In contrast, bluegill and black crappie abundance and biomass was reduced after removal of vegetation in Lake Conroe, Texas (Bettoli et al. 1993). After an increase in submergent vegetation in a Florida lake, the abundance or harvestable-sized bluegill was reduced, but black crappie populations remained unchanged (Colle et al. 1987). This was most likely due to the reduced effectiveness of predation by largemouth bass. However, Radomski et al. (1995) found no effect on bluegill abundance after vegetation removal in a Minnesota lake. Yellow perch abundance in eastern South Dakota lakes increased with increased submergent macrophytes (Lucchesi 1991). However, this regression model had low predictive capabilities (R^2 = 0.24, P=0.04).

Although indirect evidence suggests that vegetation influences abundance and size structure of panfish communities in natural lakes, the most predominant influence of vegetation appears to be reduction in growth of intermediate-aged fish. However, Schneider (1999) suggested that vegetation may not be severely detrimental to bluegill populations if harvest is kept low and there is an adequate food supply.

Management Implications

High quality panfish populations existed throughout the Nebraska Sandhill region. In contrast to many other Midwestern fisheries, there were few low quality panfish populations in Sandhill lakes. Although many interrelated factors contribute to the structure and dynamics of these populations, generalizations about the high quality bluegill, black crappie, and yellow perch populations in this study can be made.

Limnological variables measured during this study appeared to have relatively little influence on the panfish populations in these lakes, perhaps at least partially because of the narrow range of many measured variables . However, lakes with more irregular shorelines and higher productivity will most likely be better candidates to produce high quality panfish populations. In addition, shallower Sandhill lakes likely will produce higher yellow perch and bluegill size structure.

Panfish density within large (≥50 ha) lakes appeared not to influence panfish quality. However, our data suggest that smaller lakes (<50 ha) are more susceptible to density-dependent detrimental effects on bluegill and yellow perch growth. In smaller lakes, high panfish density may result in slower growth. In addition, we found little evidence of substantial interspecific competition among panfish species in the Sandhill lakes. Whatever factors created high quality bluegill fisheries also produced high quality black crappie and yellow perch fisheries. Similar results were found with black bullhead populations. Surprisingly, high black bullhead relative abundance did not adversely affect panfish populations. Few relations were evident between black bullhead and panfish population parameters. Therefore, black bullheads to not appear to be a primary competitor or predator in these Sandhill lakes.

Largemouth bass apparently control size structure of bluegill and yellow perch populations in Sandhill lakes. When relative abundance of largemouth bass was high, they consume the smaller bluegill and yellow perch, thus increasing panfish size structure. Interestingly, these relationships were evident in larger lakes as well as the smaller water bodies. Evidence for largemouth bass influence on black crappie populations was limited, perhaps because all the lakes that contain black crappie also contained other panfish. Although northern pike were sampled in 16 of the 30 study lakes, we found no evidence that they were an influential factor in structuring panfish populations. Undoubtedly they consume panfish (especially yellow perch) in these simple fish communities, but not to the extent apparent for largemouth bass, at least based on our abundance and size structure analyses. This may occur, in part, because northern pike appeared to exist in lower densities than largemouth bass in these lakes. However, our summer trap netting may not have effectively sampled these northern pike populations. More research is needed on the ecological role that northern pike play in these shallow, productive lakes, including food-habits assessments.

Zooplankton, particularly *Daphnia* and *Bosmina*, may be a very important food source for all panfish in these lakes. Although some evidence suggests that black crappie and, to some extent, bluegills, consume benthic invertebrates, zooplankton appear to be more vital in the growth and condition of panfish. High abundance and size structure of *Bosmina* and *Daphnia* likely would be beneficial for creating high quality panfish fisheries. All these speculations are based on our correlation analyses, and food habits should be assessed to confirm our suppositions.

A high proportion of submergent vegetation coverage in these lakes apparently was at least somewhat detrimental to panfish quality. Size structure for all panfish species was reduced with high submergent vegetation coverage. In addition, reduced bluegill and black crappie growth was evident in lakes with a high coverage of submergent vegetation. If submergent vegetation in overly abundant within a lake, some aspect (growth or size structure) of panfish quality may be sacrificed.

Although common carp in these lakes did not directly influence panfish populations, indirect evidence suggests that common carp may be detrimental to panfish quality. In lakes without common carp, vegetation was more abundant and, thus, these lakes had higher recruitment of largemouth bass. When largemouth bass abundance was high (as a result of high recruitment), they were able to effectively prey on the small panfish, increasing panfish size structure. Therefore, lakes with common carp may lead to lower size structure of panfish because largemouth bass recruitment will be lower.

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Table 1. Variable eigenvectors for the principal components analysis for the water chemistry analysis in the Nebraska Sandhill lakes, 1998 and 1999.

Variable	Principal component 1	Principal component 2	Principal component 3
Mean depth	0.179	-0.291	-0.432
Lake size	0.352	0.288	-0.493
Shoreline development index	0.259	0.115	-0.107
Secchi depth	-0.085	-0.602	0.402
Total alkalinity	0.520	0.175	0.343
Phosphorus	-0.390	0.309	0.135
Chlorophyll a	-0.344	0.546	0.144
Conductivity	0.479	0.182	0.492
Variance explained (%)	32.9	19.3	13.8

Table 2. Correlations between black crappie proportional stock density (PSD) and black crappie mean total length at ages 2-6 from Nebraska Sandhill lakes sampled in 1998 and 1999.

Age (years)	r	P	N
2	0.78	0.04	7
3	0.85	0.03	6
4	0.85	0.03	6
5	0.87	0.02	6
6	0.86	0.02	6

Table 3. Comparisons of water chemistry and habitat variables between Nebraska Sandhill lakes with and without common carp. Standard errors are in parentheses and an asterisk indicates a significant difference ($P<0.05$).

Common carp	Submergent vegetation (%)*	Secchi depth (cm)*	Phosphorus (mg/L)	Chlorophyll *a* (mg/L)	Total alkalinity (mg/L)
Yes	13.7(4.6)	68(11)	0.34(0.08)	5.48(2.71)	148(18)
No	57.9(6.2)	150(16)	0.46(0.12)	7.00(1.84)	148(20)

Table 4. Correlation coefficients (r) for relationships between black bullhead and bluegill mean total length (mm) at age for fish from Nebraska Sandhill lakes sampled in 1998 and 1999. Coefficients marked with an asterisk are significant at and α level of 0.10 (*) or 0.05 (**).

	Bluegill age 2	Bluegill age 3	Bluegill age 4	Bluegill age 5
Black bullhead age 2	0.31	0.66**	0.70**	0.73**
Black bullhead age 3	0.38	0.65**	0.70**	0.72**
Black bullhead age 4	0.41	0.62*	0.69**	0.72**
Black bullhead age 5	0.42	0.60*	0.67**	0.68**

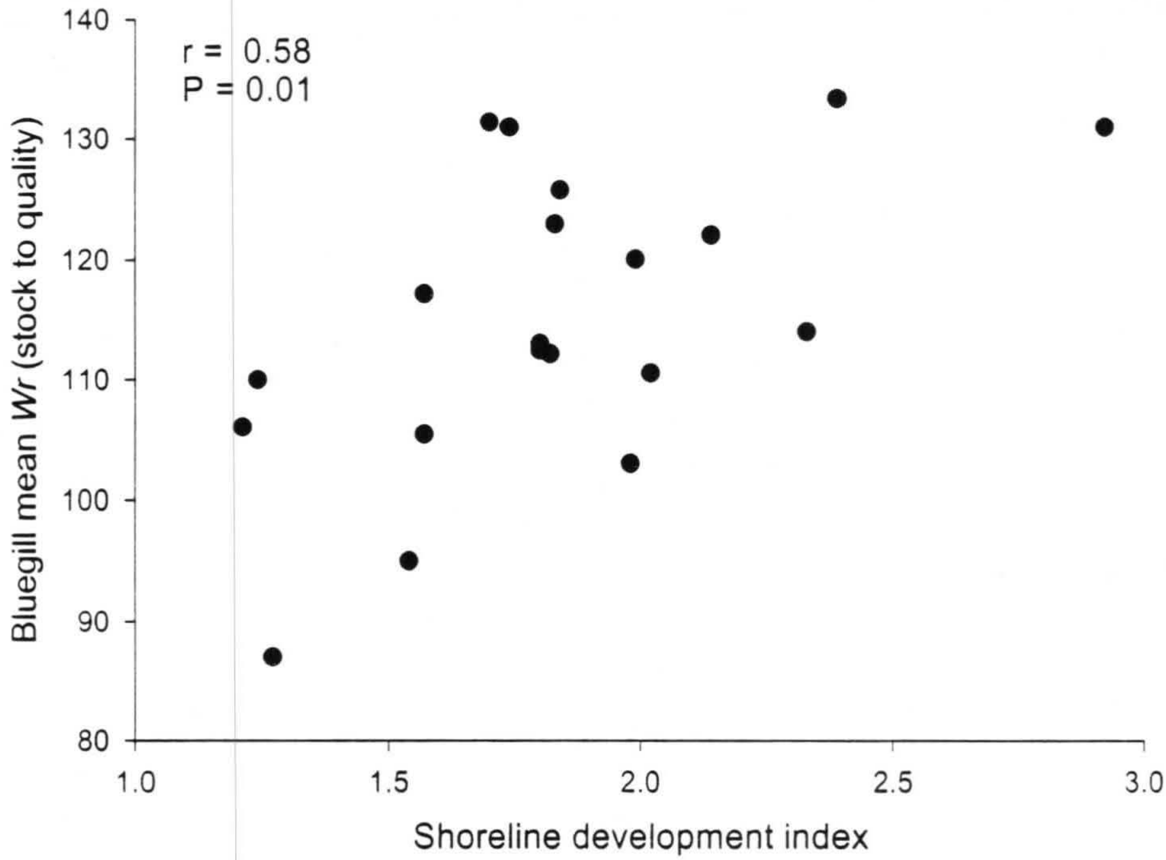

Figure 1. Relationship between mean *Wr* of stock- to quality-length of bluegills and shoreline development index in Nebraska Sandhill lakes sampled in 1998 and 1999..

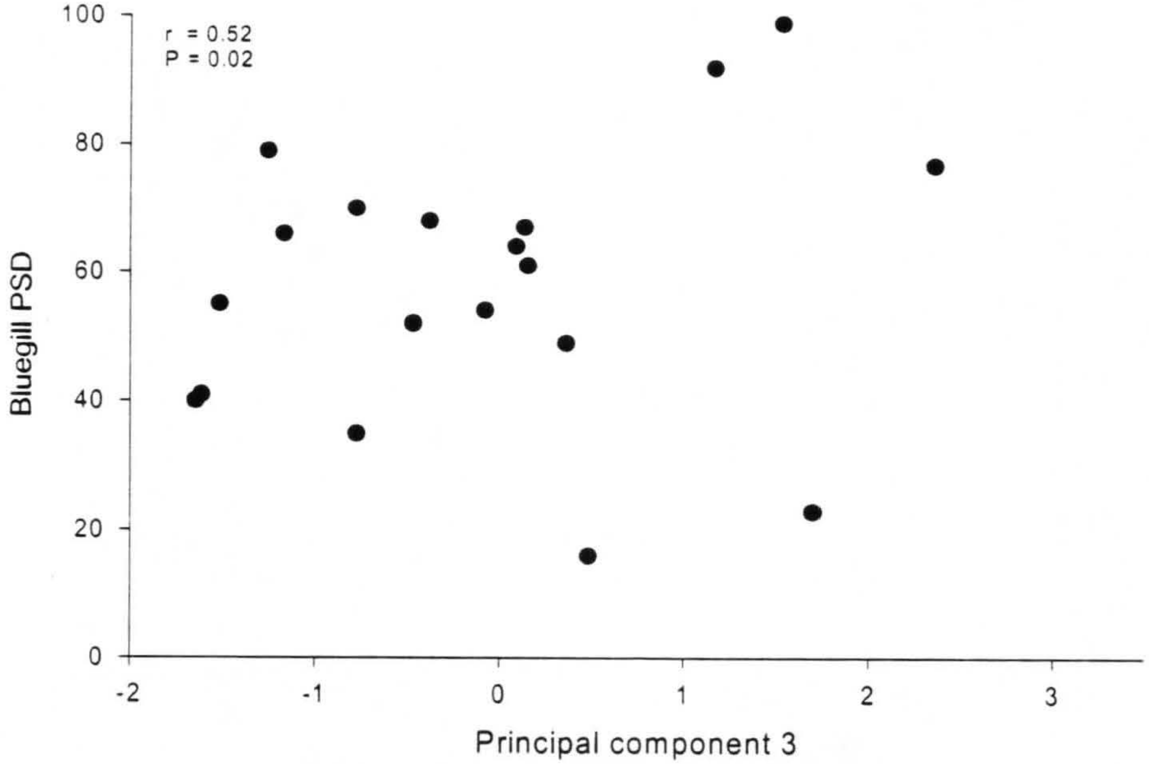

Figure 2. Relationship between bluegill proportional stock density (PSD) and principal component 3 of Nebraska Sandhill lakes sampled in 1998 and 1999. Small, shallow lakes scored high on principal component 3. The principal components analysis is summarized in Table 1.

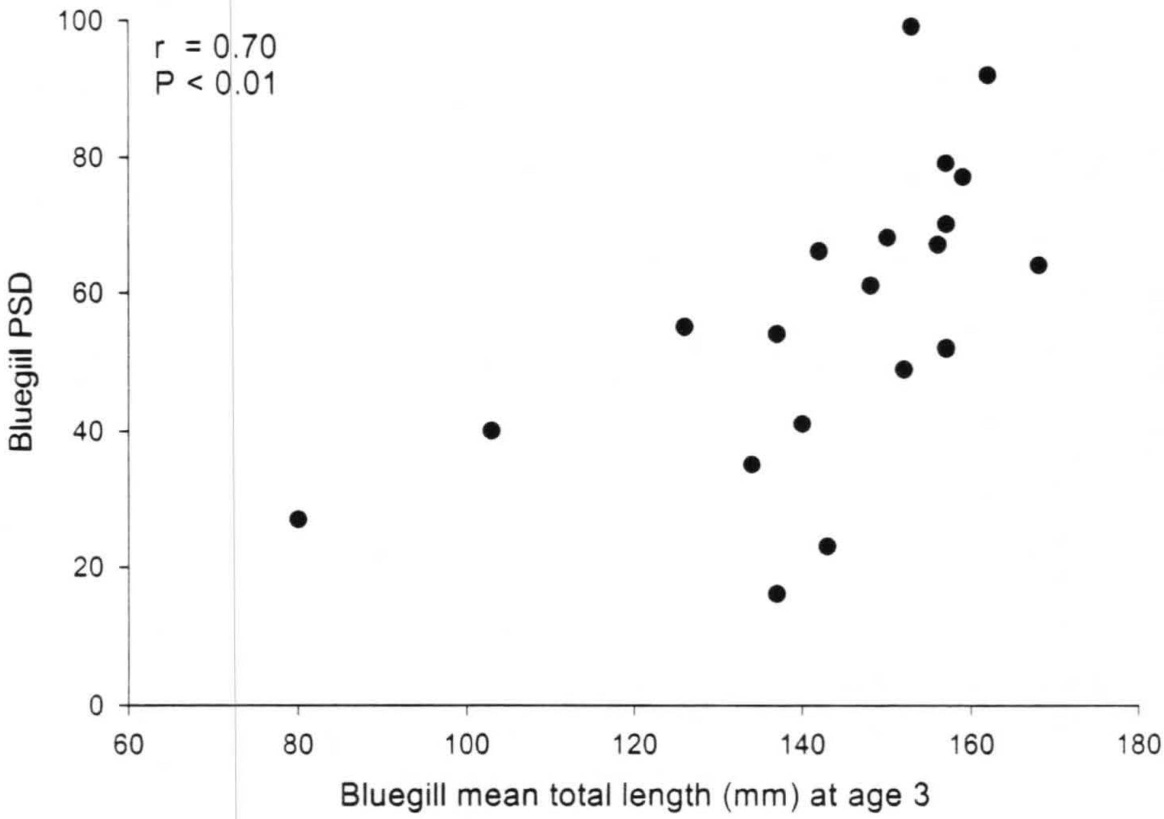

Figure 3. Correlation between bluegill proportional stock density (PSD) and mean total length at age 3 in Nebraska Sandhill lakes sampled in 1998 and 1999..

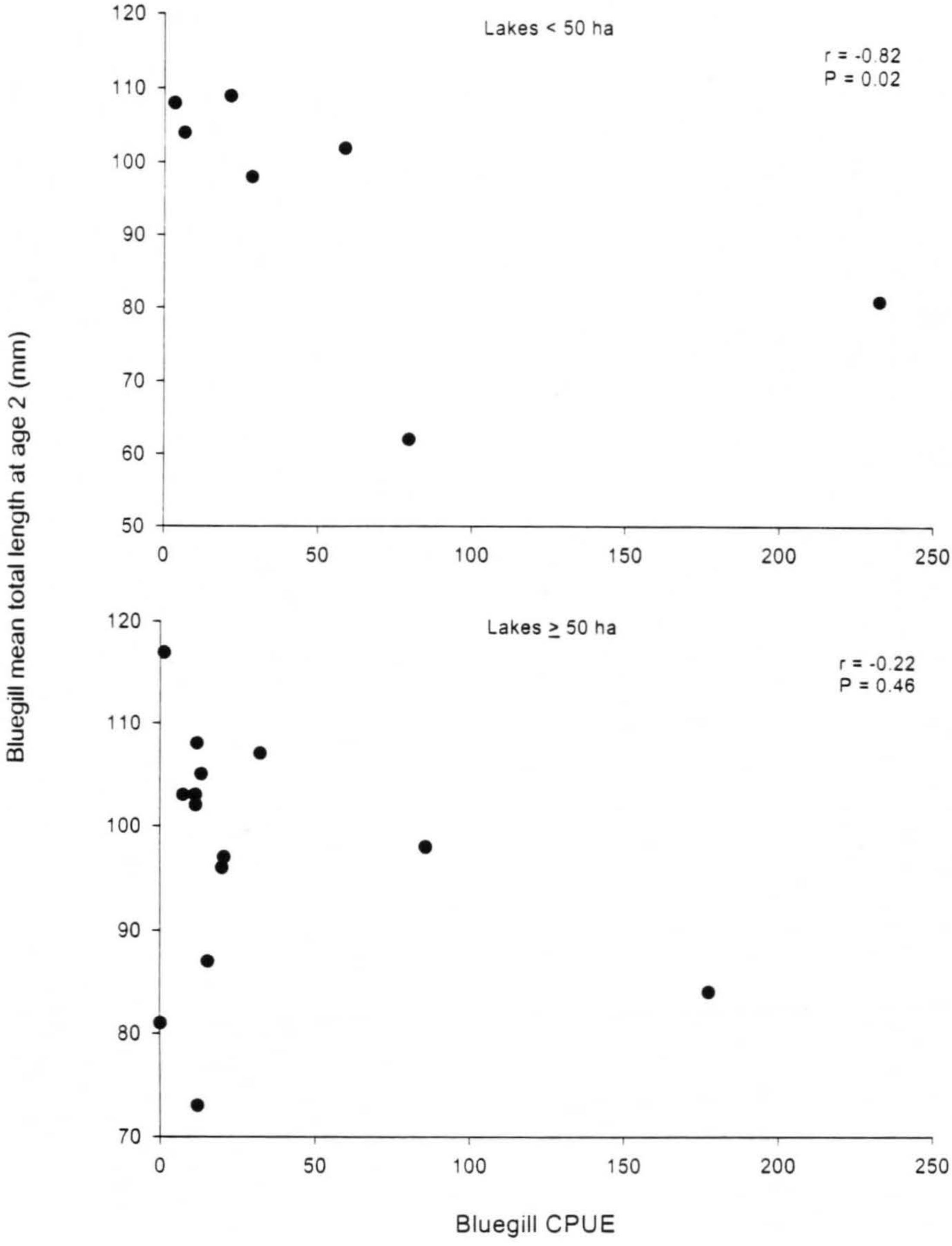

Figure 4. Relationship between bluegill catch per unit effort (CPUE; number of stock-length fish per trap net night) and mean length at age 2 in small (<50 ha) and large (≥50 ha) Nebraska Sandhill lakes sampled in 1998 and 1999.

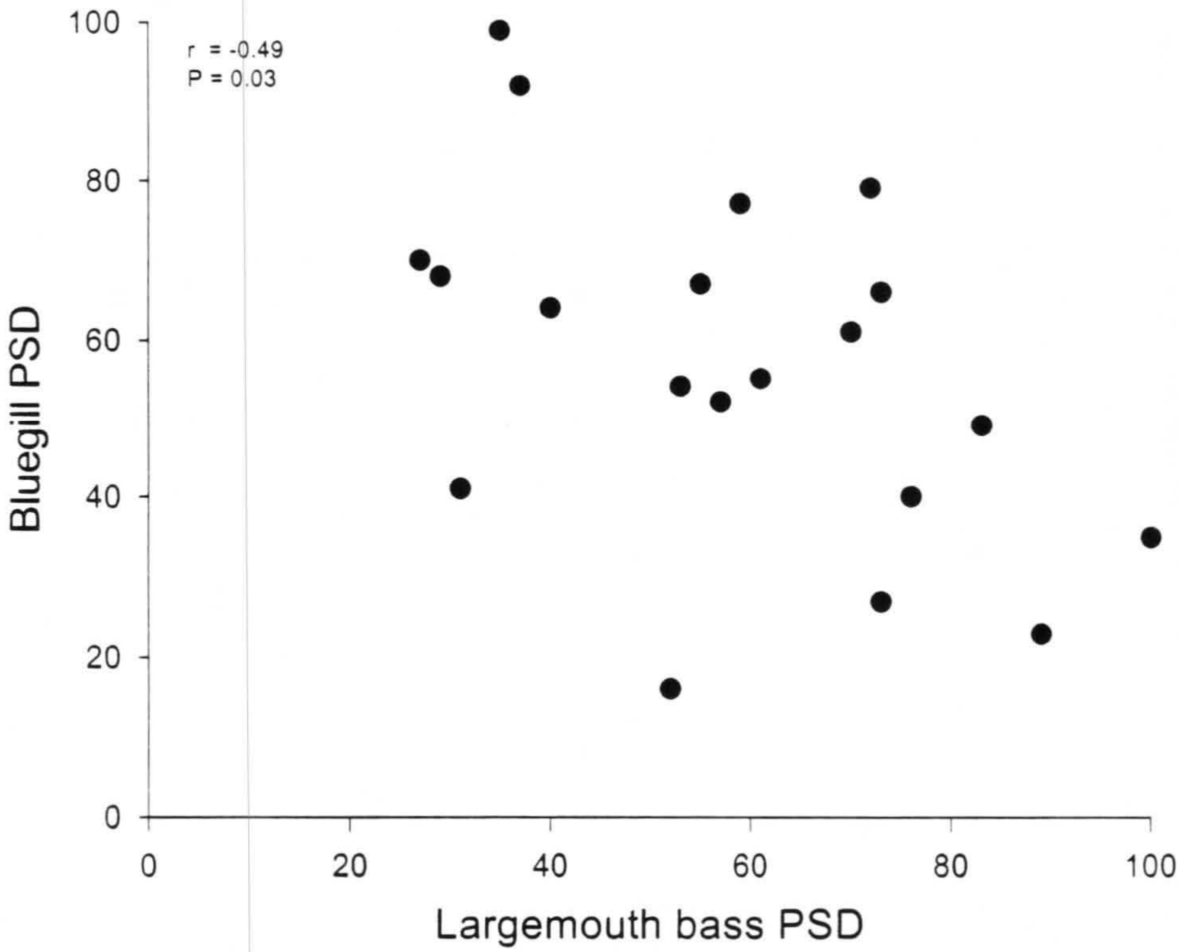

Figure 5. Relationship between largemouth bass and bluegill proportional stock density (PSD) in Nebraska Sandhill lakes sampled in 1998 and 1999.

