PREDICTING THE OCCURRENCE OF STUNTED BLUEGILL POPULATIONS FROM WISCONSIN LAKE FEATURES

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ABSTRACT

Bluegill stunting (poor growth and small size) is a fishery management problem in Wisconsin. Wisconsin has over 15,000 lakes and surveying each lake is not feasible due to lack of resources (personnel, money and time). Classifying lakes based on ecological and limnological similarities may provide a way to account for differences among lakes without having to survey all lakes. My objective was to classify stunted and non-stunted bluegill populations using features of Wisconsin lakes. Before I addressed my main objective, two subordinate objectives were addressed to establish data needs and define a stunted bluegill population for Wisconsin lakes. First, I determined if size selectivity of bluegills differed between electrofishing and Fyke netting in Wisconsin lakes. Second, I determined if size structure was related to body condition and growth of bluegill populations in Wisconsin lakes. Proportional stock density (PSD) estimated from the two primary gear types did not significantly differ, allowing me to combine data for future analyses. Mean length at age-4 was positively related to PSD, however the relationship was noisy. Bluegill relative weight (W_r) was not significantly related to PSD, suggesting, one index by itself may not provide adequate understanding of the dynamics of a bluegill population. Stunted bluegill populations were defined as having a PSD < 20 and a mean length at age-4 < 5 inches. I used linear discriminant analysis (LDA) to classify stunted and non-stunted bluegill populations based on lake features. Overall, the linear discriminant function (LDF) was 82% accurate in model creation and 85% accurate with validation. Stunted bluegill populations were predicted with 77% accuracy in model creation and 79% accuracy with validation. Non-stunted bluegill populations were predicted with 85% accuracy in model creation and 90% accuracy with

model validation. My model using easy to measure lake features can be used to classify stunted and non-stunted bluegill populations in Wisconsin lakes and allow managers to set broad-scale regulations to optimize angling opportunities for bluegills.

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INTRODUCTION

The bluegill *Lepomis macrochirus* is an ecologically important fish species in freshwater lakes (Snow et al. 1979). The bluegill is widespread throughout the eastern United States and is sporadically found in the western intermountain region (Becker 1983). In Wisconsin, the bluegill is native to the Mississippi River and Lake Michigan basins, and after stocking of bluegill into the Lake Superior basin, is now found in nearly all lakes throughout the state (Becker 1983). Bluegill commonly coexist with largemouth bass *Micropterus salmoides*, northern pike *Esox lucius*, yellow perch *Perca flavescens*, black crappie *Pomoxis nigromaculatus*, pumpkinseed *Lepomis gibbosus*, and bullheads *Ameiurus*. Many of these fish species prey on bluegill, and adult bluegill consume their own young. Bluegill often dominates the fish community of many small lakes throughout the eastern and mid-western parts of the United States and is important in organizing the fish community (Mittelbach and Osenberg 1993). Bluegill has a distinct niche shift during ontogeny, so the juveniles and adults feed on different prey. Juvenile bluegills feed primarily on littoral-zone invertebrates, whereas adult bluegills feed primarily on open-water zooplankton (*Daphnia*). Bluegill also feed on small crayfish, small fish, and aquatic vegetation (Becker 1983).

Bluegill spawn when water temperatures are 19.4–26.7°C (67-80°F), from May to early August, with peak spawning in June (Becker 1983). Male bluegills exhibit two life history strategies, parental male and cuckholder strategies (Gross 1979). Cuckholder males mature at an earlier age and size than parental male bluegills. Adult (parental) male bluegills are the first to move into spawning areas, generally in shallow water with substrate consisting of sand or gravel (Becker 1983). Males hollow out nests in the

substrate and females move in to be courted by the males. Males will protect and aerate the eggs until hatching. Cuckholders do not make nests, court females, or protect broods (Gross 1979). Rather, cuckholders access parental male nests by sneaking or mimicking females to steal opportunities to fertilize eggs. The average size of adult bluegills is 5 to 7 inches (Becker 1983). The lifespan of bluegill can be up to 13 years, but most do not live beyond 7 years of age.