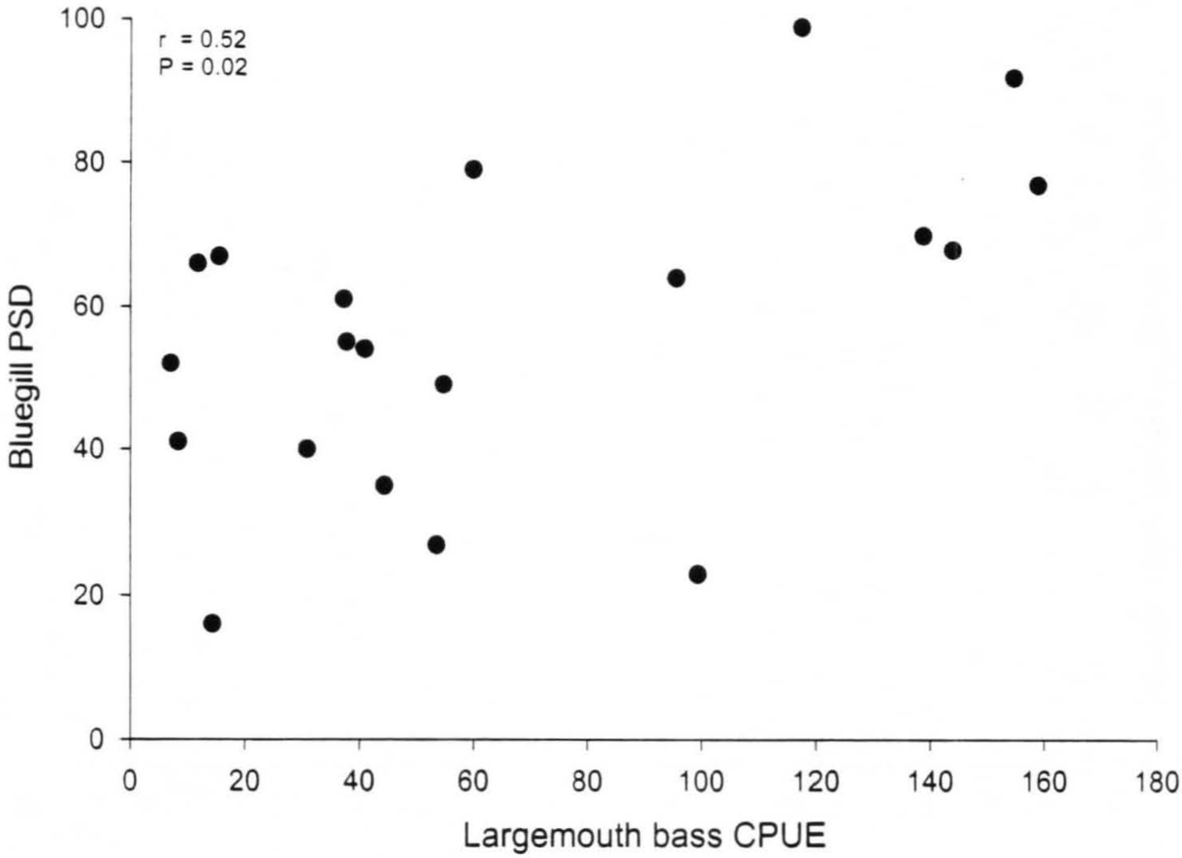

Figure 6. The relationship between largemouth bass catch per unit effort (CPUE; number of stock-length fish per hour of electrofishing) and bluegill proportional stock density (PSD) in Nebraska Sandhill lakes sampled in 1998 and 1999.

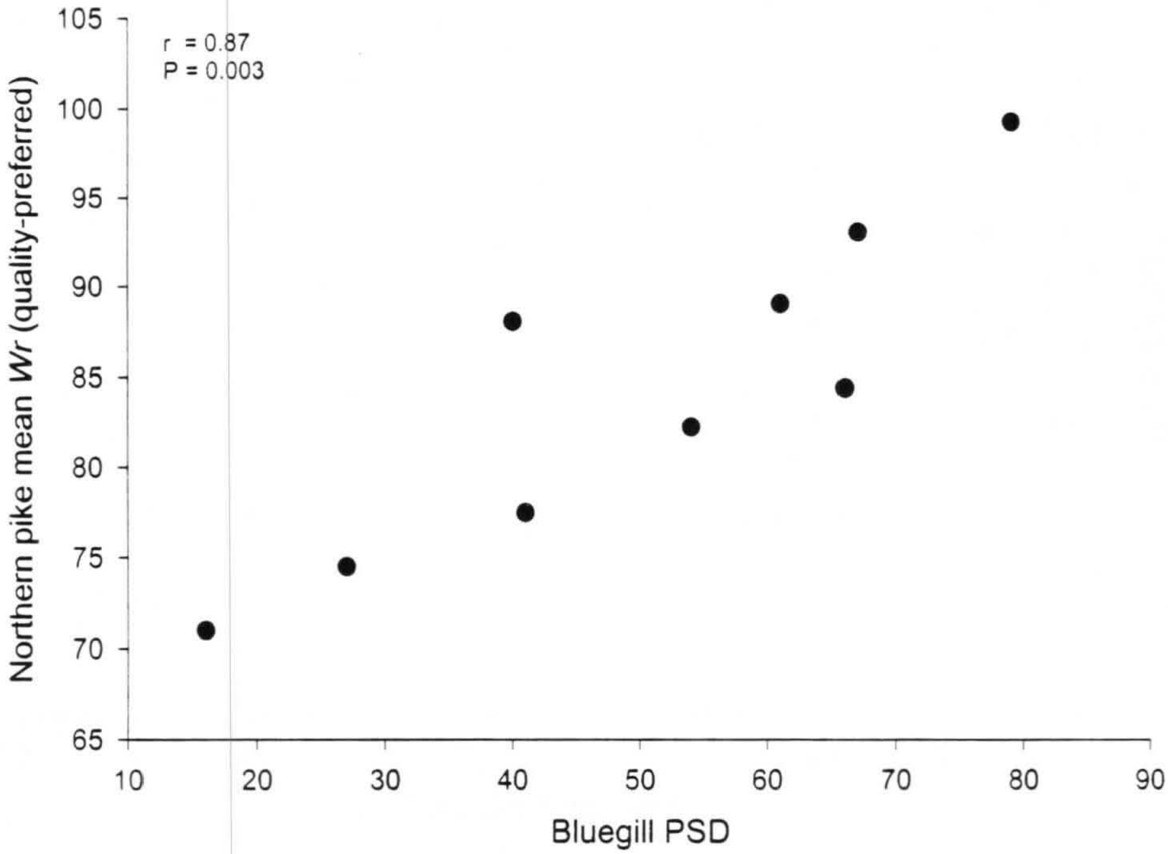

Figure 7. Correlation between bluegill proportional stock density (PSD) and mean relative weight (*Wr*) of quality- to preferred-length northern pike in Nebraska Sandhill lakes sampled in 1998 and 1999.

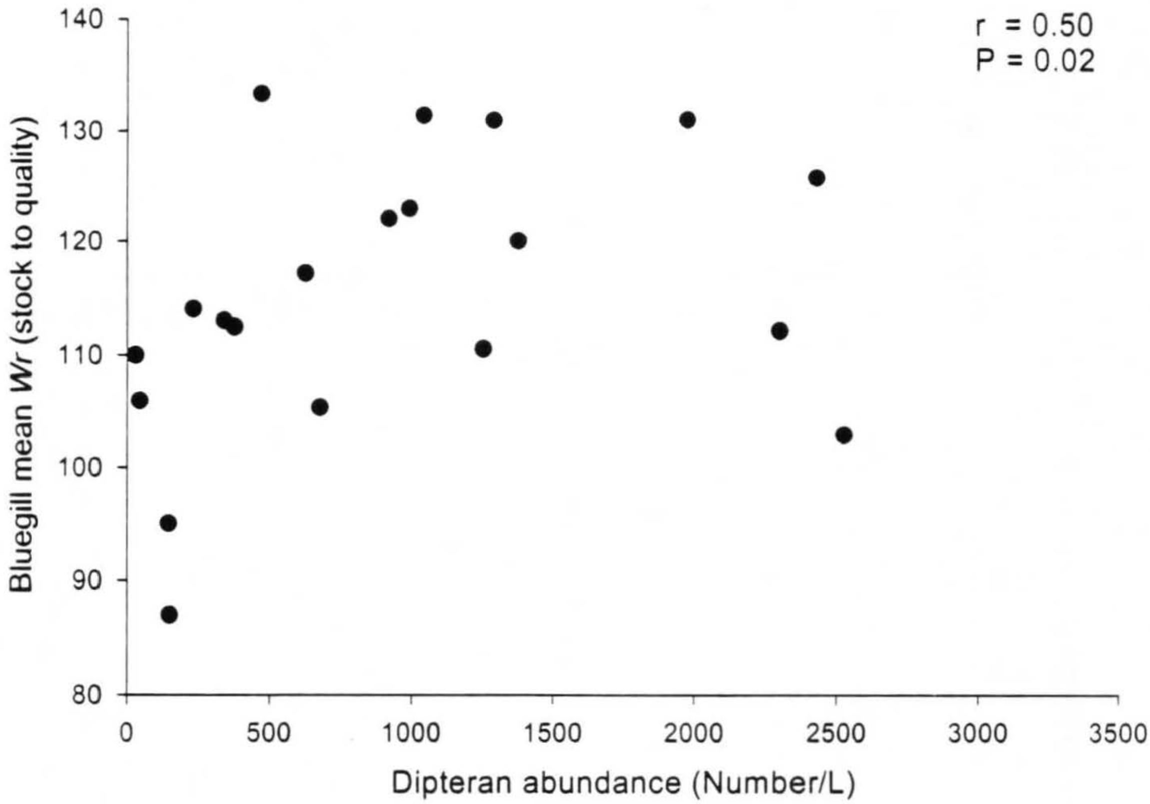

Figure 8. Relationship between mean relative weight (*Wr*) of stock- to quality-length bluegill and dipteran abundance in the Nebraska Sandhill lakes sampled during 1998 and 1999.

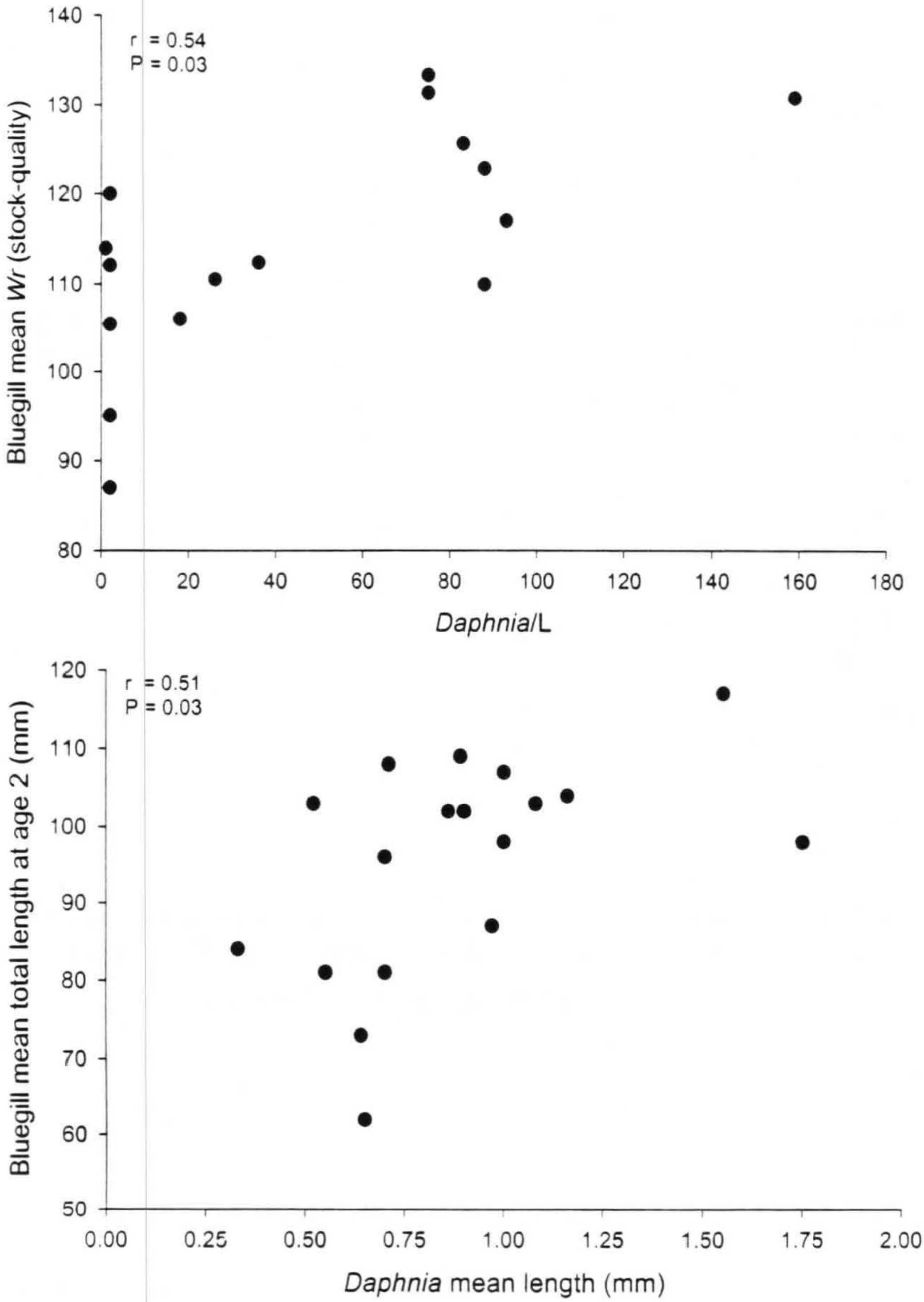

Figure 9. Relationships between bluegill condition (relative weight, *Wr*) and growth with *Daphnia* abundance and mean length in Nebraska Sandhill lakes sampled in 1998 and 1999.

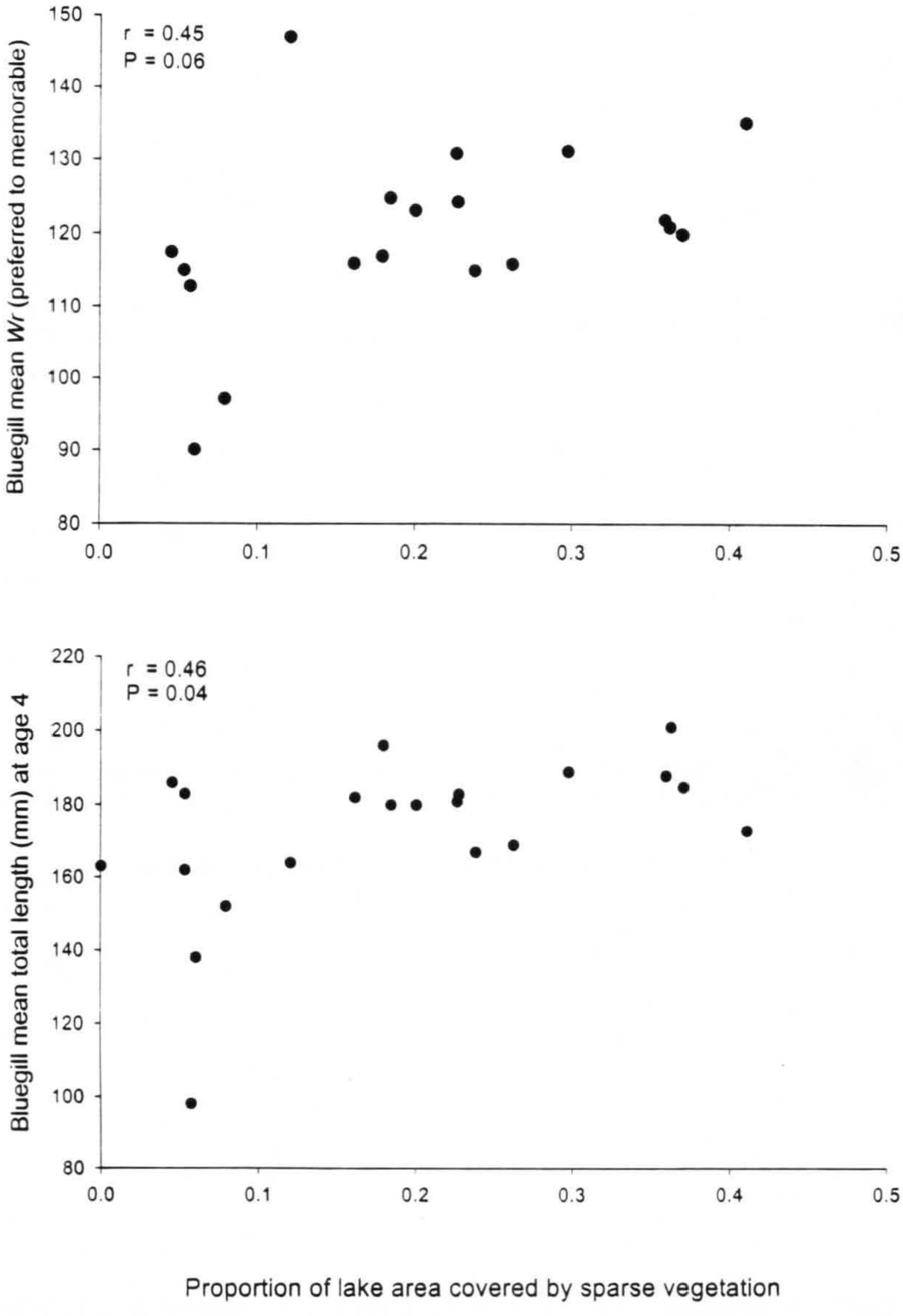

Figure 10. Relationship between the proportion of sparse vegetation within a lake and mean relative weight (*Wr*) of preferred- to- memorable-length bluegills and mean total length at age 4 of bluegills.

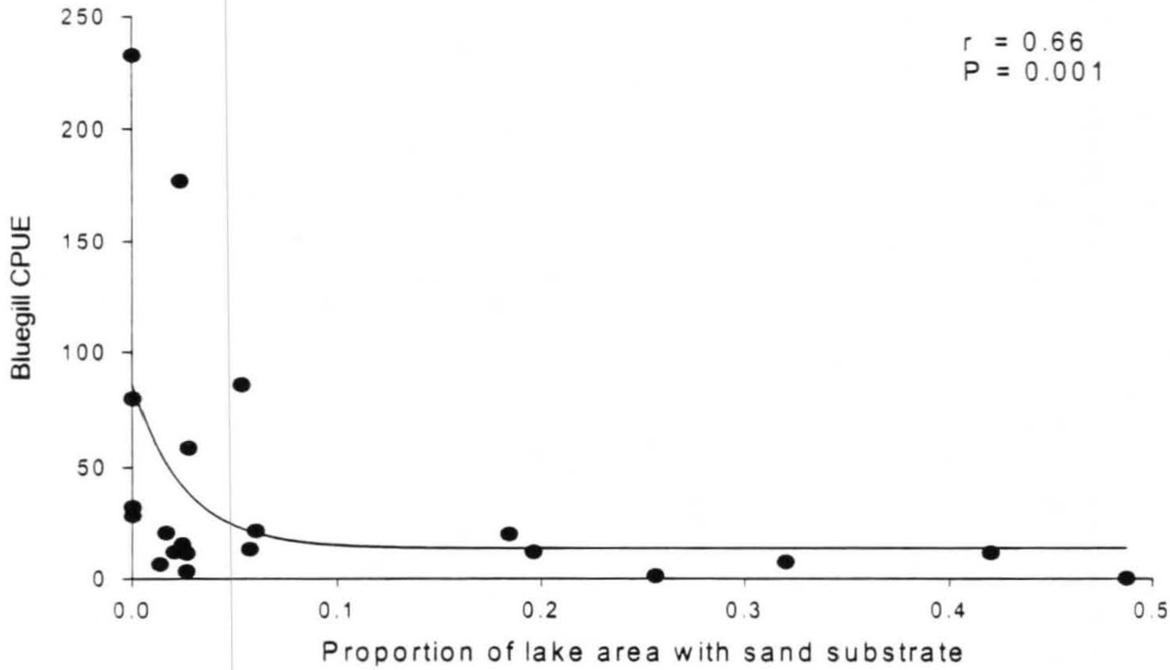

Figure 11. Relationship between the proportion of sand substrate within a lake and bluegill catch per unit effort (CPUE; number of stock-length fish collected per trap net night) in Nebraska Sandhill lakes sampled in 1998 and 1999.

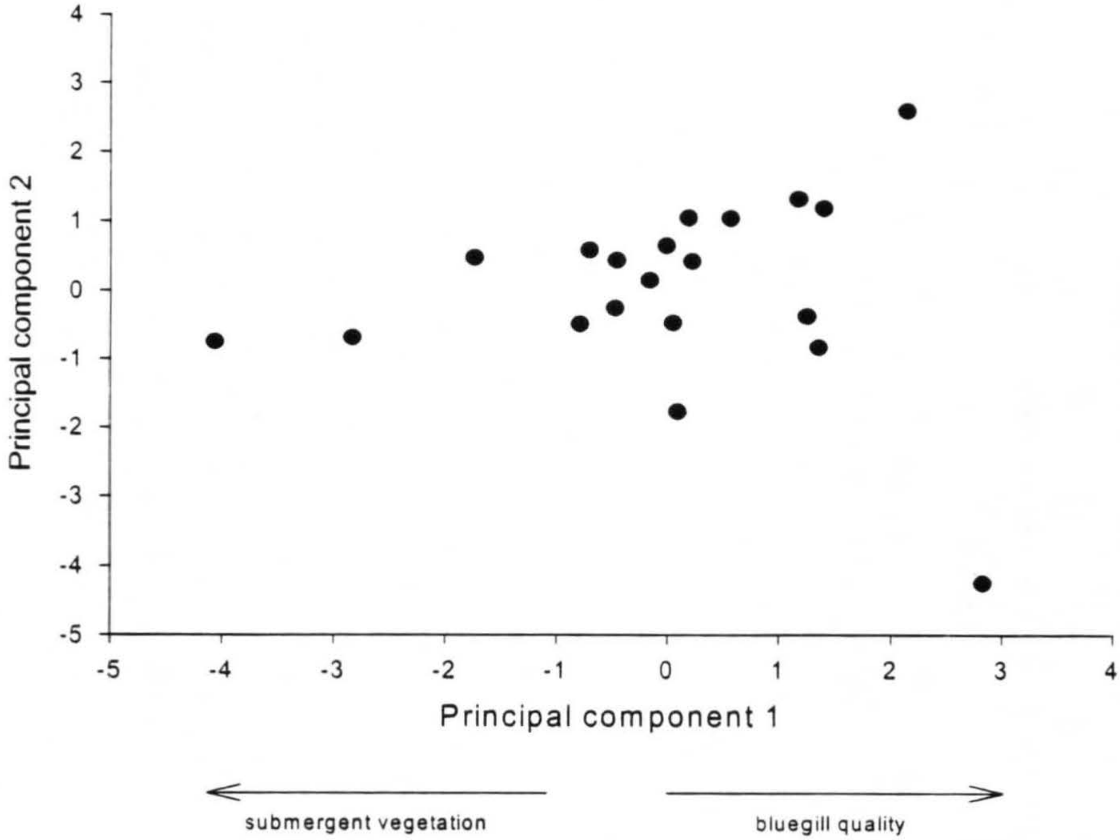

Figure 12. Scores of the first two components of a principal components analysis of bluegill quality and vegetation coverage in Nebraska Sandhill lakes sampled in 1998 and 1999. Lakes with high bluegill quality (i.e., high proportional stock density (PSD), mean relative weight (*Wr*) of stock- to quality-length fish, and mean total length at age 3) and low proportion of submergent vegetation scored high on principal component 1. Lakes with a high proportion of sand and clay substrate scored low on principal component 2.

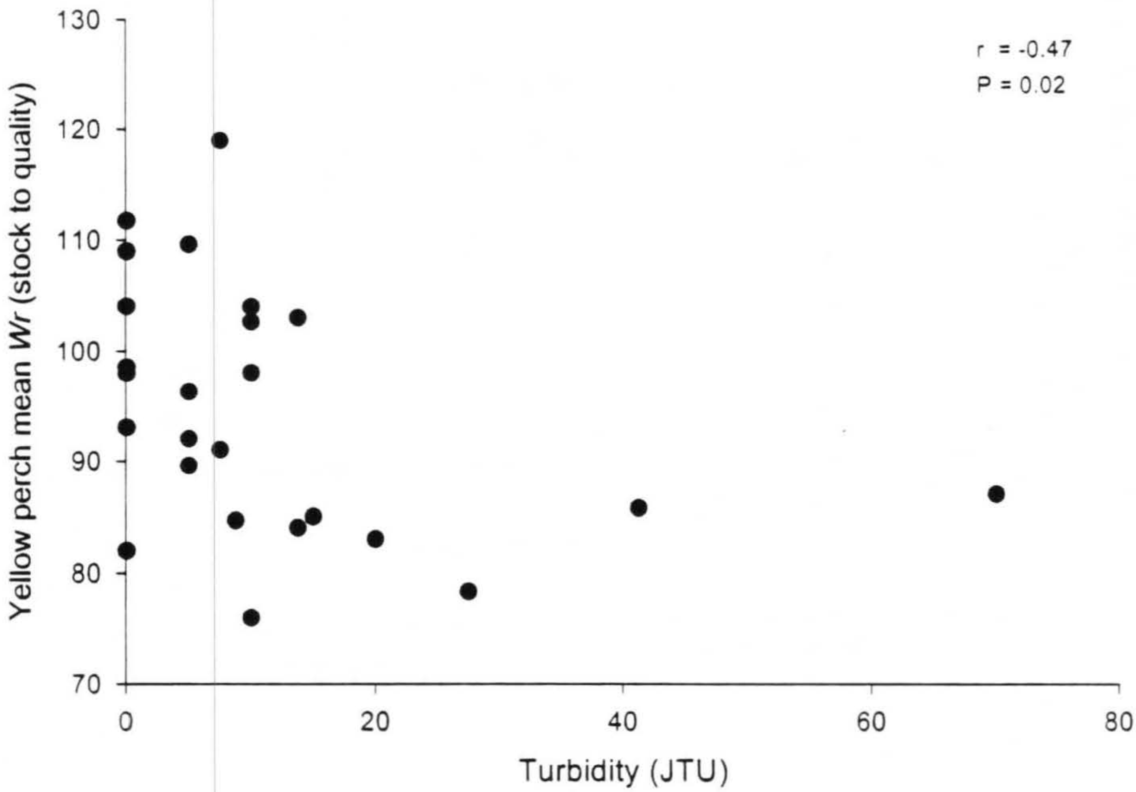

Figure 13. Relationship between mean relative weight (*Wr*) for stock to quality-length yellow perch and turbidity (Jackson turbidity units) for Nebraska Sandhill lakes sampled in 1998 and 1999.

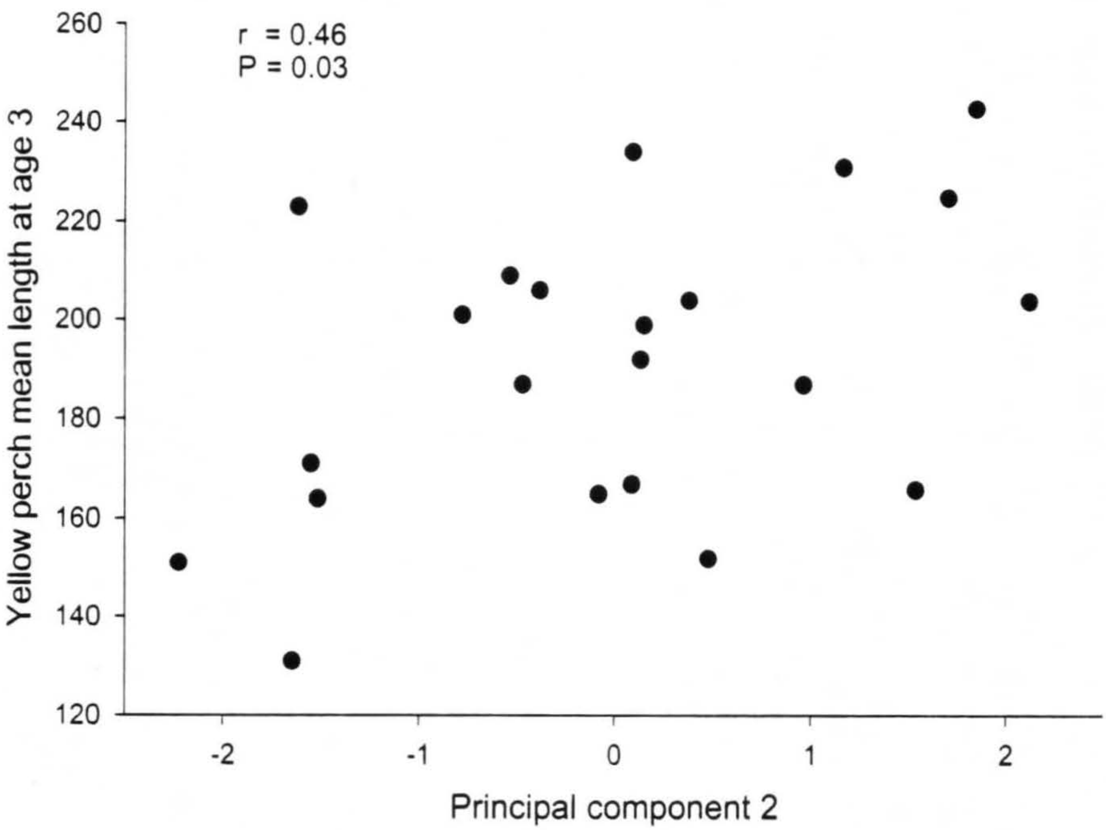

Figure 14. Relationship between yellow perch mean length at age 3 and principal component 2 of the physicochemical principal component analysis summarized in Table 1 for Nebraska Sandhill lakes sampled in 1998 and 1999. Highly productive lakes (i.e., high chlorophyll *a* and phosphorus) scored high on principal component 2.

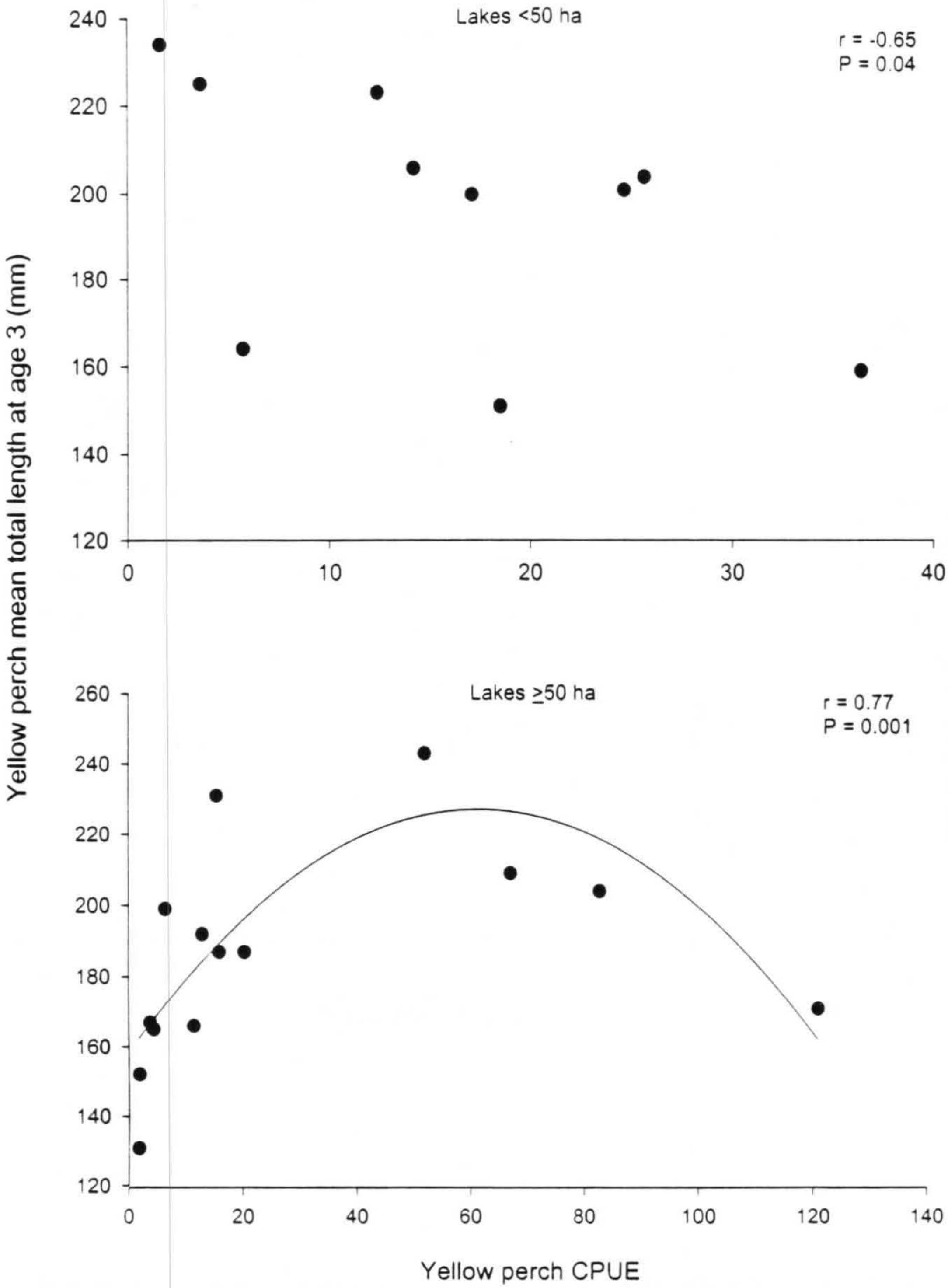

Figure 15. Relationships between yellow perch catch per unit effort (CPUE; number of stock-length fish per trap net night) and mean length at age 3 in small (<50 ha) and large (≥50 ha) Nebraska Sandhill lakes sampled in 1998 and 1999.

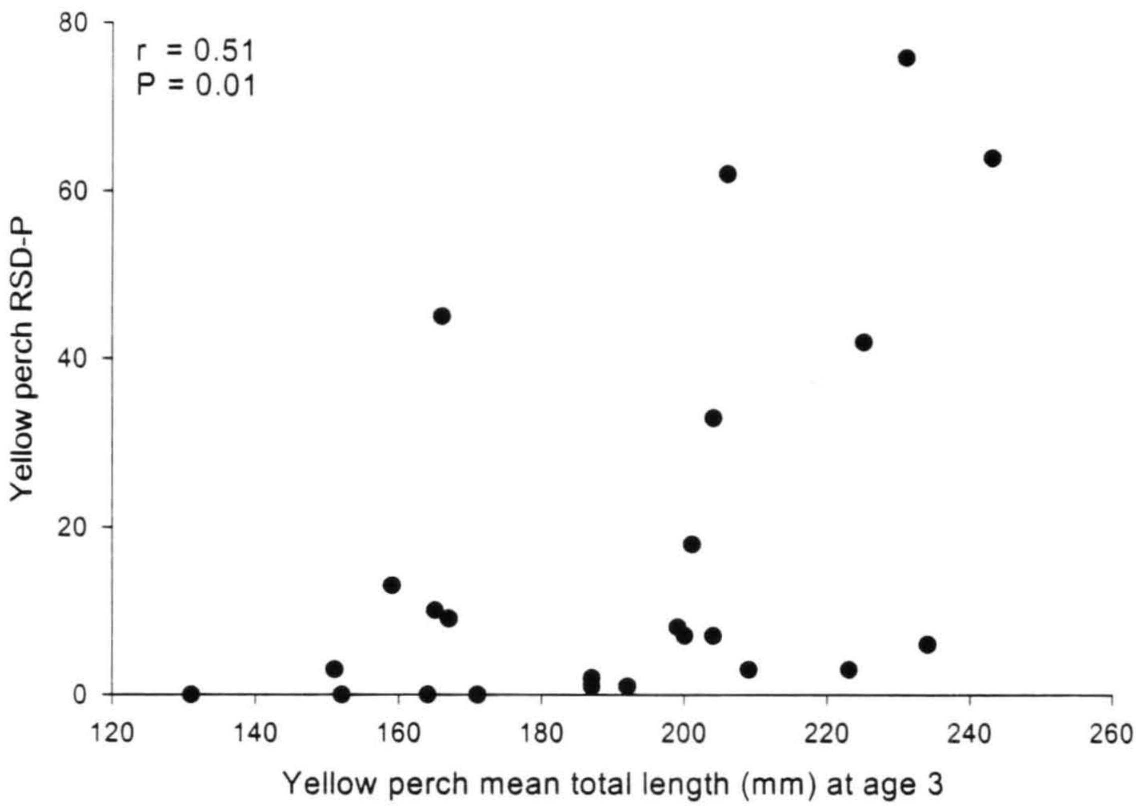

Figure 16. Correlation between relative stock density of preferred-length yellow perch (RSD-P) and mean total length at age 3 In Nebraska Sandhill lakes sampled in 1998 and 1999.

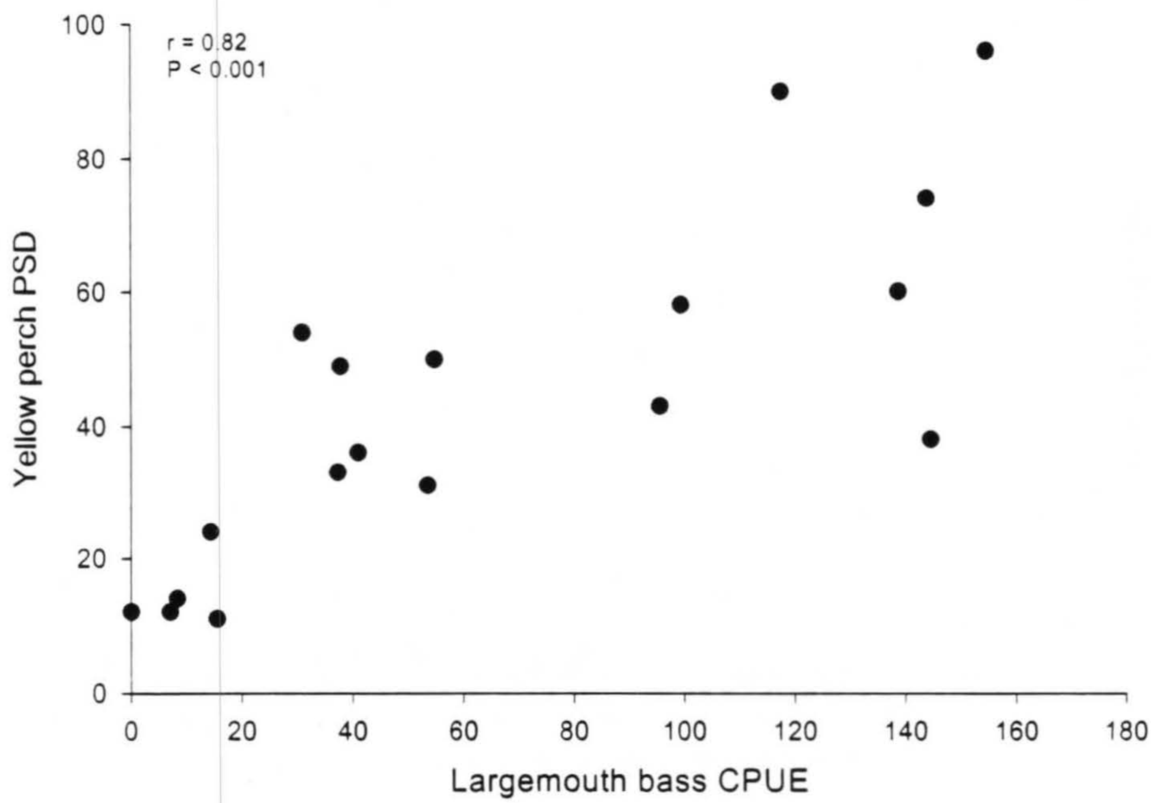

Figure 17. The relationship between largemouth bass catch per unit effort (CPUE; number of stock-length fish per hour of electrofishing) and yellow perch proportional stock density (PSD) in Nebraska Sandhill lakes sampled in 1998 and 1999.

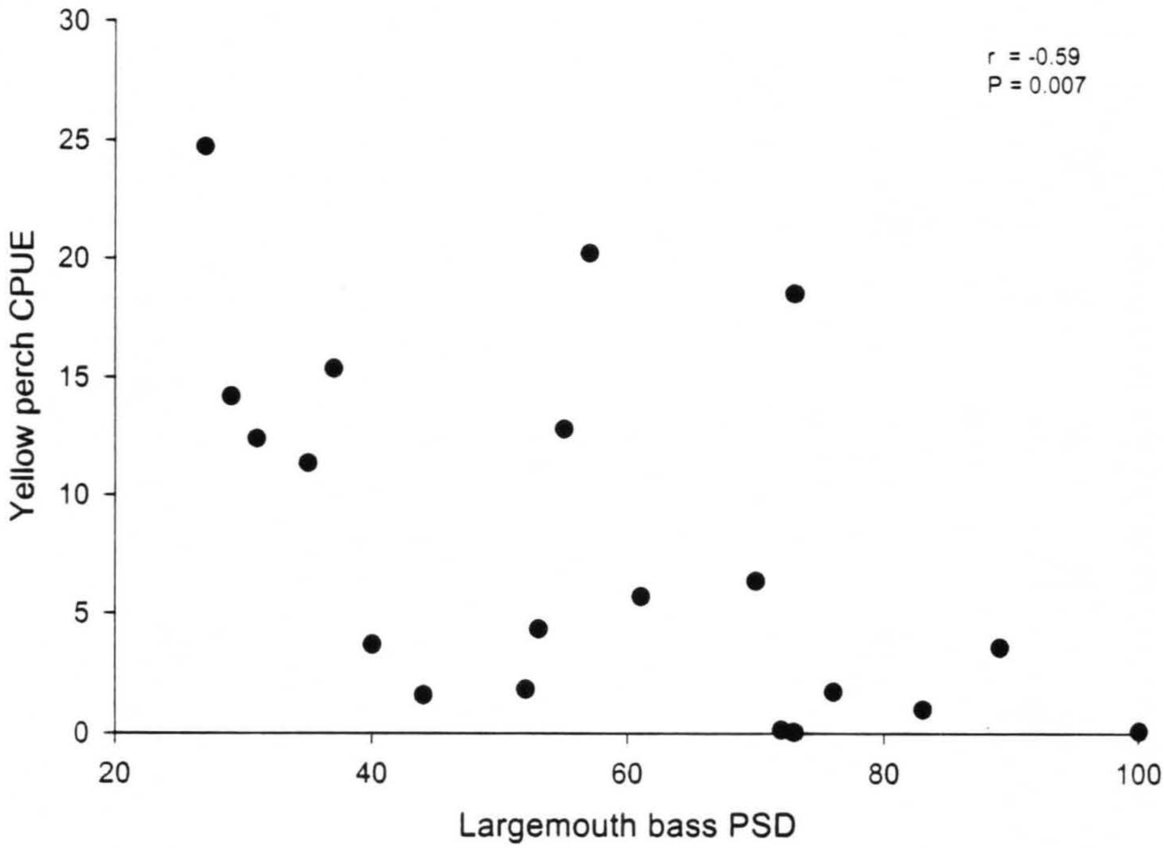

Figure 18. The relationship between largemouth bass proportional stock density (PSD) and yellow perch catch per unit effort (CPUE; number of stock-length fish per trap net night) in Nebraska Sandhill lakes sampled in 1998 and 1999.

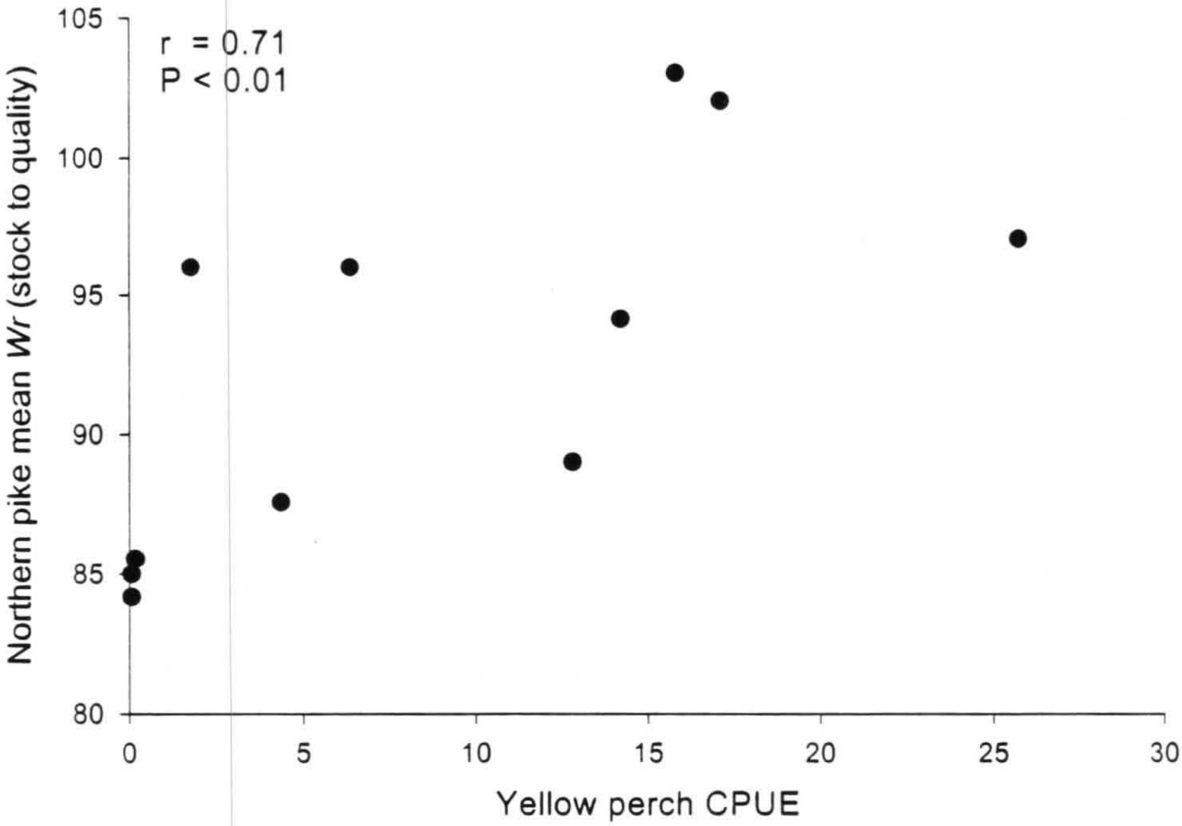

Figure 19. Relationship between mean relative weight (*Wr*) of stock- to quality-length northern pike and yellow perch catch per unit effort (CPUE; number of stock-length fish per trap net night) in Nebraska Sandhill lakes sampled in 1998 and 1999.