The bluegill is a highly-sought species in many recreational fisheries (Drake et al. 1997). According to the National Survey of Fishing, Hunting, and Wildlife Associated Recreation, of 28.0 million anglers who participated in freshwater fishing (excluding the Great Lakes), panfish anglers (i.e. those who target *Lepomis* species and yellow perch) were the second most numerous, 7.9 million, and fished 103 million days (USFWS 2002). In Wisconsin, 1.4 million freshwater anglers (excluding the Great Lakes) spent 22 million days fishing and $1 billion on fishing trips and equipment (USFWS 2003). In 2001, panfish were the most highly sought group of fish species in Wisconsin, both in numbers of anglers (in-state and out-of-state) and numbers of days spent fishing (USFWS 2003). In Wisconsin, 53,000 mail surveys were sent to anglers for the 2001 angling season and found that the bluegill is the second most sought fish species, behind the walleye *Sander vitreus*, but the bluegill had the highest catch, 26 million, and harvest, 14 million (McClanahan 2003). In many recreational fisheries, bluegills have the highest total catch in numbers and weight, and often exceed that of all other species combined (Drake et al. 1997). In Minnesota, Drake et al. (1997) reported 20 panfish (mainly bluegill) were harvested for each walleye.

Bluegill Stunting

Stunting of bluegill is a major management problem in the upper Midwestern United States (Beard et al. 1997). Stunting is the inability of fish to reach their size potential because of slow growth. Small, slow-growing individuals dominate stunted populations (Swingle and Smith 1942). Stunting of bluegills occurs in many waters throughout Wisconsin and has been called the most serious fishery management problem in the state (Becker 1983). Stunted bluegills are of little value because they are too large for predators to eat and too small for anglers to keep.

Stunting (slow growth) of the bluegill has been attributed to insufficient food resources (Gerking 1962) and life-history strategies of the bluegill to mature early due to the social structure of the population (Aday et al. 2003). Stunted bluegill populations can develop under high intraspecific competition of limited food resources (Mittelbach 1983). A life-history strategy of the bluegill is for parental male bluegills to delay maturation until a larger size at which they can compete for nest sites and defends their brood (Gross 1979). The presence of large parental males inhibits sexual maturation of juvenile bluegills in the population (Jennings et al. 1997; Aday et al. 2003). However, the bluegill's life-history strategies are plastic and respond strongly to the social structure of the population (Aday et al. 2003). Angling can cause a change in the social structure of a bluegill population by selectively removing large bluegill (Drake et al. 1997; Jennings and et al. 1997). If large parental males are removed by angling, juvenile bluegills initiate gonad development, thereby resulting in decreased size and age at maturity and reduced growth rates and maximum size.

Many factors affect growth rates, but food availability and water temperature are considered the main determinants of growth rates (Hayes et al. 1999). Food availability for fish depends on intraspecific competition, interspecific competition, lake productivity, and limnological characteristics. Food availability is complicated by the presence of predators, which influence habitat choice of vulnerable prey. For example, predators can force young bluegill to live in weedy vegetation where survival is high and food supply is low, thereby leading to slow growth of young bluegills (Werner 1983). Growth rate varies with temperature, where fish found in their optimum temperature range with unlimited amounts of food have their highest growth rate (Wootton 1992).

Classifying Bluegill Populations

Because of the large number of inland lakes in Wisconsin (15,057 inland lakes; WDNR 2001), management of individual lakes is not feasible. Resources (money, time, and personnel) are limited in relation to the number of lakes requiring surveys. Therefore, management schemes that classify lakes based on ecological and limnological similarities among lakes provide a way to account for differences in lakes without surveying each lake (Nate 1999). Lake features are easy to use and readily available, so classifying Wisconsin lakes as having potentially stunted or non-stunted bluegill populations without needing to survey the population would help fisheries managers manage bluegill fisheries in Wisconsin. For example, fisheries managers could prescribe necessary management actions based on the predicted growth status of the population.