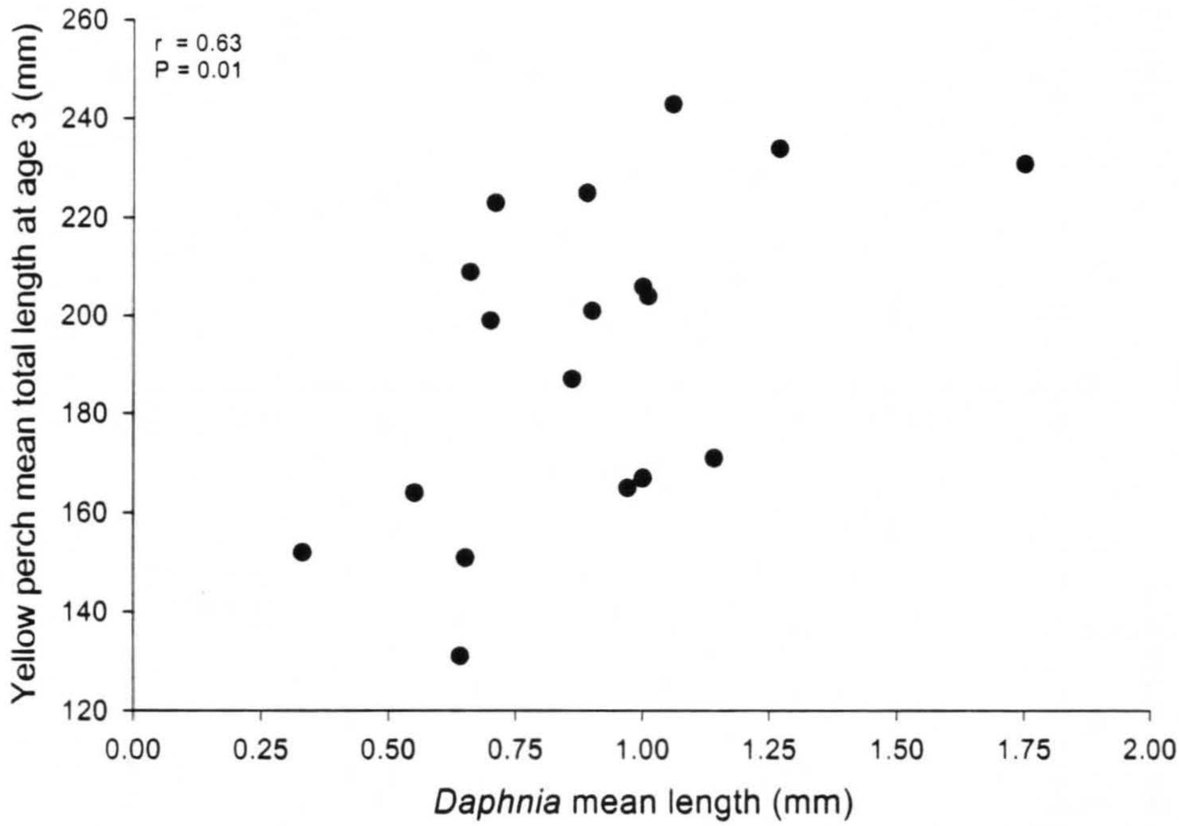

Figure 20. The relationship between yellow perch mean length at age 3 and *Daphnia* mean length in Nebraska Sandhill lakes sampled in 1998 and 1999.

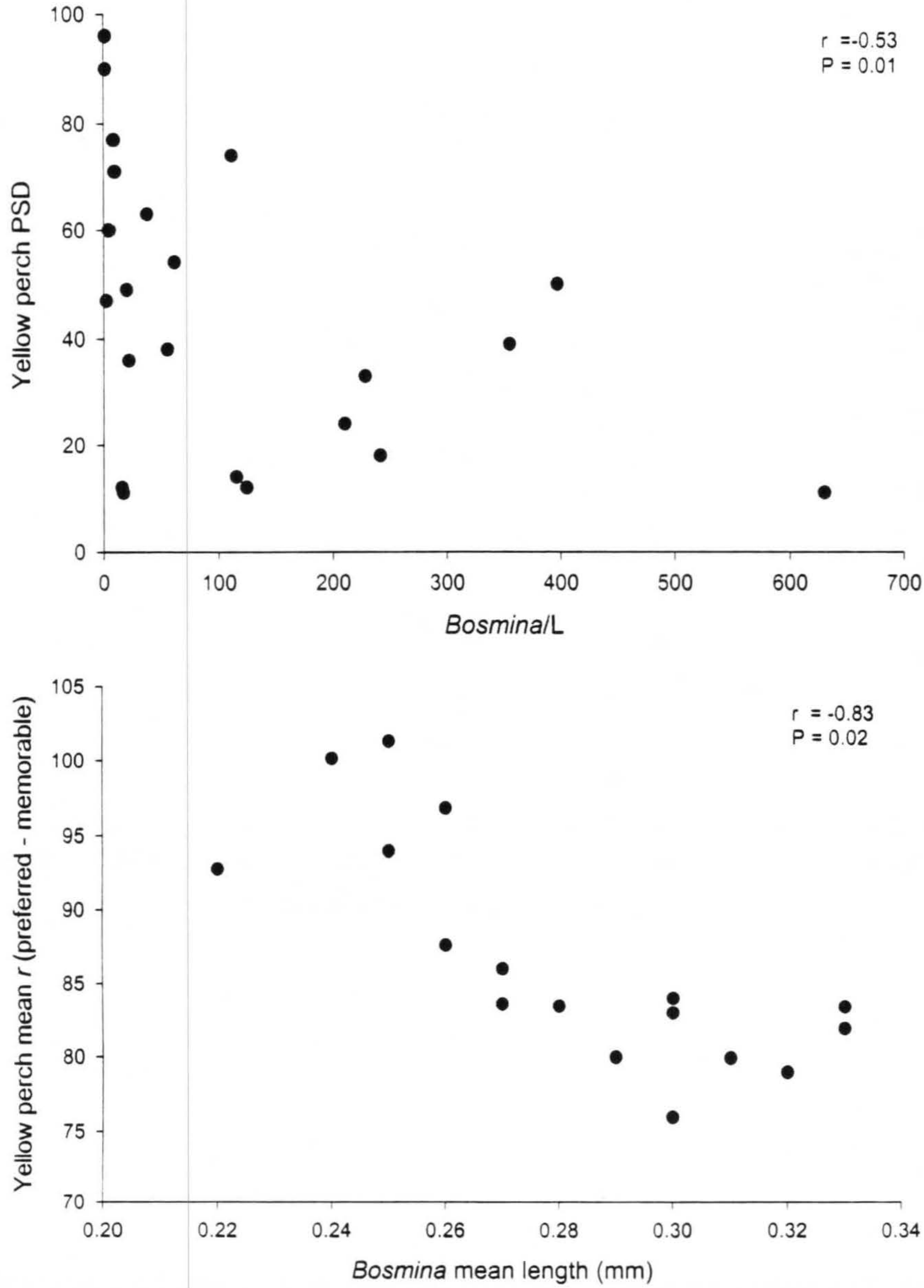

Figure 21. Relationships between yellow perch proportional stock density (PSD) and mean relative weight (*Wr*) of preferred- to memorable-length fish with *Bosmina* abundance and mean length in Nebraska Sandhill lakes sampled in 1998 and 1999.

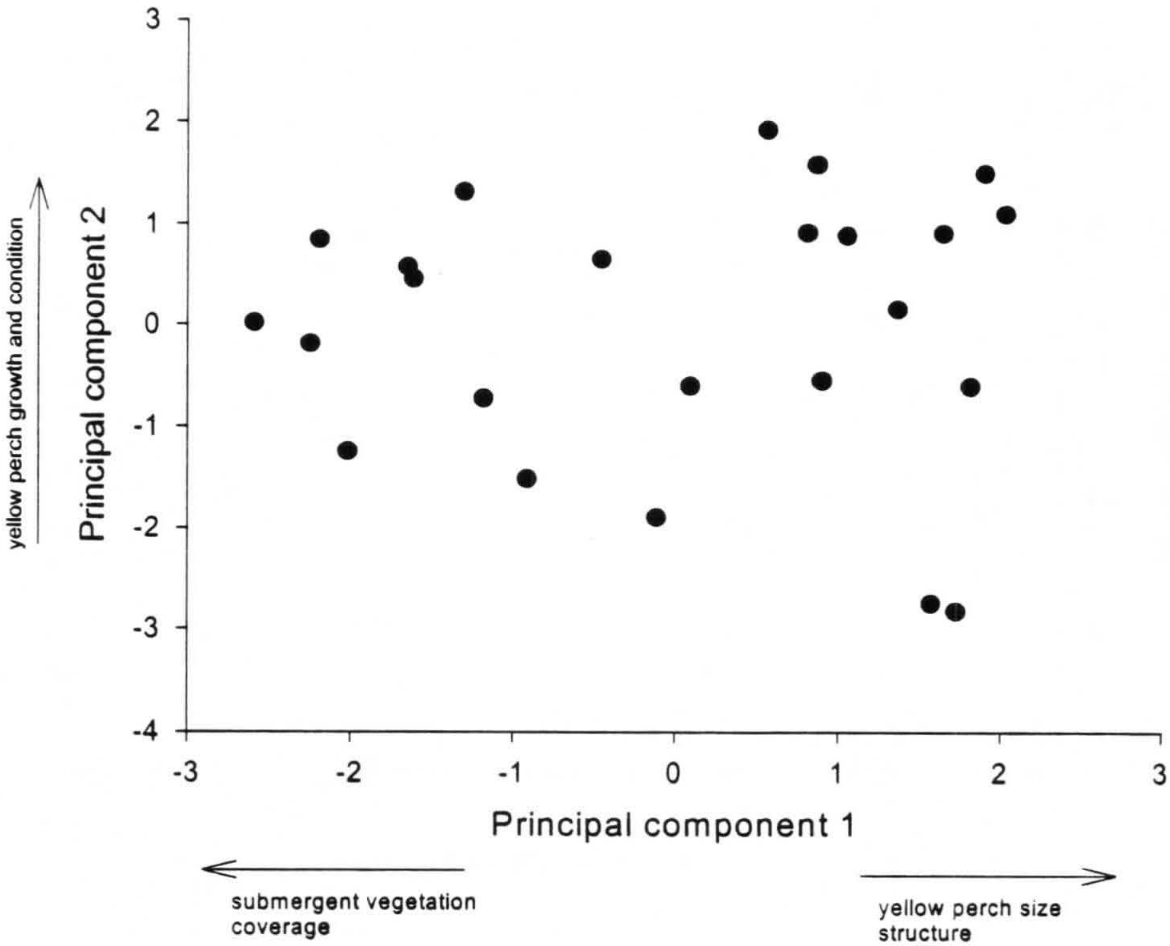

Figure 22. Scores of the first two components of a principal components analysis of yellow perch quality and vegetation coverage in Nebraska Sandhill lakes sampled in 1998 and 1999. Lakes with high yellow perch size structure and a low proportion of submergent vegetation scored high on principal component 1. Lakes with high yellow perch mean length at age 3 and mean relative weight (*Wr*) of stock to quality length fish scored high on principal component 2.

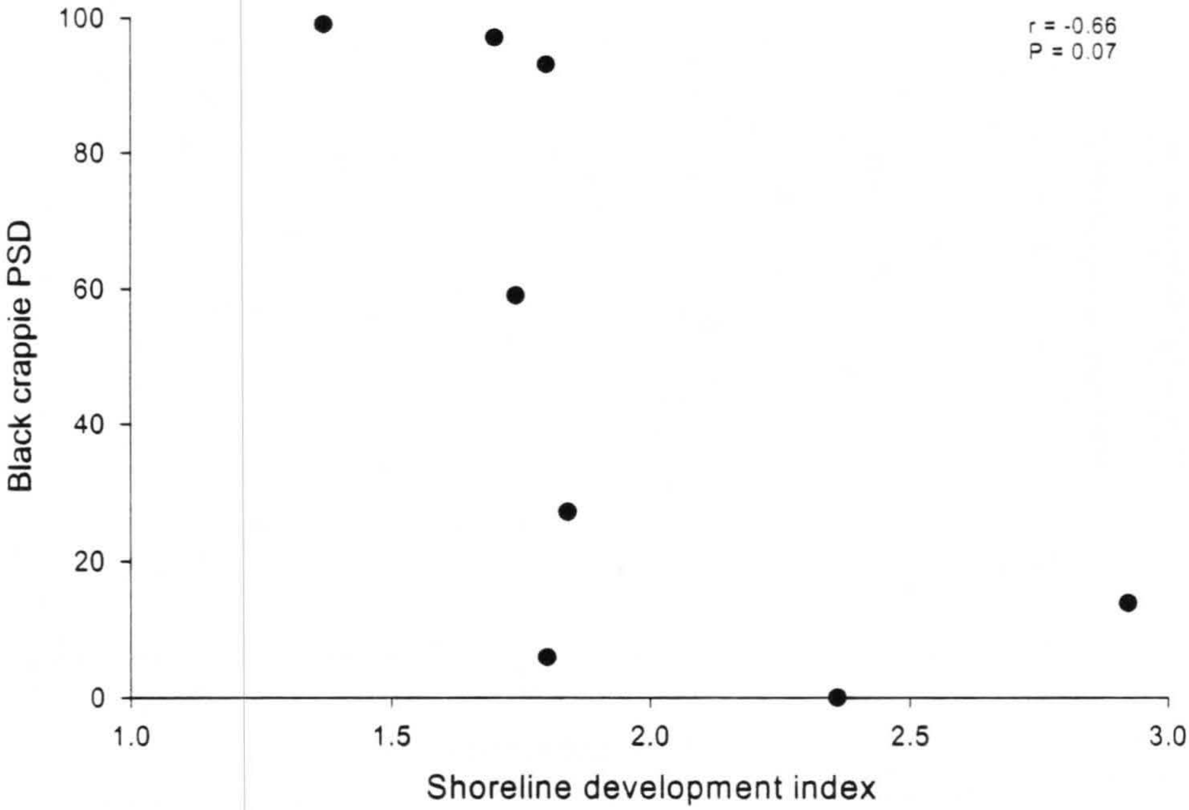

Figure 23. Correlation between black crappie proportional stock density (PSD) and shoreline development index of Nebraska Sandhill lakes sampled in 1998 and 1999.

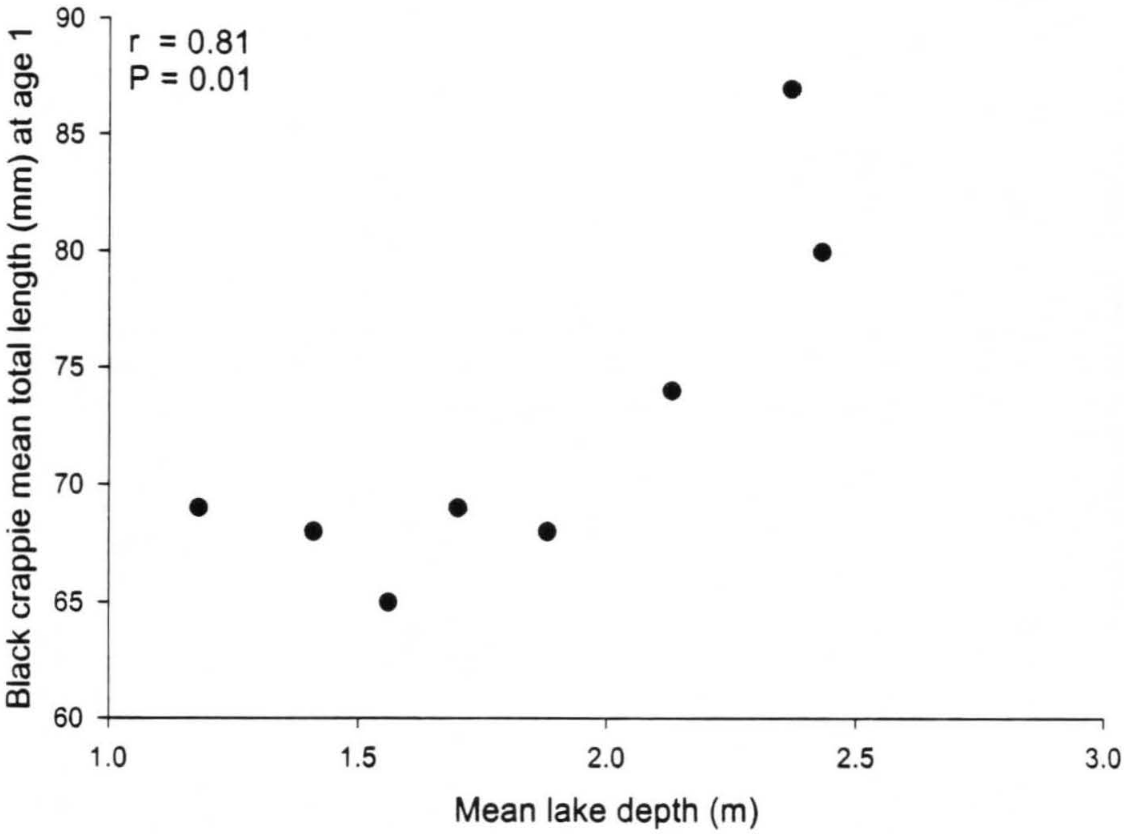

Figure 24. Relationship between black crappie mean total length (mm) at age 1 and mean lake depth (m) in Nebraska Sandhill lakes sampled in 1998 and 1999.

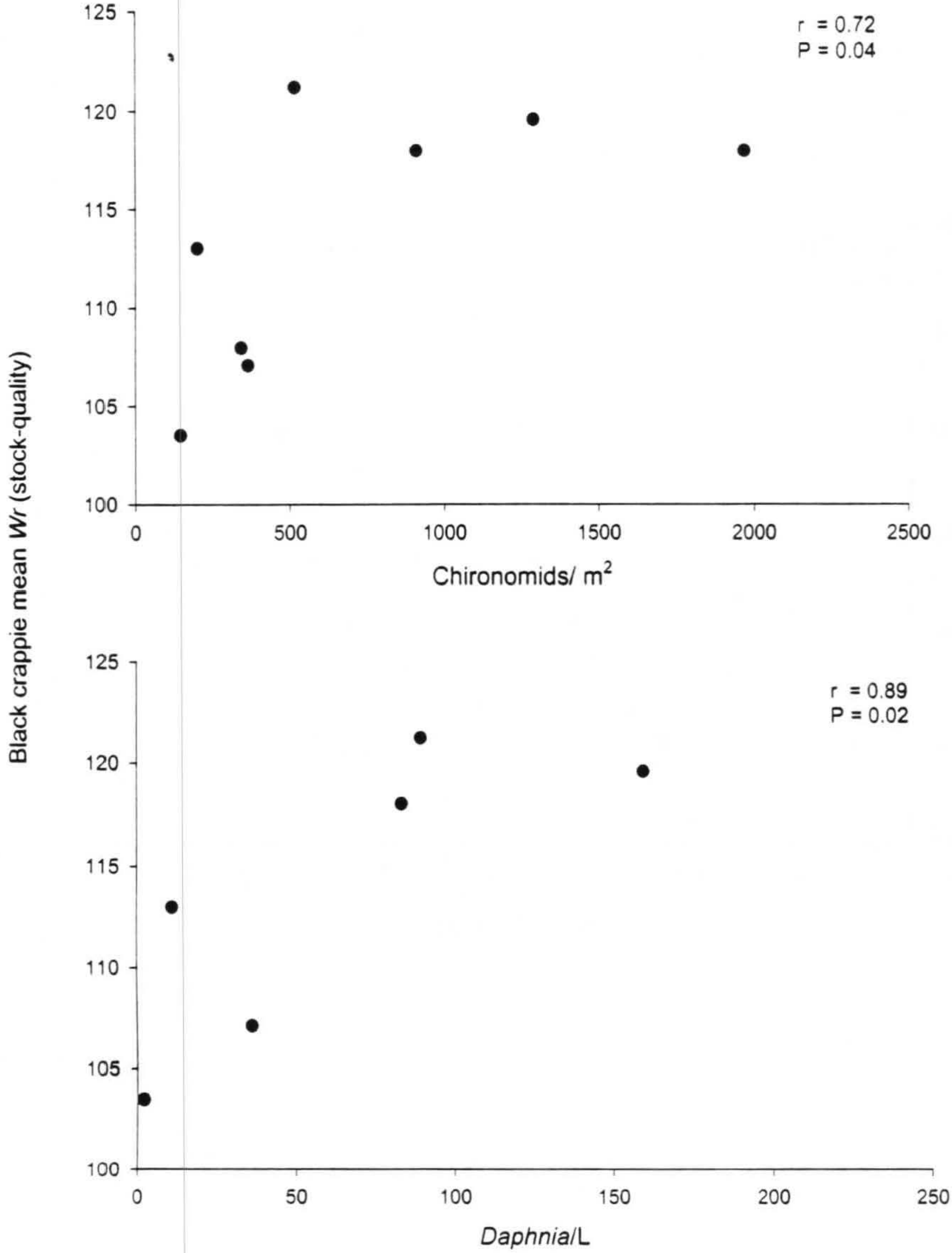

Figure 25. Correlations between mean relative weight (*Wr*) of stock- to quality-length black crappies and chironomid and *Daphnia* abundance in Nebraska Sandhill lakes sampled in 1998 and 1999.

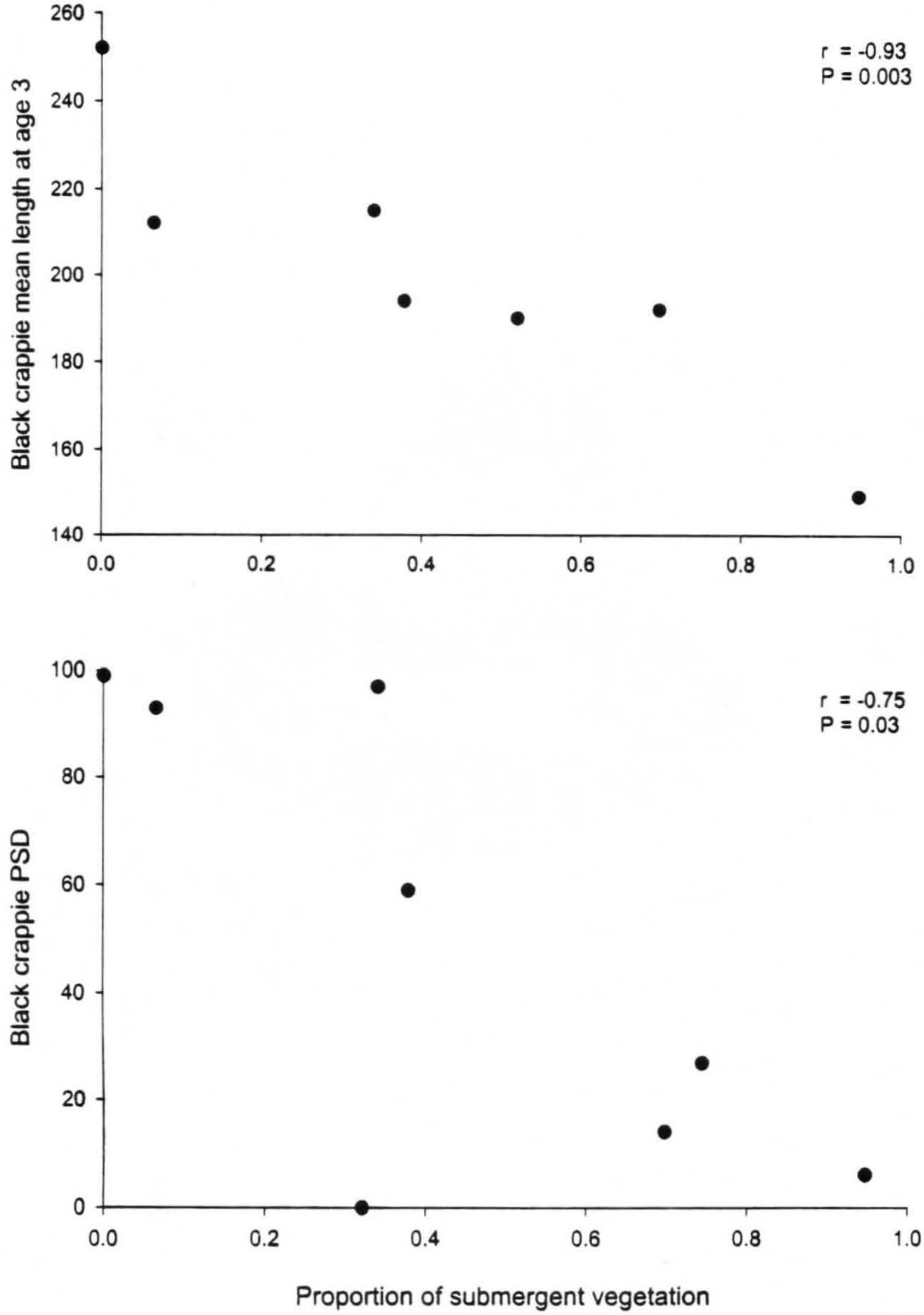

Figure 26. Relationship between submergent vegetation abundance and black crappie mean length at age 3 and proportional stock density (PSD) in Nebraska Sandhill lakes sampled in 1998 and 1999.

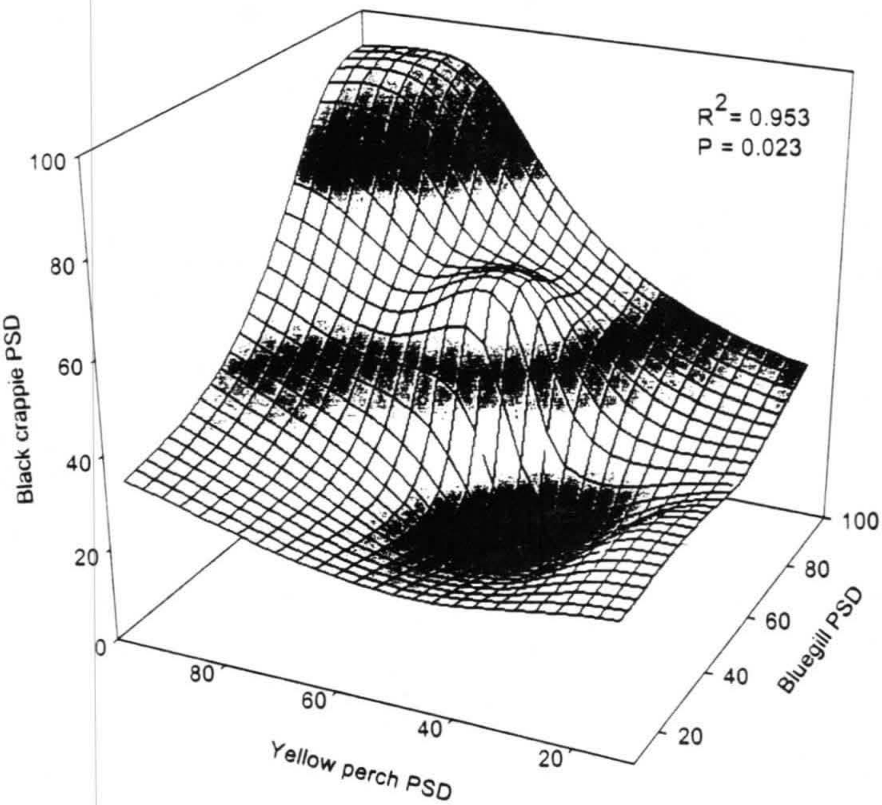

Figure 27. Relationship among proportional stock density (PSD) values for bluegill, black crappie, and yellow perch collected from Nebraska Sandhill lakes sampled in 1998 and 1999.

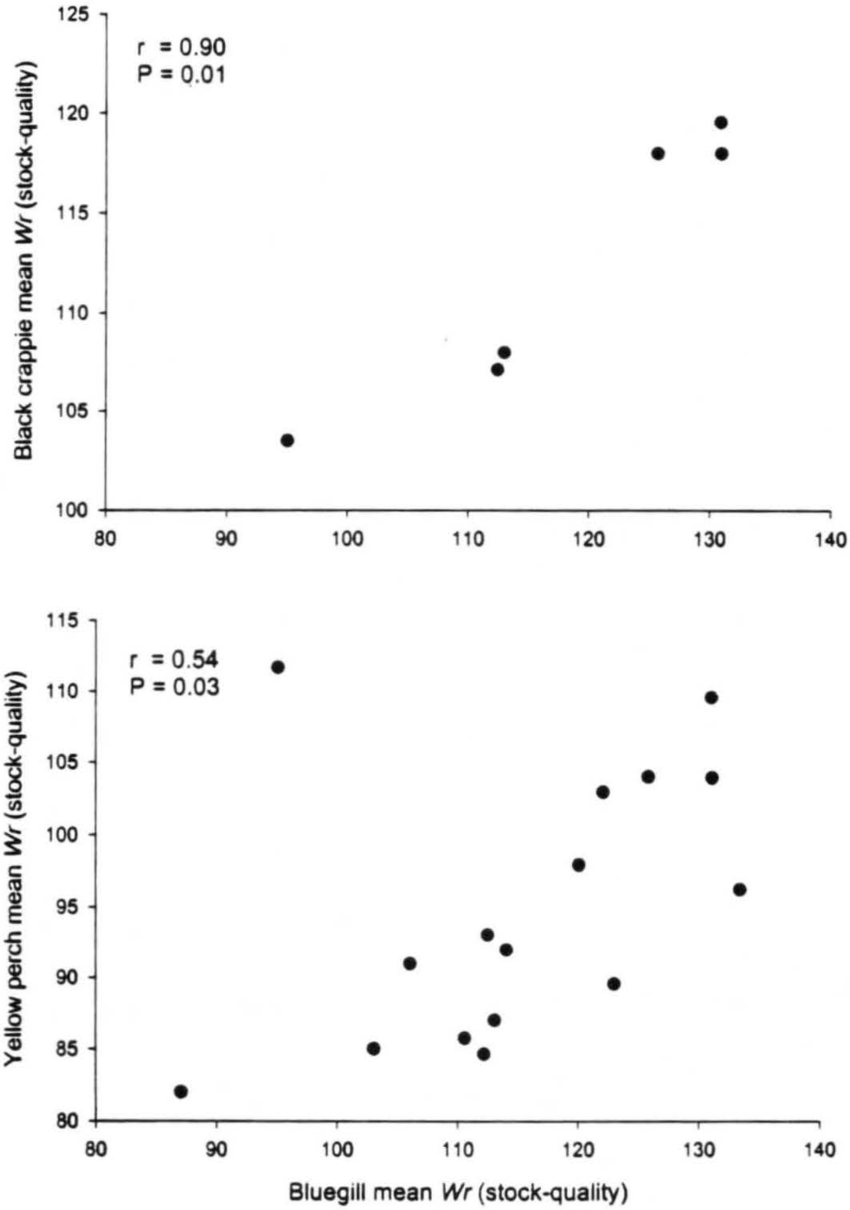

Figure 28. Relationships between mean relative weight (*Wr*) of stock- to quality-length bluegill, black crappie, and yellow perch in Nebraska Sandhill lakes sampled in 1998 and 1999.

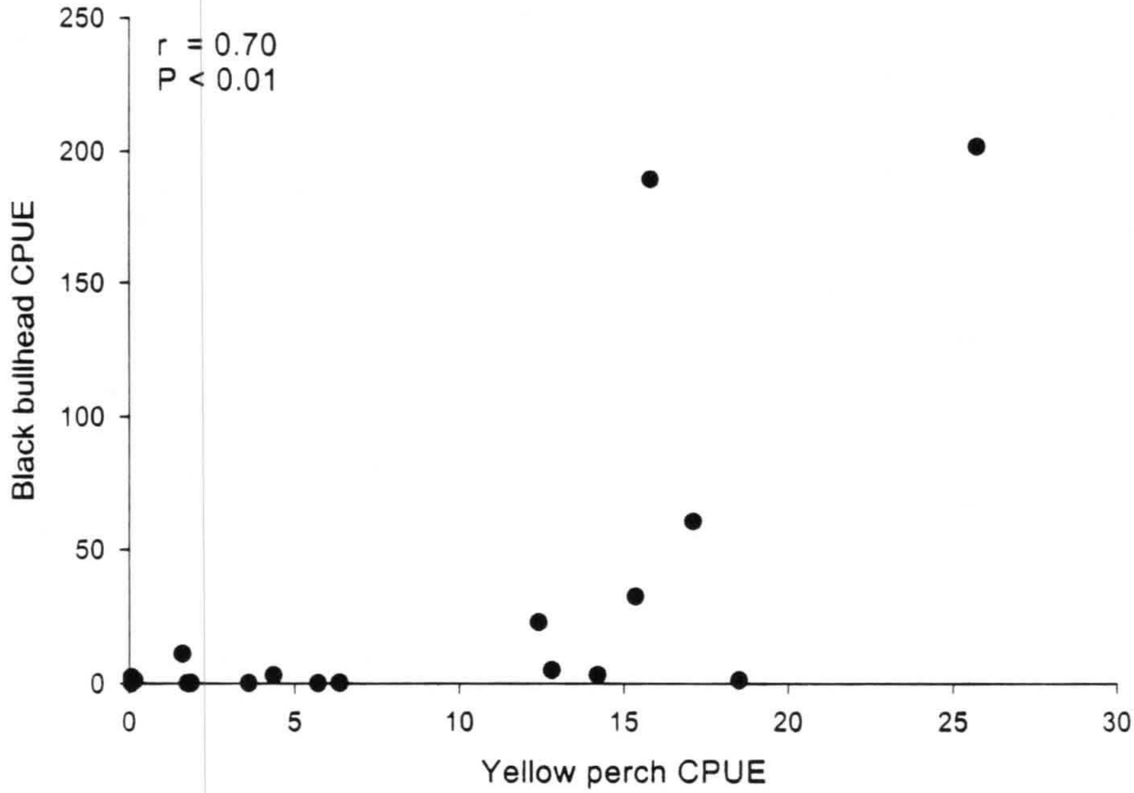

Figure 29. Relationship between black bullhead catch per unit effort (CPUE; number of stock-length fish per trap net night) and yellow perch CPUE (number of stock-length fish per trap net night) for Nebraska Sandhill lakes sampled in 1998 and 1999.

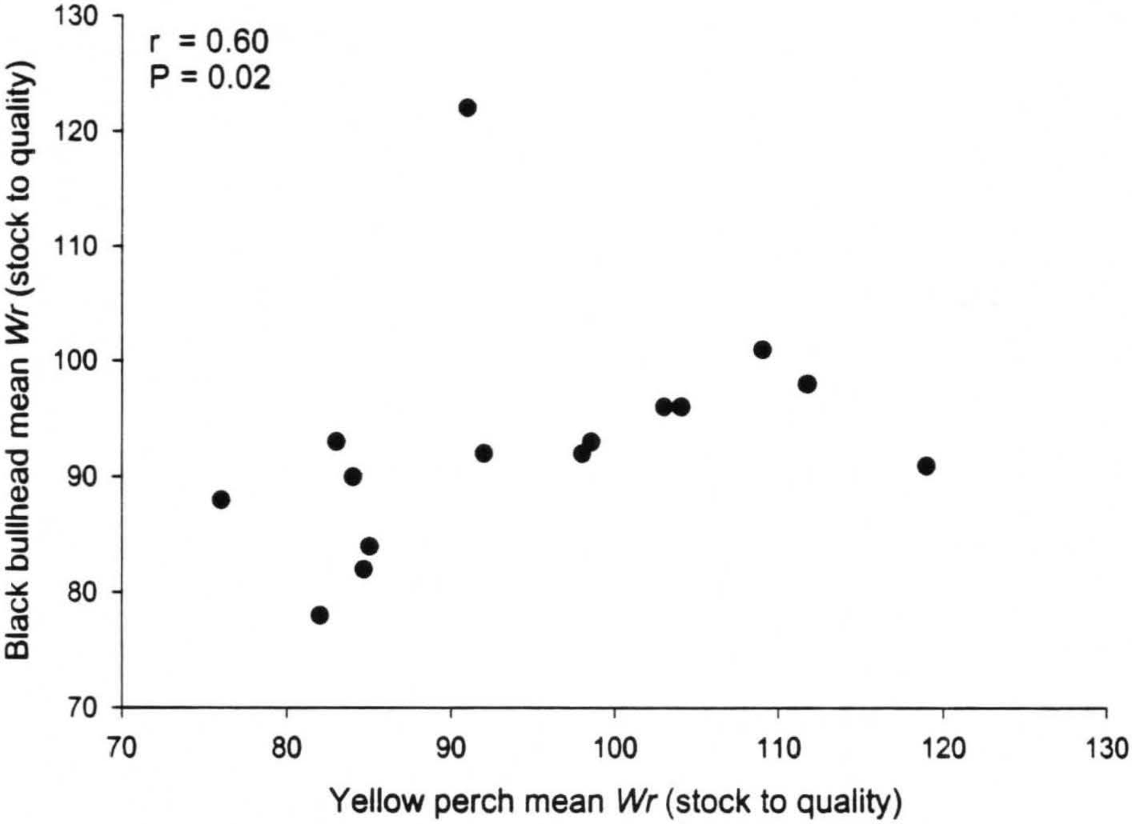

Figure 30. Correlation between mean relative weight (*Wr*) of stock- to quality-length black bullheads and yellow perch in Nebraska Sandhill lakes sampled in 1998 and 1999.

Prepared by: ____

Craig P. Paukert and David W. Willis, South Dakota State University
29 February 2000

Approved By: ____

Appendix 1. Legal description and physical characteristics of 30 Nebraska Sandhill Lakes sampled in 1998-1999.

Lake	County	Legal description	Surface area (ha)	Shoreline development index	Mean depth (m)	Maximum depth (m)
Alkali	Cherry	T26N, R40W,S10,11,12	154	2.33	1.8	2.6
Big Alkali	Cherry	T30N, R28W, S27-28,32,33	341	1.37	2.4	3.3
Cameron	Rock	T28N,R18W, S21	66	1.99	1.8	2.9
Clear	Brown	T26N R23W S6,31,36	79	1.57	2.1	3.4
Clear (VNWR[1])	Cherry	T30N R28W S19,20,21	172	1.83	2.9	4.3
Cottonwood	Cherry	T37N R34W S21	15	1.54	2.3	3.4
Cozad	Brown	T28N R20W S26	32	1.80	1.9	3.2
DeFair	Grant	T23N, R38W,S15	24	1.80	1.0	1.5
Dewey	Cherry	T30N,R28W,S28,29,30	223	2.14	1.9	2.8
Duck	Cherry	T30N,R29W,S28	27	1.21	1.7	3.3
Goose	Holt	T25N,R11W,S26	81	1.98	2.2	2.8
Hackberry	Cherry	T19-30N R29W S14,15,22,23	275	1.82	1.5	2.1
Hagan	Brown	T27N R20W S10,11	126	2.36	2.4	3.3
Home Valley	Cherry	T27N R37W S5,6	97	1.81	3.0	4.3
Island	Garden	T20N,R44W,S3, T21N,R44W,S35	283	1.80	1.4	3.7
Lackaff West	Rock	T28N,R19W,S15,16	69	2.84	1.4	2.8
Marsh	Cherry	T27N,R32W,S23,24	33	1.66	1.5	2.3
Marsh (VNWR[1])	Cherry	T29N R27W S29-32,5,6,8,9	907	2.63	1.8	2.6

Appendix 1 continued.

Lake	County	Legal description	Surface area (ha)	Shoreline development index	Mean depth (m)	Maximum depth (m)
Medicine	Cherry	T32N R35W S27,28	45	1.74	1.2	1.9
Pelican	Cherry	T29,30N R28,29W S16,34-36	332	2.02	1.6	2.8
Roseberry	Cherry	T28N R35W S25,30	33	2.01	1.4	2.0
Round	Rock	T28N,R18W,S18	17	1.18	1.0	1.6
Schoolhouse	Cherry	T31N R33W S25,30	42	1.84	2.2	3.3
Shell	Cherry	T34N,R40W,S16	66	1.27	1.6	2.7
Shoup	Cherry	T32N,R34W,S33	19	1.24	1.4	1.9
Tower	Brown	T28N,R22W,S35,36	123	2.92	1.7	4.0
Twin	Rock	T27N R19W S12,13	65	1.70	2.1	4.0
Watts	Cherry	T30N,R29W,S13,14,15	93	1.99	1.3	1.8
Willow	Brown	T29N R27W S21,22,27,28	127	1.57	2.6	4.0
West Long	Cherry	T30N R29W S33-34	25	2.39	1.2	1.8

[1] Valentine National Wildlife Refuge

Appendix 2. Physical and chemical characteristics of 30 Sandhill Lakes sampled in 1998-1999.

Lake	Secchi depth (cm)	Turbidity (NTU)	TDS [1] (μS/cm)	Conductivity (μS/cm)	Total alkalinity (mg/L)	Phenolphthalein alkalinity (mg/L)	Phosphorus (mg/L)	Chlorophyll *a* (mg/m^3)
Alkali	103	5.00	559.0	1120.75	446.75	0.00	0.050	1.40
Big Alkali	14	70.00	234.5	471.00	243.00	0.00	0.093	3.13
Cameron	48	20.00	137.3	273.50	101.25	0.00	0.658	29.51
Clear	182	1.25	212.5	233.25	111.75	23.00	0.115	2.53
Clear (VNWR[2])	96	5.00	340.0	379.50	198.25	0.00	0.085	3.84
Cottonwood	249	0.00	252.5	279.75	127.50	0.00	0.010	2.09
Cozad	213	0.00	210.0	242.00	116.00	0.00	0.065	2.66
Defair	110	0.00	214.8	430.75	118.75	47.50	0.430	1.76
Dewey	83	13.75	169.8	338.25	129.25	0.00	0.350	2.42
Duck	64	7.50	108.5	215.75	85.75	0.00	1.250	23.61
Goose	73	15.00	210.3	420.25	164.75	0.00	0.240	5.83
Hackberry	111	8.75	305.0	338.50	164.25	0.00	0.040	2.06
Hagan	235	0.00	227.5	267.50	123.50	0.00	0.085	1.80
Home Valley	27	27.5	180.5	205.00	104.50	0.00	0.105	1.14
Island	20	70.0	181.0	365.50	314.25	44.50	0.198	6.66
Lackaff West	83	13.8	142.8	285.75	131.50	0.00	0.175	14.41
Marsh	179	0.00	154.0	308.75	142.25	0.00	.	13.32

Appendix 2 continued.

Lake	Secchi depth (cm)	Turbidity (NTU)	TDS [1] (μS/cm)	Conductivity (μS/cm)	Total alkalinity (mg/L)	Phenolphthalein alkalinity (mg/L)	Phosphorus (mg/L)	Chlorophyll *a* (mg/m^3)
Marsh (VNWR[2])	82	7.50	182.5	452.25	224.75	0.00	0.125	3.70
Medicine	132	5.00	172.5	177.00	84.75	5.75	0.030	1.14
Pelican	38	41.25	180.0	200.25	100.50	0.00	0.057	2.55
Roseberry	87	10.00	182.5	187.75	84.75	0.00	0.105	.
Round	95	10.00	135.5	271.00	100.50	0.00	0.233	11.99
Schoolhouse	219	0.00	210.0	224.75	107.25	37.75	0.190	0.86
Shell	225	0.00	147.3	300.25	121.50	0.00	0.060	1.03
Shoup	95	0.00	106.5	212.75	93.50	0.00	1.790	28.73
Tower	101	10.00	111.5	222.50	120.00	0.00	0.703	4.17
Twin	225	0.00	430.0	457.75	250.50	0.00	0.100	5.00
Watts	123	10.00	107.3	213.25	93.50	0.00	0.450	7.55
Willow	258	0.00	157.5	187.75	91.50	0.00	0.280	0.66
West Long	109	5.00	280.0	309.25	138.50	0.00	0.505	2.30

[1] Total dissolved solids
[2] Valentine National Wildlife Refuge

Appendix 3. Percent of different vegetation coverages in 30 Nebraska Sandhill lakes sampled in 1998 and 1999.

Lake	Sites	Total vegetation	Sparse emer-gent	Moderate emergent	Dense emer-gent	Sparse submer-gent	Moderate submer-gent	Dense submer-gent	Sparse floating	Moderate floating	Dense floating
Alkali	47	53.2	14.9	0.0	0.0	21.3	14.9	2.1	0.0	0.0	0.0
Big Alkali	38	7.9	5.3	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cameron	40	57.5	17.5	10.0	0.0	17.5	10.0	2.5	0.0	0.0	0.0
Clear	38	76.3	0.0	0.0	0.0	18.4	36.8	21.1	0.0	0.0	0.0
Clear (VNWR[1])	44	4.5	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cottonwood	35	97.1	0.0	0.0	0.0	5.7	28.6	62.9	0.0	0.0	0.0
Cozad	38	94.7	0.0	0.0	0.0	7.9	26.3	60.5	0.0	0.0	0.0
Defair	32	100.0	0.0	0.0	6.3	9.4	28.1	56.3	0.0	0.0	0.0
Dewey	38	10.5	5.3	2.6	0.0	0.0	0.0	0.0	0.0	0.0	2.6
Duck	42	47.6	11.9	7.1	0.0	11.9	9.5	7.1	0.0	0.0	0.0
Goose	46	47.8	2.2	0.0	2.2	34.8	8.7	0.0	0.0	0.0	0.0
Hackberry	42	38.1	19.0	0.0	2.4	7.1	2.4	0.0	0.0	0.0	0.0
Hagan	56	50.0	17.9	0.0	0.0	21.4	8.9	1.8	0.0	0.0	0.0
Home Valley	43	11.6	0.0	0.0	0.0	4.7	2.3	4.7	0.0	0.0	0.0
Island	62	22.6	9.7	3.2	3.2	6.5	0.0	0.0	0.0	0.0	0.0
Lackaff West	36	72.2	8.3	0.0	0.0	25.0	27.8	11.1	0.0	0.0	0.0
Marsh	35	88.6	0.0	0.0	8.6	0.0	34.3	45.7	0.0	0.0	0.0
Marsh (VNWR[1])	50	14.0	4.0	0.0	2.0	6.0	2.0	0.0	0.0	0.0	0.0
Medicine	37	62.2	16.2	5.4	2.7	13.5	13.5	10.8	0.0	0.0	0.0
Pelican	44	36.4	9.1	2.3	2.3	13.6	4.5	4.5	0.0	0.0	0.0

Appendix 3 continued.