Physical, biological, and chemical characteristics of lakes have been used in classification schemes to explain variation in fish communities and abundance (Nate 1999). For example, Nate et al. (2003) developed a linear discriminant function using

lake surface area, mean depth, fetch, and three substrate descriptors to classify 120 northern Wisconsin lakes for the presence and absence of walleye. Similarly, Tonn et al. (1983) used patterns of fish assemblages and lake-habitat characteristics in 18 small lakes in northern Wisconsin to predict fish assemblages in 11 other lakes based on area, maximum depth, pH, watershed size, and conductivity.

Physical, biological, and chemical lake features could be used to classify stunted and non-stunted bluegill populations because lake features are often related to food availability, food productivity, and water temperature and therefore may reflect growth potential of fish. Lake morphometry affects food productivity by determining the extent of littoral, benthic, and pelagic habitats, and also physical, chemical and biological attributes of lakes (Wetzel, 2001; Reynolds 2004). For example, littoral area has been found to be positively related to bluegill growth (Tomcko and Pierce 2001), and lake morphometry was related to abundance and size of zooplankton (*Daphnia*) and the abundance and size of *Daphnia* was related to bluegill growth (Mittelbach and Osenberg 1993). Lakes that were deep, stratified, and had well-oxygenated hypolimnia produced abundant large *Daphnia* and fast-growing bluegills, whereas lakes that had limited hypolimnia produced few large *Daphnia* and slow-growing bluegills (Mittelbach and Osenberg 1993). Solar radiation is a major energy source that drives the productivity of aquatic ecosystems (Wetzel 2001). For example, secchi-disk transparency, a measure of solar radiation, and density of phytoplankton populations was negatively related to bluegill growth in Minnesota lakes (Tomcko and Pierce 2001. Slow-growing bluegill populations occurred in clear unproductive lakes in northwestern Wisconsin (Snow and Staggs 1994). Bluegill growth is also related to macrophyte density (Werner 1983;

Theiling 1990), where lake morphology affects macrophyte distribution (Theiling 1990). Alkalinity, the buffering capacity of the carbonate system in water, is determined by soil type and the equilibrium between photosynthesis and decomposition of plants, factors that are related to productivity (Reynolds 2004). Total alkalinity was positively related to bluegill growth in Minnesota lakes (Tomcko and Pierce 2001) and slow-growing bluegill populations occurred in northwestern Wisconsin lakes with low alkalinity and low conductivity (Snow and Staggs 1994).

OBJECTIVES

My main objective was to determine if the occurrence of non-stunted and stunted bluegill populations can be predicted from features of Wisconsin Lakes. In Chapter 2, I classified stunted and non-stunted bluegill populations using physical, chemical and biological variables of Wisconsin lakes that were map-based or temporally stable. I expected to find that stunted and non-stunted bluegill population could be predicted from easily-measured variables of Wisconsin lakes, which would permit fisheries managers to impose angling regulations on lakes without having to survey all lakes.

To address my main objective, two subordinate objectives were addressed first. My first objective established data needs and my second objective helped define stunted bluegill populations in Wisconsin inland lakes. After I defined a stunted bluegill population, I proceeded with my main objective to classify stunted and non-stunted bluegill populations in Wisconsin lakes.

My first objective was to determine if selectivity of electrofishing differs from selectivity of Fyke netting for bluegill in Wisconsin lakes. In Chapter 1, I compared size structure of bluegill captured by electrofishing and fyke netting in Wisconsin lakes. I

expected to find no significant difference in the size selectivity of the two gear types, which would permit me to use data from both capture methods for subsequent analyses.

My second objective was to determine if size structure is related to body condition and growth rates of bluegill populations in Wisconsin lakes. In Chapter 1, I compared size structure to body condition and growth rates of bluegill populations in Wisconsin lakes. I expected to find that size structure is significantly related to body condition and growth rate, which would permit me to use size structure as an indicator of stunted bluegill populations in Wisconsin lakes.