Lake	Sites	Total vegetation	Sparse emer-gent	Moderate emergent	Dense emer-gent	Sparse submer-gent	Moderate submer-gent	Dense submer-gent	Sparse floating	Moderate floating	Dense floating
Roseberry	40	32.5	17.5	2.5	2.5	7.5	2.5	0.0	0.0	0.0	0.0
Round	31	87.1	3.2	0.0	0.0	19.4	35.5	29.0	0.0	0.0	0.0
Schoolhouse	39	97.4	10.3	5.1	0.0	30.8	30.8	12.8	0.0	0.0	7.7
Shell	50	54.0	2.0	0.0	0.0	4.0	14.0	34.0	0.0	0.0	0.0
Shoup	39	53.8	2.6	0.0	2.6	33.3	7.7	7.7	0.0	0.0	0.0
Tower	53	69.8	0.0	0.0	0.0	22.6	26.4	20.8	0.0	0.0	0.0
Twin	50	46.0	0.0	12.0	0.0	12.0	14.0	8.0	0.0	0.0	0.0
Watts	38	71.8	7.7	2.6	5.1	10.3	30.8	15.4	0.0	0.0	0.0
West Long	25	96.0	4.0	8.0	0.0	16.0	4.0	60.0	0.0	0.0	4.0
Willow	43	7.0	0.0	2.3	0.0	0.0	4.7	0.0	0.0	0.0	0.0

[1] Valentine National Wildlife Refuge

Appendix 4. Presence or absence of fishes sampled by electrofishing and trap netting in 30 Nebraska Sandhill lakes, 1998-1999. Goldfish were found only in DeFair Lake. Grass carp were only found in Goose Lake. Saugeye were only found in Watts Lake. Walleye were only found in Alkali and Island lakes. Channel catfish were only found in Big Alkali and Home Valley lakes.

Lake	Black bullhead	Black crappie	Bluegill	Common carp	Golden shiner	Green sunfish	Grass pickerel	Hybrid sunfish	Largemouth bass	Northern pike	Pump-kinseed	Yellow perch
Alkali	X		X						X			X
Big Alkali	X	X		X						X		X
Cameron	X			X	X	X	X					X
Clear	X	X	X						X	X		X
Clear (VNWR[1])			X	X					X	X	X	X
Cottonwood	X	X	X			X	X	X	X	X	X	X
Cozad	X	X	X			X			X			X
Defair	X				X				X			X
Dewey	X		X	X					X	X		X
Duck	X							X	X		X	X
Goose	X		X	X				X	X	X	X	X
Hackberry	X		X	X					X	X		X
Hagan	X	X			X	X			X			X
'Home Valley	X			X								X
Island		X	X					X	X			X
Lackaff West	X		X		X	X	X	X		X		X
Marsh	X									X		X
Marsh (VNWR[1])	X			X	X	X	X					X

Appendix 4 continued.

Lake	Black bullhead	Black crappie	Bluegill	Common carp	Golden shiner	Green sunfish	Grass pickerel	Hybrid sunfish	Largemouth bass	Northern pike	Pump-kinseed	Yellow perch
Medicine		X	X						X		X	X
Pelican	X		X	X	X				X	X		X
Roseberry										X		X
Round	X				X	X				X		X
Schoolhouse	X	X	X		X				X	X	X	X
Shell	X	X	X				X	X	X	X	X	X
Shoup	X		X						X		X	
Tower		X	X		X	X		X	X			X
Twin	X	X	X		X	X		X	X	X		X
Watts	X		X		X			X	X			X
West Long	X		X						X	X		X
Willow	X	X	X	X		X		X	X			X

[1] Valentine National Wildlife Refuge

Appendix 5. Catch per unit effort (number of fish per trap net night) of black bullheads collected in Nebraska Sandhill Lakes, 1998 and 1999. No trophy length (≥460 mm TL) black bullhead were collected in any of the lakes. Standard errors are in parentheses. S=stock (≥150 mm); Q=quality (≥ 230 mm); P=preferred (≥300 mm); M=memorable (≥380 mm).

Lake	Total caught	CPUE (all sizes)	CPUE ≥S	CPUE ≥Q	CPUE ≥P	CPUE ≥M
Alkali	647	32.35(6.55)	32.30(6.55)	32.05(6.52)	29.00(5.72)	0.00(0.00)
Big Alkali	2	0.10(0.07)	0.10(0.07)	0.00(0.00)	0.00(0.00)	0.00(0.00)
Cameron	1,470	147.00(26.64)	89.7(16.39)	34.00(6.23)	4.60(1.00)	0.00(0.00)
Clear	22	1.10(0.54)	1.10(0.54)	0.65(0.33)	0.40(0.21)	0.00(0.00)
Cottonwood	12	1.20(0.36)	1.20(0.36)	0.50(0.17)	0.00(0.00)	0.00(0.00)
Cozad	1	0.10(0.10)	0.10(0.10)	0.10(0.10)	0.00(0.00)	0.00(0.00)
Defair	109	10.90(4.38)	10.90(4.38)	9.00(3.54)	0.30(0.15)	0.00(0.00)
Dewey	5	0.25(0.16)	0.25(0.16)	0.10(0.07)	0.00(0.00)	0.00(0.00)
Duck	2	0.20(0.13)	0.20(0.13)	0.20(0.13)	0.00(0.00)	0.00(0.00)
Goose	104	5.20(0.70)	4.90(0.71)	3.05(0.64)	0.90(0.26)	0.00(0.00)
Hackberry	136	6.80(1.30)	2.95(0.38)	1.35(0.32)	1.05(0.32)	0.30(0.18)
Hagan	2,259	564.75(174.58)	540.25(158.10)	15.75(9.68)	0.00(0.00)	0.00(0.00)
Home Valley	71	3.55(0.86)	3.55(0.86)	3.55(0.86)	0.35(0.15)	0.00(0.00)
Lackaff West	4,560	228.00(40.10)	188.85(33.19)	3.45(0.82)	0.00(0.00)	0.00(0.00)
Marsh	607	60.70(19.63)	60.70(19.63)	4.80(1.66)	0.00(0.00)	0.00(0.00)
Marsh(VNWR[1])	1,551	77.55(20.37)	20.15(5.41)	1.30(0.37)	0.10(0.07)	0.00(0.00)
Pelican	4	0.20(0.16)	0.20(0.16)	0.15(0.11)	0.00(0.00)	0.00(0.00)
Round	2,173	217.30(70.97)	201.30(66.21)	0.60(0.97)	0.00(0.00)	0.00(0.00)

Appendix 5 continued.

Lake	Total caught	CPUE (all sizes)	CPUE ≥S	CPUE ≥Q	CPUE ≥P	CPUE ≥M
Schoolhouse	239	23.90(6.42)	22.70(6.11)	3.50(1.51)	1.90(1.10)	0.00(0.00)
Shell	2	0.10(0.07)	0.10(0.07)	0.10(0.07)	0.00(0.00)	0.00(0.00)
Shoup	36	3.60(1.52)	3.60(1.52)	1.90(0.77)	0.90(0.43)	0.00(0.00)
Twin	74	3.70(1.50)	2.25(0.56)	0.10(0.07)	0.00(0.00)	0.00(0.00)
Watts	3	0.15(0.08)	0.15(0.08)	0.10(0.07)	0.05(0.05)	0.00(0.00)
Willow	28	1.40(0.34)	1.40(0.34)	1.40(0.34)	1.30(0.33)	0.00(0.00)
West Long	31	3.10(0.62)	3.10(0.62)	2.90(0.55)	0.70(0.15)	0.00(0.00)

[1] Valentine National Wildlife Refuge

Appendix 6. Stock density indices and mean Wr values for black bullhead collected in Nebraska Sandhill Lakes, 1998 and 1999. Confidence intervals (95%) for stock density indices and standard errors for the Wr values are in parentheses. No trophy length ($\geq$460 mm TL) black bullhead were collected in any of the lakes. PSD=proportional stock density; RSD-P=relative stock density of preferred length fish; RSD-M=relative stock density of memorable length fish.

Lake	PSD	RSD-P	RSD-M	Wr $\geq$S	Wr S-Q	Wr Q-P	Wr P-M	Wr M-T
Alkali	99(1)	90(3)	0	98(1.1)	92(0.0)	115(2.6)	97(1.2)	
Big Alkali[1]				88(0.0)	88(0.0)			
Cameron	38(3)	5(2)	0	93(1.3)	93(2.0)	92(1.5)	103(1.6)	
Clear	59 (22)	36 (22)	0	92(0.5)	78(4.5)	91(8.1)	107(1.5)	
Cottonwood	42 (32)	0	0	95(1.5)	98(1.3)	90(1.3)		
Defair	83(8)	3(3)	0	97(0.8)	101(2.1)	96(1.0)	92(8.0)	
Dewey[2]				97(5.7)	96(8.8)	99(9.4)		
Duck[1]				122(12.9)	122(12.9)			
Goose	62(10)	18(8)	0	89(1.4)	84(0.2)	85(3.1)	107(2.2)	
Hackberry	46 (13)	36 (12)	10 (8)	88(0.9)	82(1.5)	92(2.9)	96(1.8)	94(2.4)
Hagan	3 (1)	0	0	93(2.3)	93(2.4)	95(1.2)		
Home Valley	100 (100)	10 (7)	0	83(1.2)		82(1.4)	89(0.9)	
Lackaff West	2(1)	0	0	90(2.5)	90(1.1)	93(0.6)		
Marsh	8(2)	0	0	91(2.0)	92(2.1)	81(2.1)		
Marsh (VNWR[3])	6 (2)	0 (1)	0	91(1.2)	91(1.3)	96(0.3)		

Appendix 6 continued.

Lake	PSD	RSD-P	RSD-M	Wr ≥S	Wr S-Q	Wr Q-P	Wr P-M	Wr M-T
Pelican[1]								
Round	0	0	0	88(1.5)	88(1.5)	80(1.1)		
Schoolhouse	15 (5)	8 (4)	0	96(1.4)	96(1.7)	96(1.1)	94(2.9)	
Shell[1]				78(3.0)		78(3.0)		
Shoup	53(17)	25(15)	0	96(1.3)	88(2.7)	102(1.2)	105(1.9)	
Twin	4 (7)	0	0	90(1.4)	90(1.4)			
Watts[4]				97(6.0)				
Willow	100 (100)	93 (10)	0	108(1.3)			108(1.4)	
West Long	94 (10)	23 (15)	0	104(0.6)		105(0.9)	103(4.6)	

[1] Low sample size (two fish in trap nets) prohibited calculation of indices.
[2] Low sample size (five fish in trap nets) prohibited calculation of indices.
[3] Valentine National Wildlife Refuge.
[4] Low sample size (three fish in trap nets) prohibited calculation of indices.

Appendix 7. Mean back calculated total length (mm) at age for black bullheads collected in Nebraska Sandhill Lakes, 1998 and 1999. Standard errors are in parenthesis.

Lake	Number aged	1	2	3	4	5	6	7	8
Alkali	52	112(9)	206(9)	267(9)	295(9)	314(9)	326(1)	348	
Cameron	69	84(3)	156(7)	206(8)	242(7)	275(3)	297(4)	326	
Clear	17	88(10)	174(9)	233(13)	300(5)	323			
Cottonwood	10	57(6)	128(12)	167(18)	191(26)	198(10)	227		
Defair	39	95(6)	179(9)	223(5)	253(0)	282			
Goose	64	92(9)	157(7)	208(3)	249(2)	278(2)	305		
Hackberry	28	107(10)	178(17)	244(17)	307(17)	350(5)	366(4)	380	
Hagan	30	83(10)	158(20)	194(17)	227(15)	255			
Home Valley	24	91(10)	173(12)	223(11)	248(13)	266(12)	282(13)	289	
Lackaff West	54	73(6)	129(8)	166(6)	190(9)	198			
Marsh	37	76(4)	137(9)	188(12)	217(14)	240(25)	283		
Marsh(VNWR[1])	19	101(5)	185(14)	226(26)	280(13)	321	340	357	371
Round	49	75(5)	125(7)	165(5)	196(10)	228			
Schoolhouse	16	100(11)	179(11)	260(14)	311	326			
Shoup	30	123(12)	236(2)	313					
Twin	15	88(9)	144(17)	181(24)	202(29)	208	222		
Willow	17	86(13)	152(21)	221(29)	265(25)	307(14)	325(12)	348(20)	349
West Long	12	89(13)	167(23)	257(9)	293(15)	339			

[1] Valentine National Wildlife Refuge

Appendix 8. Catch per unit effort (number per trap net night) of black crappies collected in Nebraska Sandhill Lakes, 1998 and 1999. Standard errors are in parentheses. S=stock (≥130 mm); Q=quality (≥ 200 mm); P=preferred (≥250 mm); M=memorable (≥300 mm); T=trophy (≥380 mm).

Lake	Total caught	CPUE (all sizes)	CPUE ≥S	CPUE ≥Q	CPUE ≥P	CPUE ≥M	CPUE ≥T
Big Alkali	178	8.90(3.15)	8.50(3.19)	8.45(3.18)	7.25(2.82)	1.15(0.40)	0.10(0.07)
Clear	4	0.20(0.09)	0.10(0.07)	0.10(0.07)	0.00(0.00)	0.00(0.00)	0.00(0.00)
Cottonwood	5	0.50(0.31)	0.50(0.31)	0.20(0.13)	0.00(0.00)	0.00(0.00)	0.00(0.00)
Cozad	217	21.70(5.29)	21.70(5.29)	1.40(0.54)	0.30(0.15)	0.00(0.00)	0.00(0.00)
Hagan	93	23.25(2.63)	5.50(1.50)	0.00(0.00)	0.00(0.00)	0.00(0.00)	0.00(0.00)
Island	58	2.90(0.89)	2.90(0.89)	2.70(0.81)	1.80(0.48)	0.50(0.17)	0.00(0.00)
Medicine	68	6.80(3.28)	6.30(3.32)	3.70(2.34)	1.20(0.59)	0.70(0.42)	0.00(0.00)
Schoolhouse	11	1.10(0.59)	1.10(0.59)	0.30(0.21)	0.20(0.13)	0.00(0.00)	0.00(0.00)
Shell	16	0.80(0.37)	0.55(0.34)	0.55(0.34)	0.45(0.29)	0.30(0.18)	0.00(0.00)
Tower	29	2.90(1.08)	2.90(1.08)	0.40(0.22)	0.30(0.21)	0.00(0.00)	0.00(0.00)
Twin	53	2.65(0.61)	0.85(0.40)	1.75(0.57)	1.55(0.56)	1.45(0.54)	0.00(0.00)
Willow	5	0.25(0.12)	0.05(0.05)	0.05(0.05)	0.05(0.05)	0.00(0.00)	0.00(0.00)

Appendix 9. Stock density indices and mean Wr values of black crappies collected in Nebraska Sandhill Lakes, 1998 and 1999. Confidence intervals (95%) for stock density indices and standard errors for mean relative weight values are in parentheses. PSD=proportional stock density; RSD-P=relative stock density of preferred length fish; RSD-M=relative stock density of memorable length fish; RSD-T=relative stock density of trophy length fish.

Lake	PSD	RSD-P	RSD-M	RSD-T	Wr ≥S	Wr S-Q	Wr Q-P	Wr P-M	Wr M-T
Big Alkali	99(1)	85(6)	14(6)	1(2)	108(2.4)	113(0.0)	108(0.7)	109(3.3)	102(2.0)
Clear[1]					105(0.8)		105(0.8)		
Cottonwood[2]					99(3.6)	104(3.2)	92(3.5)		
Cozad	6(4)	1(2)	0		106(0.9)	107(1.0)	97(1.9)	82(1.0)	
Hagan	0	0	0		121(3.0)	121(3.0)			
Island	93(7)	62(13)	17(10)	0	97(0.3)	108(4.0)	103(1.0)	97(0.7)	83(0.6)
Medicine	59(13)	19(10)	11(8)		115(0.4)	120(0.5)	119(0.9)	105(2.9)	88(3.5)
Schoolhouse	27(32)	18(27)	0		116(2.0)	118(1.0)	123	104(0.0)	
Shell	100(0)	82(27)	55(36)	0	93(1.7)		88(9.7)	91(2.7)	95(0.8)
Tower	14(14)	10(10)	0	0	117(0.3)	118(0.4)	116(-)	112(2.2)	
Twin	97(5)	86(12)	81(13)		105(0.6)	119	114(1.2)	112(0.0)	103(0.8)
Willow[2]					86			86	

[1] Low sample size (4 fish) prohibited calculation of many indices.
[2] Low sample size (5 fish) prohibited calculation of many indices.

Appendix 10. Mean back calculated total length (mm) at age for black crappie collected in Nebraska Sandhill Lakes, 1998 and 1999. Standard errors are in parentheses.

Lake	Number aged	1	2	3	4	5	6	7	8	9	10	11
Big Alkali	61	80(4)	168(10)	252(9)	298(10)	331(10)	361(11)	378(2)	387			
Cozad	44	68(2)	109(3)	149(1)	175(4)	195(1)	202					
Hagan	23	87(22)	127									
Island	48	68(3)	139(1)	212(2)	254(3)	279(2)	296(6)	306(6)	319			
Medicine	51	69(3)	135(6)	194(4)	235(2)	265(3)	288(2)	302(3)	315(3)	322(2)	325	330
Shell	15	65(4)	12593)	190(8)	230(5)	264(5)	284(5)	304(3)	309			
Tower	25	69(6)	138(12)	192(11)	238(4)	259(5)	267					
Twin	41	74(3)	149(6)	215(13)	272(11)	313(1)	333(2)	350				

Appendix 11. Number of black crappie collected in each age group for fish sampled in Nebraska Sandhill lakes during 1998 and 1999. Only fish fully recruited to the gear (i.e., age-2 and older) are included. The recruitment variability index (RVI) ranges from -1 (very inconsistent recruitment) to 1 (very consistent recruitment).

Lake	2	3	4	5	6	7	8	9	10	11	RVI
Big Alkali	1	107	50	9	1	1	1				0.793
Cozad	11	124	16	58	9						0.664
Island	2	0	0	11	0	9	3				-0.395
Medicine	25	23	6	2	0	3	1	1	0	1	0.464
Tower	25	1	0	1	2						0.488
Twin	0	1	5	24	4	2					0.292

Appendix 12. Catch per unit effort (number per trap net night) of bluegills collected in Nebraska Sandhill Lakes, 1998 and 1999. No bluegills trophy size and larger (≥300 mm TL) were collected in any of the lakes. Standard errors are in parentheses. S=stock (≥80 mm); Q=quality (≥ 150 mm); P=preferred (≥200 mm); M=memorable (≥250 mm).

Lake	Total caught	CPUE (all sizes)	CPUE ≥S	CPUE ≥Q	CPUE ≥P	CPUE ≥M
Alkali	1,712	85.60(23.42)	85.60(23.42)	78.85(21.89)	18.50(5.11)	0.00(0.00)
Big Alkali	1	0.05(0.05)	0.05(0.05)	0.05(0.05)	0.00(0.00)	0.00(0.00)
Clear	231	11.55(2.19)	11.30(0.10)	8.95(2.18)	1.60(0.35)	0.00(0.00)
Clear (VNWR[1])	242	12.10(2.81)	11.35(2.78)	5.85(1.46)	2.45(0.65)	0.05(0.05)
Cottonwood	851	86.10(17.81)	79.50(17.59)	21.10(7.46)	1.20(0.66)	0.00(0.00)
Cozad	2,325	232.50(29.02)	232.50(29.02)	128.40(16.79)	0.30(0.21)	0.00(0.00)
Dewey	399	19.95(4.17)	19.85(4.17)	12.20(2.98)	2.70(0.81)	0.10(0.10)
Duck	213	21.30(10.89)	21.30(10.89)	4.80(0.98)	0.40(0.16)	0.00(0.00)
Goose	237	11.80(1.93)	11.75(1.94)	7.90(1.41)	1.15(0.25)	0.00(0.00)
Hackberry	321	16.05(2.64)	15.25(2.59)	8.25(1.47)	2.10(0.42)	0.10(0.07)
Island	410	20.50(3.89)	20.50(3.89)	20.20(3.87)	15.20(2.93)	0.05(0.05)
Lackaff West	12	0.60(0.15)	0.60(0.15)	0.35(0.13)	0.00(0.00)	0.00(0.00)
Medicine	584	58.40(15.04)	58.40(15.04)	41.10(10.65)	5.80(1.64)	0.60(0.34)
Pelican	3,716	185.80(26.35)	177.15(24.87)	27.85(5.98)	17.35(5.00)	7.35(2.68)
Schoolhouse	34	3.40(2.24)	3.20(2.24)	1.30(1.19)	0.00(0.00)	0.00(0.00)
Shell	267	13.35(2.44)	11.95(2.10)	4.75(0.90)	0.70(0.28)	0.00(0.00)
Shoup	64	6.40(1.31)	6.40(1.31)	4.90(0.88)	2.50(0.56)	0.00(0.00)
Tower	140	14.00(3.91)	13.10(3.85)	6.40(2.35)	0.90(0.41)	0.00(0.00)
Twin	190	9.50(2.06)	7.3(1.63)	4.85(1.25)	2.90(0.63)	0.05(0.05)
Watts	644	32.20(4.14)	32.05(4.14)	20.60(3.21)	3.90(0.86)	0.00(0.00)
Willow	30	1.50(0.91)	1.15(0.63)	0.40(0.30)	0.00(0.00)	0.00(0.00)
West Long	283	28.30(4.50)	28.30(4.50)	19.30(4.35)	0.00(0.00)	0.00(0.00)

[1] Valentine National Wildlife Refuge

Appendix 13. Stock density indices and Wr values of bluegills collected in Nebraska Sandhill Lakes, 1998 and 1999. Confidence intervals (95%) for stock density indices and standard errors for mean Wr values are in parentheses. No bluegills trophy size and larger (≥300 mm TL) were collected in any of the lakes. PSD=proportional stock density; RSD-P=relative stock density of preferred length fish; RSD-M=relative stock density of memorable length fish.

Lake	PSD	RSD-P	RSD-M	Wr ≥S	Wr S-Q	Wr Q-P	Wr P-M	Wr M-T
Alkali	92(1)	22(2)	0	119(1.2)	114(3.4)	118(1.6)	121(2.0)	
Big Alkali[1]								
Clear	79(5)	14(4)	0	113(1.3)	105(1.9)	113(1.8)	125(2.0)	
Clear (VNWR[2])	52(7)	22(5)	0(1)	120(1.6)	123(3.2)	118(1.1)	117(1.6)	126
Cottonwood	27(3)	2(1)	0	99(1.7)	95(2.3)	111(1.7)	113(1.5)	
Cozad	55(2)	0	0	109(1.1)	112(1.8)	106(1.3)	97(1.8)	
Dewey	61(4)	14(4)	1(1)	119(1.3)	122(3.2)	118(1.2)	115(1.5)	122(0.0)
Duck	23(6)	2(2)	0	108(1.0)	106(1.3)	111(1.4)	115(0.0)	
Goose	67(6)	10(4)	0	105(1.3)	103(2.9)	1.4(1.5)	120(1.2)	
Hackberry	54(6)	14(4)	1(1)	117(1.6)	112(3.1)	123(1.5)	116(1.5)	120(0.0)
Island	99(2)	74(4)	0	117(1.9)	113(3.5)	119(1.9)	107(1.6)	
Lackaff West	58(33)	0	0	107(0.6)	110(0.4)	106(0.40		
Medicine	70(4)	10(2)	1(1)	133(1.2)	131(2.7)	135(1.5)	131(1.4)	122(3.4)
Pelican	16(2)	10(1)	4(1)	112(2.5)	111(3.0)	118(1.6)	124(2.2)	123(2.0)
Schoolhouse	41(18)	9(11)	0	132(0.3)	126(0.6)	144(2.0)	135(0.0)	

Appendix 13 continued.

Lake	PSD	RSD-P	RSD-M	Wr ≥S	Wr S-Q	Wr Q-P	Wr P-M	Wr M-T
Shell	40(7)	6(30	0	89(1.4)	87(2.2)	94(1.5)	90(2.7)	
Shoup	77(11)	39(12)	0	121(0.8)	110(0.6)	122(0.6)	122(2.0)	
Tower	49(9)	7(5)	0	130(1.1)	131(1.1)	129(2.2)	131(1.4)	
Twin	66(8)	40(8)	1(1)	142(1.3)	131(2.8)	146(1.4)	147(2.2)	145
Watts	64(3)	12(2)	0	121(1.1)	120(2.2)	122(1.5)	117(2.0)	
Willow	35(21)	0	0	122(1.3)	117(2.0)	130(1.7)		
West Long	68(6)	40(5)	0	119(1.1)	133(1.7)	118(1.8)	123(2.2)	

[1] Low sample size (one fish in trap nets) prohibited calculation of many indices
[2] Valentine National Wildlife Refuge

Appendix 14. Mean back calculated total length (mm) at age for bluegill collected in Nebraska Sandhill Lakes, 1998 and 1999. Standard errors are in parentheses.