CHAPTER 1: SELECTIVITY OF SAMPLING GEARS AND THE RELATIONSHIP BETWEEN SIZE STRUCTURE, GROWTH, AND BODY CONDITION FOR BLUEGILLS IN WISCONSIN LAKES

Abstract

Fisheries managers often use biological statistics, such as population size structure and body condition, to assess the status of fish populations for guiding management decisions. Relationships among biological statistics are often assumed to exist through density dependent processes affecting growth, size structure, and body condition. I quantified the relationship between bluegill *Lepomis macrochirus* size structure, body condition and growth for populations in Wisconsin lakes. First, I examined potential size selectivity of bluegills from electrofishing and fyke netting, to determine if sampling information from both gears could be combined in a single analysis for bluegill populations surveyed in the spring, early summer, and late summer. I used proportional stock density (PSD) to index population size structure of bluegills sampled by both capture methods. I then used errors-in-variables models to describe the relationship between PSD estimates derived from both capture methods. Multiple comparisons (un-paired t-tests) were used to determine if parameter estimates of the relationship differed among seasons. Second, I used PSD to index population size structure, relative weight to index body condition, and mean length at age-4 to index growth rate. I then used errors-in-variables models to describe relationships between size structure and body condition and size structure and growth. Multiple comparisons (un-paired t-tests) were used to determine if parameter estimates of the relationships differed

among seasons and between gear types. I found that PSD of bluegill did not differ significantly between fyke netting and electrofishing in spring, early summer, late summer, or all seasons combined. I also found that PSD was positively related to mean length at age 4, but not to relative weight of bluegill in Wisconsin lakes. I conclude that fisheries biologists should not use indices of population size structure (PSD), body condition (W_r), or growth (size at age) individually to manage bluegill populations in Wisconsin lakes, but rather, should interpret bluegill population status from a combination of multiple population indices.

Introduction

In many recreational fisheries, bluegills *Lepomis macrochirus* have the highest total catch in numbers and weight, and often exceed that of all other species combined (Drake et al. 1997). In Minnesota, Drake et al. (1997) reported that 20 panfish (mainly bluegill) were harvested for each walleye. In Wisconsin, a statewide survey sent to over 53,000 anglers for the 2000-2001 angling season found that the bluegill was the second most sought fish species, behind the walleye *Sander vitreus*, but the bluegill had the highest catch, 26 million, and harvest, 14 million (McClanahan 2003).

Bluegill fisheries have been thought to be self regulating because bluegills reproduce at a young age and small size. Therefore, bluegills have been managed in many geographic locations with liberal angling regulations, such as high bag limits and no season closures (Coble 1988). While bluegill fisheries may not face recruitment over fishing, quality over fishing can occur (Olson and Cunningham 1989; Coble 1988). Management is now shifting toward minimum length limits, reduced bag limits, stocking predators, and removing small bluegills from populations to improve size structure, body condition, and growth (Quinn 2004).

Fishery managers often use biological statistics, such as size structure and body condition, to assess the status of fish populations for guiding management decisions (Ney 1999). Population size structure reflects underlying rates of recruitment, growth, and mortality (Anderson and Neumann 1996). Weight-length relationships are used to describe the "plumpness" or "well-being" of an individual or group and are thought to reflect conditions for feeding and growth (Murphy et al. 1991; Anderson and Neumann 1996). However, one biological statistic alone cannot provide adequate information for

making management decisions (Ney 1999). Decisions about which biological statistics are needed for guiding management decisions are made by balancing the amount of effort needed to collect data, and risks associated with each type of management decision. Because bluegill are thought to be prolific (i.e. low risk of extinction), the tendency is to make decisions with little information.

Relationships among biological statistics have been evaluated for some species, but relationships are often assumed to exist through density dependent processes affecting size structure, body condition, and growth. For example, faster growing populations are assumed to be of low density, good size structure, and good body condition, whereas slower growing populations are assumed to be of high density, poor size structure, and poor body condition. Bluegill population size structure was positively correlated to bluegill growth in Minnesota and Missouri lakes (Tomcko and Pierce 2005; Novinger and Legler 1978). Similarly, size structure was positively correlated to growth and condition for northern pike populations in eight states (Willis and Scalet 1989). Relationships between bluegill size structure, body condition, and growth have not been examined for bluegill populations in Wisconsin lakes.