Lake	Number aged	1	2	3	4	5	6	7	8	9	10	11	12	13
Alkali	63	44(2)	98(3)	162(5)	201(5)	217(5)	231							
Clear	80	42(3)	103(3)	157(4)	180(5)	196(3)	206(2)	215						
Clear (VNWR[1])	79	44(2)	102(3)	157(4)	186(6)	200(10)	208(17)	215(30)	190	196				
Cottonwood	73	38(1)	62(2)	80(3)	98(4)	112(5)	127(5)	143(5)	1564)	165(4)	174(6)	185(8)	198(10)	212
Cozad	55	44(2)	81(3)	126(10)	152(9)	174(10)	195(16)	224(11)	216					
Dewey	80	47(4)	96(4)	148(5)	183(3)	202(3)	216(4)	230(4)	240(5)	250(1)	254			
Duck	58	53(2)	109(7)	143(7)	167(7)	188(4)	202							
Goose	63	57(7)	108(7)	156(5)	185(5)	199(3)	208(3)	215(6)	225					
Hackberry	97	40(1)	87(3)	137(5)	169(7)	195(5)	214(4)	229(2)	236(2)	240(1)	250			
Island	55	47(5)	97(4)	153(5)	182(3)	202(3)	212(1)	221(1)	228					
Medicine	79	47(4)	102(4)	157(4)	189(5)	210(7)	233(5)	249(3)	256(4)	267				
Pelican	106	44(4)	84(5)	137(6)	183(4)	211(7)	234(5)	249(3)	252					
Schoolhouse	33	43(4)	108(9)	140(9)	173(7)	189(7)	208(6)	217(5)	220					
Shell	72	44(2)	73(2)	103(4)	138(5)	164(5)	180(4)	190(4)	198(2)	202(1)	209			
Shoup	51	46(3)	104(7)	159(7)	188(4)	204(3)	216(3)	227(6)	235					
Tower	74	47(2)	105(6)	152(6)	181(4)	202(3)	217	223						
Twin	66	41(2)	103(3)	142(3)	164(3)	177(4)	189(4)	196(5)	203(5)	210(7)	211(5)	212		
Watts	84	49(6)	107(3)	168(3)	196(2)	210(3)	224(6)	240						

Appendix 14 continued.

Lake	Number aged	1	2	3	4	5	6	7	8	9	10	11	12	13
Willow	27	46(7)	117(10)	134(8)	163(15)	159	174							
West Long	71	43(1)	98(3)	150(5)	180(6)	196(6)	206(7)	217(13)	239					

[1] Valentine National Wildlife Refuge

Appendix 15. Number of bluegills collected in each age group for fish sampled in Nebraska Sandhill lakes during 1998 and 1999. Only fish fully recruited to the gear (i.e., age-2 and older) are included. The recruitment variability index (RVI) ranges from -1 (very inconsistent recruitment) to 1 (very consistent recruitment).

Lake	2	3	4	5	6	7	8	9	10	11	12	13	RVI
Alkali	6	612	939	148	5								0.654
Clear	36	38	76										0.577
Clear (VNWR[1])	103	54	32	17	14	2	0	3					0.592
Cottonwood	15	145	194	44	91	107	59	129	47	11	9	1	0.668
Cozad	6	403	746	846	320	1	1						0.362
Dewey	88	30	97	44	30	7	4	2	1				0.795
Duck	115	6	33	9	1								0.874
Goose	68	72	34	37	6	5	1						0.804
Hackberry	114	77	55	23	16	6	9	2	1				0.843
Island	6	67	32	82	52	113	58						0.478
Medicine	218	243	71	33	8	5	3	2					0.877
Pelican	467	2,663	132	89	128	142	56						0.815
Schoolhouse	22	0	0	7	0	2	1						-0.380
Shell	6	2	108	47	37	11	10	3	3				0.673
Shoup	20	9	9	11	8	2	1						0.744
Tower	74	32	8	4	5	1							0.885
Twin	14	4	8	6	13	8	38	6	5	5			0.547
Watts	163	321	56	29	16	6							0.826

Appendix 15 continued.

Lake	2	3	4	5	6	7	8	9	10	11	12	13	RVI
Willow	6	0	3	0	1								-0.167
West Long	78	29	45	66	48	16	1						0.699

[1] Valentine National Wildlife Refuge

Appendix 16. Catch per unit effort (number per hour of electrofishing) of common carp collected in Nebraska Sandhill Lakes, 1998 and 1999. Standard errors are in parentheses. S=stock (≥280 mm); Q=quality (≥ 410 mm); P=preferred (≥530 mm); M=memorable (≥660 mm); T=trophy (≥840 mm).

Lake	Total caught	CPUE (all sizes)	CPUE ≥S	CPUE ≥Q	CPUE ≥P	CPUE ≥M	CPUE ≥T
Big Alkali	3	1.96(1.03)	1.96(1.03)	1.96(1.03)	1.34(0.91)	0.71(0.71)	0.00
Cameron	4	3.86(3.02)	0.00	0.00	0.00	0.00	0.00
Clear (VNWR[1])	25	12.50(3.58)	12.50(3.58)	12.50(3.58)	12.50(3.58)	11.50(3.50)	1.50(1.08)
Dewey	41	22.63(5.48)	22.63(5.48)	22.63(5.48)	22.00(4.95)	21.38(4.98)	1.00(0.67)
Goose	2	1.00(0.67)	1.00(0.67)	1.00(0.67)	1.00(0.67)	0.50(0.50)	0.00(0.00)
Home Valley	121	87.86(24.55)	77.14(20.00)	76.43(19.56)	39.29(9.77)	6.71(2.43)	0.00(0.00)
Marsh(VNWR[1])	19	23.81(9.67)	23.81(9.67)	17.14(8.81)	17.14(8.81)	17.14(8.81)	0.00(0.00)
Pelican	3	1.39(0.73)	1.39(0.73)	1.39(0.73)	1.39(0.73)	0.92(0.62)	0.00(0.00)
Willow	40	19.67(17.93)	14.33(13.45)	0.00(0.00)	0.00(0.00)	0.00(0.00)	0.00(0.00)

[1] Valentine National Wildlife Refuge

Appendix 17. Stock density indices and mean Wr values for common carp collected in Nebraska Sandhill Lakes, 1998 and 1999. Confidence intervals (95%) for stock density indices and standard errors for mean Wr values are in parentheses. PSD=proportional stock density; RSD-P=relative stock density of preferred length fish; RSD-M=relative stock density of memorable length fish; RSD-T=relative stock density of trophy length fish.

Lake	PSD	RSD-P	RSD-M	RSD-T	Wr ≥S	Wr S-Q	Wr Q-P	Wr P-M	Wr M-T
Big Alkali[1]					86				
Clear (VNWR[2])	100(100)	100(100)	92(9)	12(14)	93(2.6)			92	93(3.2)
Dewey	100(0)	98(5)	95(7)	5(5)	99(0.3)		104(1.2)	93(4.3)	98(0.4)
Goose[3]									
Hackberry[4]	100(100)	88(9)	58(15)	0	91(0.5)		100(5.4)	89(1.6)	91(0.3)
Home Valley	99(2)	50(10)	8(5)	0	70(0.4)	78(1.6)	72(0.7)	68(0.5)	68(0.9)
Marsh[3]	64(5)	19(5)	5(2)	0	96(0.6)	95(0.9)	100(1.1)	90(0.7)	87(1.7)
Pelican	100(100)	84(15)	60(21)	0	91(1.8)		87(3.1)	86(3.7)	91(2.3)
Willow[5]	0	0	0	0	120(1.6)	120(1.6)			

[1] Low sample size (three fish) prohibited calculation of many indices
[2] Valentine National Wildlife Refuge
[3] Low sample size (two fish) prohibited calculation of many indices
[4] Stock density indices and Wr values based on trap netting
[5] Based on 29 fish collected electrofishing

Appendix 18. Catch per unit effort (number per trap net night) of green sunfish collected in Nebraska Sandhill Lakes, 1998 and 1999. Standard errors are in parentheses. S=stock (≥80 mm); Q=quality (≥ 150 mm); P=preferred (≥200 mm). No fish memorable length (250 mm) or longer were collected.

Lake	Total caught	CPUE (all sizes)	CPUE ≥S	CPUE ≥Q	CPUE ≥P
Cameron	117	11.70(15.35)	11.70(15.35)	1.50(2.16)	0.00
Cottonwood	30	3.00(0.92)	3.00(0.92)	0.00	0.00
Cozad	2	0.20(0.13)	0.20(0.13)	0.20(0.13)	0.00
Hagan	5,794	1,448.50(457.54)	2,164.82(449.44)	78.75(23.11)	0.97(0.29)
Lackaff West	370	18.50(2.73)	18.30(2.68)	0.80(0.19)	0.00
Marsh (VNWR[1])	316	15.80(4.110	15.75(4.110	5.55(1.56)	0.00
Round	22	2.20(0.47)	2.20(0.47)	0.10(0.10)	0.00
Tower	26	2.60(0.85)	2.30(0.78)	0.50(0.22)	0.00
Twin	13	0.65(0.23)	0.60(0.24)	0.05(0.05)	0.00
Willow	120	6.00(2.15)	5.40(1.98)	0.75(0.33)	0.00

[1] Valentine National Wildlife Refuge

Appendix 19. Stock density indices and Wr values for green sunfish collected in Nebraska Sandhill Lakes, 1998 and 1999. Confidence intervals (95%) for stock density indices and standard errors for mean Wr values are in parentheses. PSD=proportional stock density; RSD-P=relative stock density of preferred length fish. No fish memorable length (250 mm) or longer were collected.

Lake	PSD	RSD-P	Wr ≥S	Wr S-Q	Wr Q-P	Wr P-M
Cameron	13(5)	0	105(1.5)	105(1.8)	110(0.8)	
Cottonwood	0	0	107(2.7)	107(2.7)		
Cozad[1]						
Hagan	6(1)	0	101(2.4)	100(2.5)	109(3.0)	100(0.0)
Lackaff West	4(2)	0	96(2.1)	96(2.2)	101(0.9)	
Marsh (VNWR[2])	35(5)	0	121(2.1)	121(2.8)	121(2.8)	
Round	5(5)	0	99(1.8)	100(1.8)	87	
Tower	22(18)	0	108(2.4)	107(2.4)	112(7.1)	
Twin	8(8)	0	118(4.6)	118(5.0)	124	
Willow	14(7)	0	127(1.3)	128(1.5)	119(1.7)	

[1] Low samples size (2 fish) prohibited calculation of many indices
[2] Valentine National Wildlife Refuge

Appendix 20. Catch per unit effort (number per hour of electrofishing) of largemouth bass collected in Nebraska Sandhill Lakes, 1998 and 1999. No largemouth bass trophy size and larger (≥630 mm TL) were collected in any of the lakes. Standard errors are in parentheses. S=stock (≥200 mm); Q=quality (≥ 300 mm); P=preferred (≥380 mm); M=memorable (≥510 mm).

Lake	Total caught	CPUE (all sizes)	CPUE ≥S	CPUE ≥Q	CPUE ≥P	CPUE ≥M
Alkali	311	155.50(21.34)	154.50(20.98)	56.50(9.05)	8.50(2.61)	0.00
Clear	100	70.54(12.81)	59.91(10.53)	43.04(7.25)	15.89(3.92)	0.71(0.71)
Clear (VNWR[1])	16	8.00(2.98)	7.00(2.43)	4.00(1.71)	2.50(1.16)	0.00(0.00)
Cottonwood	49	53.45(8.92)	53.45(8.920	39.27(7.78)	18.55(4.95)	0.00(0.00)
Cozad	107	50.82(5.80)	37.74(4.25)	22.44(4.04)	9.59(2.80)	0.00(0.00)
Defair	159	175.60(25.48)	144.40(24.48)	63.60(13.68)	0.00(0.00)	0.00(0.00)
Dewey	71	39.63(9.19)	37.25(8.46)	25.88(5.95)	15.13(3.68)	0.00(0.00)
Duck	111	107.83(10.58)	99.31(11.98)	88.94(12.29)	41.96(7.99)	2.06(1.37)
Goose	31	29.50(6.02)	15.50(3.09)	8.50(2.39)	5.00(1.45)	0.50(0.50)
Hackberry	93	50.73(8.15)	40.91(7.41)	21.83(4.60)	13.09(2.78)	0.00(0.00)
Hagan	2	1.36(0.92)	0.00(0.00)	0.00(0.00)	0.00(0.00)	0.00(0.00)
Island	267	133.50(21.30)	117.50(20.10)	41.00(6.80)	8.00(1.86)	0.00(0.00)
Medicine	291	251.25(30.62)	138.63(18.74)	37.13(5.77)	17.00(4.73)	1.25(0.84)
Pelican	42	19.39(4.08)	14.31(3.36)	7.34(2.65)	5.54(2.09)	0.00(0.00)
Schoolhouse	53	34.61(8.340	8.29(4.53)	2.86(2.86)	0.7190.71)	0.00(0.00)
Shell	50	30.82(7.84)	30.82(7.84)	23.73(6.81)	10.91(4.25)	0.00(0.00)
Shoup	211	310.75(44.63)	158.75(28.79)	93.25(15.04)	32.00(10.17)	0.00(0.00)
Tower	98	60.72(15.47)	54.72(14.16)	45.64(11.14)	11.18(1.92)	0.00(0.00)
Twin	52	28.75(6.71)	11.75(2.69)	8.50(2.35)	3.88(1.63)	0.00(0.00)
Watts	274	137.00(19.84)	95.50(12.74)	38.50(5.19)	6.50(1.16)	0.00(0.00)
Willow	90	44.33(8.54)	44.33(8.54)	44.33(8.54)	26.99(6.35)	0.00(0.00)
West Long	126	157.50(33.43)	143.75(32.14)	41.25(17.07)	12.50(5.000	2.50(1.58)

[1] Valentine National Wildlife Refuge

Appendix 21. Stock density indices and mean Wr values for largemouth bass collected in Nebraska Sandhill Lakes, 1998 and 1999. Confidence intervals (95%) for stock density indices and standard errors for mean relative Wr values are in parentheses. No largemouth bass trophy size and larger (≥630 mm TL) were collected in any of the lakes. PSD=proportional stock density; RSD-P=relative stock density of preferred length fish; RSD-M=relative stock density of memorable length fish.

Lake	PSD	RSD-P	RSD-M	Wr ≥S	Wr S-Q	Wr Q-P	Wr P-M	Wr M-T
Alkali	37(6)	6(3)	0	99(0.8)	95(1.2)	104(1.1)	110(0.8)	
Clear	72(10)	27(10)	1(3)	116(0.8)	118(0.4)	116(1.7)	115(1.3)	102
Clear (VNWR[1])	57(30)	36(28)	0	116(2.1)	118(1.7)	114(5.7)	114(4.7)	
Cottonwood	73(13)	35(14)	0	116(0.9)	119(1.7)	118(1.5)	113(1.2)	
Cozad	61(11)	25(10)	0	100(0.2)	95(0.3)	98(0.2)	109(0.7)	
Defair	44(9)	0	0	106(0.8)	109(1.2)	101(1.1)		
Dewey	70(11)	40(12)	0	124(0.7)	121(0.9)	123(1.2)	127(1.2)	
Duck	89(6)	42(10)	2(2)	108(0.4)	103(0.8)	106(0.7)	111(0.4)	115(13.1)
Goose	55(19)	32(17)	3(3)	114(0.1)	110(0.3)	118(1.3)	117(2.4)	126
Hackberry	53(12)	32(11)	0	122(0.4)	122(0.7)	122(0.7)	123(0.3)	
Hagan[2]								
Island	35(6)	7(3)	0	104(0.7)	106(0.9)	99(1.1)	107(1.6)	
Medicine	27(7)	13(5)	1(2)	107(1.1)	108(1.5)	102(1.3)	103(0.5)	105(7.1)
Pelican	52(18)	39(18)	0	122(2.2)	121(1.9)	113(14.3)	127(2.6)	
Schoolhouse	31(29)	8(16)	0	121(3.1)	124(3.3)	119(7.8)	107	
Shell	76(12)	36(14)	0	106((1.2)	99(2.3)	104(1.5)	114(0.6)	

Appendix 21 continued.

Lake	PSD	RSD-P	RSD-M	Wr ≥S	Wr S-Q	Wr Q-P	Wr P-M	Wr M-T
Shoup	59(9)	20(7)	0	112(0.8)	118(1.8)	103(0.4)	116(1.8)	
Tower	83(8)	19(8)	0	113(0.6)	121(0.1)	112(1.0)	112(1.7)	
Twin	73(20)	32(21)	0	120(2.6)	115(8.5)	119(2.3)	127(0.9)	
Watts	40(7)	7(4)	0	101(0.8)	101(1.1)	102(1.1)	104(1.9)	
Willow	100(100)	61(10)	0	123(0.9)	123(1.6)	122(1.0)		
West Long	29(8)	9(5)	2(2)	110(0.8)	113(1.2)	104(0.9)	105(2.0)	101(0.0)

[1] Valentine National Wildlife Refuge
[2] Low sample size (2 fish) prohibited calculation of indices.

Appendix 22. Mean back calculated total length (mm) at age for largemouth bass collected in Nebraska Sandhill Lakes, 1998 and 1999. Standard errors are in parentheses.

Lake	Number aged	1	2	3	4	5	6	7	8	9	10	11	12	13
Alkali	104	88(8)	198(10)	283(11)	326(10)	359(12)	386(4)	401(1)	411(5)	425				
Clear	67	84(4)	196(7)	291(8)	346(11)	385(8)	408(10)	430(11)	450(17)	462(22)	454			
Clear(VNWR[1,2])														
Cottonwood	49	72(3)	142(11)	204(10)	258(9)	299(7)	332(6)	357(7)	378(7)	401(9)	420(13)	429(24)	462	
Cozad	71	111(8)	209(14)	279(20)	333(18)	371(16)	407(18)	439						
Defair	59	87(8)	186(13)	250(10)	284(10)	305(6)	314							
Dewey	67	86(8)	192(13)	295(9)	361(10)	404(7)	433(5)	452(3)	470(5)	483(0)	500			
Duck	75	84(4)	175(7)	263(3)	323(4)	364(4)	394(6)	419(6)	438(10)	460(9)	483			
Goose	50	90(9)	216(14)	313(14)	371(19)	417(20)	456(12)	482(14)	507					
Hackberry	65	86(5)	204(5)	289(5)	341(5)	376(5)	399(4)	414(3)	423(6)	436				
Island	103	96(5)	209(7)	287(11)	331(12)	364(15)	395(19)	421(18)	446(13)	469(13)	492	503		
Medicine	88	81(3)	180(4)	257(5)	309(6)	350(7)	381(8)	406(11)	424(12)	446(12)	467(12)	495(1)	505(4)	521
Pelican	30	96(6)	210(11)	300(10)	349(8)	384(9)	405(9)	423(10)	439(12)	459(11)	480(10)	498	505	
Schoolhouse[3]														
Shell	48	76(7)	185(7)	256(5)	303(6)	331(8)	358(8)	382(3)	401(2)	417(4)	421	432		
Shoup	81	76(5)	165(8)	253(7)	318(7)	355(10)	381(10)	405(9)	426(10)	449(15)	466(22)	455		
Tower	65	91(3)	190(3)	285(3)	347(5)	386(7)	415(10)	440(7)	458					
Twin	22	111(7)	229(10)	304(7)	346(10)	371(13)	381(17)	376						

Appendix 22 continued.

Lake	Number aged	1	2	3	4	5	6	7	8	9	10	11	12	13
Watts	87	91(5)	200(5)	277(12)	323(16)	355(19)	384(21)	411(23)	446(27)	482	492			
Willow	56	100(7)	212(15)	309(15)	353(11)	384(10)	414(9)	438(9)	457(8)	466(11)	465	473		
West Long	68	78(7)	175(12)	249(10)	307(13)	359(16)	405(20)	448(21)	485(9)	508(3)	515			

[1] Valentine National Wildlife Refuge
[2] Low samples size (16 fish) prohibited meaningful calculation of age and growth.
[3] Only 13 stock-length and longer fish were collected

Appendix 23. Catch per unit effort (number per trap net night) of northern pike collected in Nebraska Sandhill Lakes, 1998 and 1999. No northern pike trophy size and larger (≥1120 mm TL) were collected in any of the lakes. Standard errors are in parentheses. S=stock (≥350 mm); Q=quality (≥ 530 mm); P=preferred (≥710 mm); M=memorable (≥860 mm).

Lake	Total caught	CPUE (all sizes)	CPUE ≥S	CPUE ≥Q	CPUE ≥P	CPUE ≥M
Big Alkali	19	0.95(0.28)	0.80(0.25)	0.05(0.12)	0.00(0.00)	0.00(0.00)
Clear	21	1.05(0.19)	1.05(0.19)	0.45(0.11)	0.15(0.08)	0.00(0.00)
Clear (VNWR[1])	7	0.35(0.11)	0.35(0.11)	0.35(0.11)	0.30(0.11)	0.00(0.00)
Cottonwood	2	0.20(0.13)	0.20(0.13)	0.20(0.13)	0.00(0.00)	0.00(0.00)
Dewey	51	2.55(0.46)	2.55(0.46)	2.40(0.44)	2.00(0.39)	0.35(0.15)
Goose	31	1.55(0.36)	1.40(0.36)	1.35(0.32)	0.20(0.09)	0.00(0.00)
Hackberry	26	1.30(0.33)	1.30(0.33)	1.20(0.34)	0.25(0.16)	0.20(0.16)
Lackaff West	15	0.75(0.18)	0.75(0.18)	0.50(0.15)	0.20(0.09)	0.00(0.00)
Marsh	8	0.80(0.33)	0.60(0.22)	0.02(0.13)	0.00(0.00)	0.00(0.00)
Pelican	13	0.65(0.18)	0.65(0.18)	0.65(0.18)	0.15(0.08)	0.00(0.00)
Roseberry	28	2.80(0.99)	2.10(0.78)	2.10(0.78)	0.50(0.17)	0.00(0.00)
Round	21	2.10(0.48)	1.90(0.50)	1.60(0.27)	0.20(0.13)	0.00(0.00)
Schoolhouse	15	1.50(0.56)	1.50(0.56)	1.30(0.59)	0.10(0.10)	0.00(0.00)
Shell	30	1.50(0.37)	1.45(0.37)	1.10(0.35)	0.25(0.14)	0.05(0.05)
Twin	35	1.75(0.35)	1.70(0.32)	1.35(0.28)	0.45(0.14)	0.15(0.08)
West Long	2	0.20(0.13)	0.10(0.10)	0.00(0.00)	0.00(0.00)	0.00(0.00)

[1] Valentine National Wildlife Refuge

Appendix 24. Stock density indices and mean Wr values for northern pike collected in Nebraska Sandhill Lakes, 1998 and 1999. Confidence intervals (95%) for stock density indices and standard errors for mean Wr values are in parentheses. No northern pike trophy size and larger (≥1120 mm) were collected in any of the lakes. PSD=proportional stock density; RSD-P=relative stock density of preferred length fish; RSD-M=relative stock density of memorable length fish.

Lake	PSD	RSD-P	RSD-M	Wr ≥S	Wr S-Q	Wr Q-P	Wr P-M	Wr M-T
Big Alkali	84(18)	5(11)	0	85(1.6)	85(5.6)	84(1.6)	93	
Clear	43(23)	14(17)	0	90(2.8)	86(3.0)	99(5.0)	94(9.9)	
Clear(VNWR[1,2])				88(5.5)		98	86(6.3)	
Cottonwood[3]				74(0.1)		74(0.1)		
Dewey	94(7)	78(11)	14(10)	87(0.8)	96(5.0)	89(1.6)	86(0.8)	88(2.2)
Goose	96(5)	14(14)	0	92(2.0)	89(0.0)	93(2.4)	91(3.1)	
Hackberry	92(11)	19(16)	15(15)	86(0.3)	88(1.2)	82(0.3)	100	97(4.4)
Lackaff West	67(37)	27(26)	0	93(3.0)	103(3.2)	93(4.1)	81(1.7)	
Marsh[3]				101(2.0)	102(2.3)	97(3.3)		
Pelican	100(100)	23(27)	0	77(2.8)		77(3.10)	76(7.8)	
Roseberry	100(100)	24(20)	0	97(1.5)		96(1.6)	98(3.8)	
Round	84(16)	11(15)	0	93(1.6)	97(2.0)	93(1.6)	84(8.6)	
Shell	76(17)	17(15)	3(8)	89(1.7)	96(1.7)	88(2.4)	84(2.6)	99
Schoolhouse	87(20)	7(14)	0	76(3.3)	68(7.1)	77(3.9)	77	
Twin	79(15)	26(16)	9(10)	85(1.0)	84(2.0)	84(1.6)	88(1.1)	87(4.4)

Appendix 24 continued.

Lake	PSD	RSD-P	RSD-M	Wr ≥S	Wr S-Q	Wr Q-P	Wr P-M	Wr M-T
West Long[3]				94	94			

[1] Valentine National Wildlife Refuge
[2] Low sample size (7 fish) prohibited calculation of many indices
[3] Low sample size (2 fish) prohibited calculation of many indices
[4] Low sample size (8 fish) prohibited calculation of many indices

Appendix 25. Mean back calculated total length (mm) at age for northern pike collected in Nebraska Sandhill Lakes, 1998 and1999. Standard errors are in parentheses.

Lake	Number aged	1	2	3	4	5	6	7	8	9	10
Big Alkali	18	251(9)	445(11)	542(9)	595(10)	656					
Clear	20	280(16)	515(23)	668(37)	748(42)	802(33)	845				
Dewey	50	241(15)	470(24)	628(23)	712(22)	764(9)	792(12)	820(3)	839(9)	856(1)	868
Goose	31	289(19)	472(15)	594(10)	668(14)	719(18)	759				
Hackberry	25	368(34)	632(46)	758(57)	834(61)	927(10)	951(17)	978			
Lackaff West	15	423(16)	633(14)	729(23)	783						
Roseberry	27	295(30)	553(8)	660							
Round	21	253(20)	440(33)	514(36)	609(41)	648(26)	662				
Schoolhouse	15	308(42)	517(22)	655(67)	766						
Shell	29	259(9)	434(15)	531(18)	610(15)	661(28)	721(26)	714	731		
Twin	33	372(34)	625(53)	743(44)	820(21)	856(29)	900				

Appendix 26. Catch per unit effort (number per trap net night) of pumpkinseed sunfish collected in Nebraska Sandhill Lakes, 1998 and 1999. Standard errors are in parentheses. S=stock (≥80 mm); Q=quality (≥ 150 mm). No fish preferred length (200 mm) or longer were collected.

Lake	Total caught	CPUE (all sizes)	CPUE ≥S	CPUE ≥Q
Clear (VNWR[1])	24	1.20(0.58)	1.20(0.58)	0.00
Cottonwood	76	7.60(1.69)	7.50(1.67)	1.20(0.51)
Duck	56	5.60(3.19)	5.60(3.19)	2.00(0.83)
Goose	68	3.40(1.74)	3.40(1.74)	2.20(0.90)
Medicine	13	1.30(0.63)	1.30(0.63)	0.90(0.41)
Schoolhouse	45	4.50(0.90)	4.40(0.92)	0.30(0.15)
Shell	12	0.60(0.23)	0.55(0.86)	0.00
Shoup	16	1.60(0.40)	1.60(0.40)	0.60(0.22)

[1] Valentine National Wildlife Refuge

Appendix 27. Stock density indices and mean Wr values for pumpkinseed sunfish collected in Nebraska Sandhill Lakes, 1998 and 1999. Confidence intervals (95%) for stock density indices and standard errors for mean Wr values are in parentheses. PSD=proportional stock density. No fish preferred length (200 mm) or longer were collected.

Lake	PSD	Wr ≥S	Wr S-Q	Wr Q-P
Clear (VNWR[1])	0	114(0.9)	114(0.9)	
Cottonwood	16(8)	113(2.9)	113(3.4)	111(1.7)
Duck	36(13)	104(0.5)	102(0.4)	107(1.0)
Goose	65(12)	103(0.6)	102(1.1)	103(0.7)
Medicine	69(29)	124(2.9)	121(8.2)	125(3.0)
Schoolhouse	7(7)	122(1.3)	122(1.4)	122(0.0)
Shell	0	82(4.9)	82(4.9)	
Shoup	38(27)	109(1.7)	108(2.7)	110(1.2)

[1] Valentine National Wildlife Refuge

Appendix 28. Catch per unit effort (number per trap net night) of yellow perch collected in Nebraska Sandhill Lakes, 1998 and 1999. No yellow perch trophy size and larger (≥380 mm TL) were collected in any of the lakes. Standard errors are in parentheses. S=stock (≥130 mm); Q=quality (≥ 200 mm); P=preferred (≥250 mm); M=memorable (≥300 mm).

Lake	Total caught	CPUE (all sizes)	CPUE ≥S	CPUE ≥Q	CPUE ≥P	CPUE ≥M
Alkali	307	15.35(4.16)	15.35(4.16)	14.70(4.09)	11.70(3.52)	1.90(0.50)
Big Alkali	3	0.15(0.08)	0.05(0.05)	0.00(0.00)	0.00(0.00)	0.00(0.00)
Cameron	915	91.50(12.53)	82.60(11.77)	51.70(7.82)	27.60(4.25)	1.80(0.42)
Clear	3	0.15(0.08)	0.15(0.08)	0.15(0.08)	0.15(0.08)	0.00(0.00)
Clear (VNWR[1])	481	24.05(5.43)	20.20(4.75)	2.50(0.80)	0.25(0.16)	0.00(0.00)
Cottonwood	217	21.70(3.65)	18.50(3.27)	5.70(0.84)	0.50(0.27)	0.00(0.00)
Cozad	57	5.70(2.560	5.70(2.56)	2.80(1.29)	0.00(0.00)	0.00(0.00)
Defair	19	1.90(0.77)	1.60(0.73)	0.60(0.31)	0.10(0.10)	0.00(0.00)
Dewey	275	13.75(4.99)	6.35(2.22)	2.10(0.83)	0.50(0.26)	0.05(0.05)
Duck	39	3.9(1.73)	3.6(1.53)	2.1(0.77)	1.5(0.60)	0.00(0.00)
Goose	257	12.85(4.17)	12.80(4.14)	1.40(0.50)	0.15(0.08)	0.05(0.05)
Hackberry	284	14.20(7.42)	4.35(1.26)	1.55(0.47)	0.45(0.18)	0.00(0.00)
Hagan	571	142.75(70.86)	120.75(63.13)	14.50(7.75)	0.50(0.50)	0.00(0.00)
Home Valley	1,648	82.40(10.22)	66.95(10.27)	25.95(5.50)	1.95(0.46)	0.20(0.09)
Island	229	11.45(3.02)	11.35(3.01)	10.25(2.75)	5.15(1.56)	0.00(0.00)
Lackaff West	316	15.80(3.38)	15.80(3.38)	2.90(0.56)	0.35(0.18)	0.25(0.12)
Marsh	177	17.70(4.51)	17.10(4.56)	8.10(2.32)	1.20(0.39)	0.10(0.10)
Marsh (VNWR[1])	1,080	54.00(9.74)	51.85(9.57)	36.90(6.52)	33.25(5.83)	16.10(2.71)

Appendix 28 continued.

Lake	Total caught	CPUE (all sizes)	CPUE ≥S	CPUE ≥Q	CPUE ≥P	CPUE ≥M
Medicine	249	24.90(11.46)	24.70(11.41)	14.70(9.50)	4.40(3.74)	0.80(0.80)
Pelican	73	3.65(0.87)	1.85(0.43)	0.45(0.15)	0.00(0.00)	0.00(0.00)
Roseberry	364	36.40((12.83)	36.40(12.83)	28.10(8.82)	4.80(1.67)	0.80(0.36)
Round	303	30.30(7.60)	25.70(6.46)	2.70(4.23)	1.90(0.85)	0.40(0.31)
Schoolhouse	222	22.20(10.43)	12.40(5.36)	1.70(0.60)	0.40(0.22)	0.10(0.10)
Shell	39	1.95(0.53)	1.75(0.51)	0.95(0.32)	0.00(0.00)	0.00(0.00)
Tower	12	1.20(0.41)	1.00(0.33)	0.50(0.22)	0.10(0.10)	0.00(0.00)
Watts	117	5.85(1.78)	3.70(0.86)	1.60(0.38)	0.35(0.13)	0.00(0.00)
Twin	3	0.15(0.11)	0.05(0.05)	0.00(0.00)	0.00(0.00)	0.00(0.00)
Willow	2	0.10(0.07)	0.10(0.07)	0.10(0.07)	0.05(0.05)	0.05(0.05)
West Long	148	14.80(2,82)	14.20(2.86)	10.50(2,97)	8.80(3.06)	0.40(0.22)

[1] Valentine National Wildlife Refuge

Appendix 29. Stock density indices and mean Wr values for yellow perch collected in Nebraska Sandhill Lakes, 1998 and 1999. Confidence intervals (95%) for stock density indices and standard errors for mean Wr values are in parentheses. No yellow perch trophy size and larger (≥380 mm TL) were collected in any of the lakes. PSD=proportional stock density; RSD-P=relative stock density of preferred length fish; RSD-M=relative stock density of memorable length fish.

Lake	PSD	RSD-P	RSD-M	Wr ≥S	Wr S-Q	Wr Q-P	Wr P-M	Wr M-T
Alkali	96(2)	76(5)	12(3)	85(0.7)	92(0.5)	94(1.3)	84(1.0)	74(1.2)
Big Alkali[1]				79	79			
Cameron	63(4)	33(4)	2(1)	81(0.8)	83(1.4)	81(1.4)	79(1.1)	82(1.5)
Clear[1]	53(25)	21(20)	0	107(2.3)	112(3.7)	100(1.5)	107(3.6)	
Clear (VNWR[2])	12(4)	1(1)	0	87(1.2)	90(1.4)	82(1.5)	83(4.6)	
Cottonwood	31(7)	3(2)	0	108(1.3)	112(1.9)	103(1.0)	82(5.5)	
Cozad	49(14)	0	0	89(0.6)	93(0.9)	86(0.6)		
Defair	38(27)	6(12)	0	106(1.3)	109(0.7)	99(1.9)	92(-)	
Dewey	33(8)	8(5)	1(0)	99(2.0)	103(2.9)	109(2.9)	94(1.4)	87
Duck	58(17)	42(17)	0	88(0.2)	91(0.5)	86(0.9)	86(0.5)	
Goose	11(4)	1(1)	0	84(1.2)	85(1.3)	80(0.9)	75(0)	79(0)
Hackberry	36(10)	10(7)	0	86(0.8)	85(1.2)	91(1.4)	84(2.0)	
Hagan	12(3)	0(1)	0	97(1.9)	99(2.2)	82(1.6)	83(0.8)	
Home Valley	39(3)	3(1)	0	81(2.2)	78(1.4)	84(5.7)	80(0.8)	86(2.5)
Island	90(4)	45(6)	0	83(1.0)	87(0.4)	84(1.4)	80(1.6)	
Lackaff West	18(5)	2(2)	2(2)	83(1.0)	84(1.2)	78(1.9)	89(4.5)	80(2.8)

Appendix 29 continued.

Lake	PSD	RSD-P	RSD-M	Wr ≥S	Wr S-Q	Wr Q-P	Wr P-M	Wr M-T
Marsh	47(7)	7(4)	1(1)	93(0.9)	98(1.5)	89(1.0)	83(2.5)	
Marsh (VNWR[2])	71(3)	64(3)	31(3)	105(0.6)	119(1.3)	104(0.9)	100(1.2)	98(1.0)
Medicine	60(6)	18(5)	3(2)	105(1.4)	110(1.3)	105(3.1)	97(1.0)	91(2.5)
Pelican	24(15)	0	0	86(0.7)	86(0.9)	88(2.6)		
Roseberry	77(5)	13(4)	2(2)	95(1.2)	103(1.2)	94(1.8)	88(1.8)	70(2.3)
Round	11(4)	7(4)	2(20	76(1.4)	76(1.6)	7791.6)	76(0.9)	
Schoolhouse	14(6)	3(3)	1(1)	102(2.2)	104(2.6)	101(0.4)	101(2.3)	91
Shell	54(18)	0	0	79(0.5)	82(0.8)	77(0.5)		
Tower	50(38)	10(10)	0	100(2.6)	104(3.3)	101(0.8)	82(-)	
Twin[1]				106	106			
Watts	43(11)	9(6)	0	94(0.3)	98(0.5)	91(0.6)	80(1.9)	
Willow[3]				96(2.0)		94		98
West Long	74(7)	62(8)	3(3)	94(0.5)	96(0.6)	98(0.8)	93(0.9)	86(2.1)

[1] Low sample size (3 fish in trap nets) prohibited calculation of many indices.
[2] Valentine National Wildlife Refuge
[3] Low sample size (2 fish in trap nets) prohibited calculation of many indices.

Appendix 30. Mean back calculated total length (mm) at age for yellow perch collected in Nebraska Sandhill Lakes, 1998 and 1999. Standard errors are in parenthesis.

Lake	Number aged	1	2	3	4	5	6	7	8	9	10	11	12
Alkali	77	88(5)	174(9)	231(11)	268(10)	289(9)	306(10)	322					
Cameron	99	94(2)	161(3)	204(3)	235(1)	255(2)	270(3)	287(1)	300	307			
Clear (VNWR[1])	84	78(3)	142(5)	187(9)	208(12)	219(16)	252(13)	257					
Cottonwood	76	79(2)	120(3)	151(6)	174(7)	190(8)	202(10)	213(12)	217(15)	228(26)	213		
Cozad	38	84(2)	136(2)	164(4)	180(6)	197(3)	207(1)	213					
Defair	19	96(17)	174(21)	234(23)	267								
Dewey	88	75(5)	138(8)	199(10)	228(8)	249(8)	265(9)	284(8)	302(7)	318			
Duck	36	98(2)	182(8)	225(9)	254(8)	269(9)	277						
Goose	57	85(6)	141(7)	192(10)	216(12)	235(16)	253(22)	271(33)	247	251			
Hackberry	88	73(3)	122(5)	165(5)	197(4)	216(6)	228(8)	237(9)	253(6)	262(6)	268(8)	280	
Hagan	77	88(2)	134(2)	171(1)	195(2)	218(7)	236(9)	248(17)	271				
Home Valley	107	110(4)	166(7)	209(8)	237(9)	263(11)	291(5)	308					
Island	70	70(4)	118(3)	166(3)	198(6)	228(4)	246(3)	259(4)	268(5)	279(5)	292		
Lackaff West	60	83(5)	143(6)	187(9)	221(9)	247(12)	268(15)	283(18)	295(24)	299(36)	268		
Marsh	73	85(4)	148(7)	200(10)	236(9)	259(3)	270(1)	280	288				
Marsh(VNWR[1])	115	103(4)	186(11)	243(6)	268(4)	287(3)	305(4)	319(3)	331(5)	342(7)	356(2)	360(2)	362
Medicine	90	72(3)	143(4)	201(5)	234(4)	257(5)	278(4)	292(5)	307(2)	316(0)	322		
Pelican	49	63(1)	106(3)	152(3)	188(5)	207(8)	224(2)	233					

Appendix 30 continued.

Lake	Number aged	1	2	3	4	5	6	7	8	9	10	11	12
Roseberry	72	68(2)	125(6)	159(8)	188(5)	204(4)	215(6)	225(8)	233(12)	243(17)	254(31)	226	
Round	72	82(1)	148(6)	204(9)	244(9)	272(4)	289(1)	298					
Schoolhouse	44	109(5)	183(11)	223(12)	249(19)	281							
Shell	37	64(2)	104(5)	131(4)	156(3)	174(3)	194(3)	213(4)	225(6)	246			
Watts	73	67(4)	115(3)	167(6)	204(4)	227(4)	241(5)	254(7)	269				
West Long	80	83(4)	154(3)	206(7)	245(3)	267(1)	279(2)	287					

[1] Valentine National Wildlife Refuge

Appendix 31. Number of yellow perch collected in each age group for fish sampled in Nebraska Sandhill lakes during 1998 and 1999.. Only fish fully recruited to the gear (i.e., age-2 and older) are included. The recruitment variability index (RVI) ranges from -1 (very inconsistent recruitment) to 1 (very consistent recruitment).

Lake	2	3	4	5	6	7	8	9	10	11	12	RVI
Alkali	0	40	54	122	88	3						0.321
Cameron	259	72	203	172	81	29	0	10				0.644
Clear (VNWR[1])	258	7	5	13	1	1						0.963
Cottonwood	92	20	18	28	25	16	10	1	3			0.784
Cozad	1	15	3	21	15	1						0.557
Defair	10	5	1									0.854
Dewey	101	24	12	10	6	3	1	1				0.897
Duck	20	1	9	5	1							0.789
Goose	123	87	29	7	8	1	0	1				0.527
Hackberry	165	50	20	10	3	5	3	3	2	1		0.914
Hagan	237	154	50	35	6	5	1					0.877
Home Valley	487	390	222	85	6	4						0.676
Island	0	6	8	20	76	79	32	4	1			0.379
Lackaff West	85	91	121	9	3	2	3	0	1			0.637
Marsh	39	57	62	6	3	0	3					0.500
Marsh(VNWR[1])	95	80	38	153	214	119	69	40	1	3	1	0.656
Medicine	75	52	72	14	22	5	5	1	1			0.821
Pelican	34	19	9	8	3	1						0.825

Appendix 31 continued.

Lake	2	3	4	5	6	7	8	9	10	11	12	RVI
Roseberry	1	8	54	74	118	82	13	4	9			0.404
Round	171	86	9	7	6	5						0.901
Schoolhouse	17	1	3	4								0.810
Shell	1	1	1	4	11	9	9	1				0.442
Watts	29	18	21	11	10	4	2					0.752
West Long	36	6	7	38	52	11						0.556

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Appendix 32. Abundance (Number/L) of common zooplankton in 30 Nebraska Sandhill lakes 1998-1999.

Lake	Bosmina	Chydorus	Cyclops	Daphnia	Diaptomus	Keratella	Copepod Nauplii	All zooplankton
Alkali	1	1		1	3	65	8	78
Big Alkali	9	25	5	11	4	76	53	187
Cameron	37	325	18	43	1	29	43	512
Clear	51	9	30	2		185	39	565
Clear (VNWR[1])	124	12	17	88	6	55	162	2260
Cottonwood			59	2		106	211	517
Cozad	19	1	6	36		146	28	275
Defair	55	14	17	8	1	48	41	218
Dewey	228	15	27		1	349	44	670
Duck		189	14	18		15	12	248
Goose	630	260	11			297	61	1273
Hackberry	21	1	4	2	1	23	21	86
Hagan	15	46	29	89	1	85	48	486
Home Valley	355	525	99	196	42	34	86	1816
Island	1	4	5		6	55	37	108
Lackaff West	25	23	54			247	133	756
Marsh	2	26	26			88	95	268
Marsh (VNWR[1])	9	10	7	39	36	916	39	1098

Appendix 32 continued.

Lake	Bosmina	Chydorus	Cyclops	Daphnia	Diaptomus	Keratella	Copepod Nauplii	All zooplankton
Medicine	4	17	14	159	1	87	58	901
Pelican	210	752	22	26		12	60	1178
Roseberry	8	4	9			333	29	617
Round	16	17	6			44	24	191
Schoolhouse	115	207	346	83	3	80	311	1293
Shell	61		3	2		50	17	188
Shoup		49	3	88			10	150
Tower	397	25	45		16	31	58	588
Twin	2	46	10	75	7	22	31	2466
Watts		32	6	2		22	30	120
West Long	111	84	26	75	1	346	32	675
Willow	3	31	21	93	44	8	69	291

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Appendix 33. Abundance (Number/m^2) of common benthic invertebrates in 30 Nebraska Sandhill lakes sampled 1998-1999. Standard errors are in parentheses.

Lake	Amphipods	Chironomids	Gastropods	Odonates	Oligocheates	Pelecyopods	All benthos
Alkali	0	232(144)	3,910(1,485)	0	0	0	4,141(1,628)
Big Alkali	0	199(57)	15(15)	0	0	0	246(52)
Cameron	0	282(93)	0	0	0	0	301(101)
Clear	417(402)	670(376)	62(44)	0	2,076(915)	40(40)	3,373(576)
Clear (VNWR[1])	0	971(484)	308(111)	7(7)	902(132)	163(126)	2,388(640)
Cottonwood	43(21)	145(60)	3,003(777)	14(10)	0	0	3,206(702)
Cozad	141(113)	362(136)	395(390)	4(4)	51(17)	36(19)	1,022(340)
Defair	69(26)	14(6)	12,902(4,225)	0	4(4)	0	12,989(4,250)
Dewey	0	906(445)	94(57)	0	0	0	1,015(439)
Duck	11(7)	44(19)	101(67)	0	18(7)	0	156(53)
Goose	0	2,493(498)	4,884(1,017)	0	11(7)	29(17)	7,438(822)
Hackberry	0	2,294(262)	159(155)	4(4)	1,808(485)	0	4,286(483)
Hagan	4(4)	514(254)	0	0	630(568)	29(21)	1,203(792)
Home Valley	0	978(131)	0	0	33(24)	0	1,036(148)
Island	0	340(234)	206(145)	0	0	0	547(187)
Lackaff West	0	127(51)	33(33)	0	0	18(18)	181(35)
Marsh	47(33)	1,583(1,506)	9,605(3,976)	0	0	58(58)	11,293(3,037)
Marsh (VNWR[1])	4(4)	1,815(702)	1,304(758)	7(7)	148(94)	11(11)	3,384(316)

Appendix 33 continued.

Lake	Amphipods	Chironomids	Gastropods	Odonates	Oligocheates	Pelecyopods	All benthos
Medicine	199(123)	1,290(814)	11(11)	18(11)	40(12)	25(21)	1,598(936)
Pelican	0	830(391)	18(14)	0	83(58)	0	1377(664)
Roseberry	0	2,891(980)	0	0	330(117)	0	3,275(1,084)
Round	254(130)	464(264)	105(41)	0	7(4)	29(17)	855(259)
Schoolhouse	7(4)	909(275)	1,272(495)	0	1,848(1,412)	7(7)	5,562(3,174)
Shell	4(4)	145(126)	54,112(12,216)	11(11)	0	0	54,275(12,308)
Shoup	11(7)	29(24)	21(7)	0	11(11)	0	62(38)
Tower	0	1971(708)	214(140)	0	0	18(7)	2207(646)
Twin	0	1,022(806)	116(54)	11(7)	476(278)	80(61)	1761(1067)
Watts	0	1,372(952)	213(213)	0	0	0	1,589(1,158)
West Long	196(99)	362(53)	51(51)	18(18)	623(253)	4(4)	1381(254)
Willow	40(16)	627(499)	1,420(970)	0	1,841(1,073)	218(198)	5,044(2,656)

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