Biological statistics may not reflect population attributes when the sampling method is biased (Anderson and Neumann 1996). Sampling bias is related to an individual's vulnerability to the sampling gear, which is influenced by when and where a gear is used. Fish may be present, absent or not accessible to a gear because of behavior or habitat preferences at the time of sampling (Anderson and Neumann 1996). For example, catch rates of large bluegills declined from June to August in Minnesota lakes likely because of bluegill spawning behavior (Cross et al. 1995). Selectivity of the gear

to fish of particular sizes also affects a fish's vulnerability to sampling (Anderson and Neumann 1996). For example, trap-nets selected larger sizes of bluegills in Manistee Lake, Michigan (Laarman and Ryckman 1982).

My objective was to determine if size structure was related to body condition and growth of bluegill populations in Wisconsin lakes. First, I determined if size selectivity of bluegills differed between electrofishing and fyke netting in Wisconsin lakes. I used proportional stock density (PSD) to index population size structure of bluegills sampled by both capture methods. I then used errors-in-variables models to describe the relationship between PSD estimates derived from both capture methods for multiple seasons. Next, I used PSD to index size structure, relative weight to index body condition, and mean length at age-4 to index growth rate. I then used errors-in-variables models to describe relationships between size structure, growth rate, and body condition.

Methods

Fisheries survey data were obtained from the Wisconsin Department of Natural Resources (WDNR) Fisheries Management Database and a WDNR historic database. Fisheries surveys were conducted using fyke netting or electrofishing on Wisconsin inland lakes in spring (January – May), early summer (June – July), late summer (August – September), and autumn (October – December) during 1946 – 2006.

Selectivity of Electrofishing and Fyke-Netting for Bluegill

Data.—Surveys were included if: (1) data entry was complete and proofed; (2) bluegill length was measured from populations sampled by electrofishing (via boom shocker) and fyke netting in the same lake, year, and season; and (3) a minimum of 16

stock length (≥ 3 inches) bluegills were captured. The final dataset included 69 paired electrofishing and fyke-netting surveys on 67 lakes in Wisconsin (Figure 1).

Proportional stock density (*PSD*) was calculated for bluegill caught using electrofishing and fyke netting. The *PSD* index summarizes length-frequency data as the percentage of stock-length fish that are also of quality length (Anderson and Weithman 1978; Willis et al. 1993):

$$PSD = \frac{Number\ of\ \ fish \geq quality\ length}{Number\ of\ \ fish \geq stock\ length} \times 100 .$$

In the *PSD* index, quality length is 6 inches and stock length is 3 inches for bluegill (Gabelhouse 1984). Quality and stock lengths are about 25% and 40% of the world record length of the bluegill. A minimum sample size of 16 stock length bluegills was used to estimate PSD with a 5% probability that the predicted confidence interval would exceed 0.25 on each side of the hypothesized *PSD* of 50 (Miranda 1993).

Data analysis.—Proportional stock density was compared between sampling gears (*f* = fyke netting; *e* = electrofishing) using linear regression:

$$PSD_f = b_0 + b_1 PSD_e + \varepsilon .$$

In the linear model, b_0 is the intercept, b_1 is the slope, and ε is residual error. Proportional stock density is measured with error, so ordinary least-squares parameter estimates are biased (Ricker 1975). Therefore, measurement errors were incorporated by estimating the slope and intercept using an errors-in-variables (EIV) model:

$$\hat{b}_1 = \frac{m_{YY} - \delta m_{XX} + \sqrt{(m_{YY} - \delta m_{XX})^2 + 4\delta m^2{}_{XY}}}{2m_{XY}} .$$

In the EIV model, $\hat{b}_1$ is the bias-corrected slope, m_{YY} is the variance in PSD_f, δ is the measurement-error ratio, m_{XX} is the variance in PSD_e, and m_{XY} is the covariance between PSD_f and PSD_e (Fuller 1987). The measurement-error ratio (MER = δ) was:

$$\delta = \frac{\overline{\sigma PSD_f}}{\overline{\sigma PSD_e}}.$$

In the MER, $\overline{\sigma PSD_f}$ is the mean standard deviation of PSD_f estimates and $\overline{\sigma PSD_e}$ is the mean standard deviation of PSD_e estimates. Standard deviations of PSD_f and PSD_e estimates were estimated as:

$$\sigma PSD = \sqrt{\frac{PSD(100 - PSD)}{n - 1}}.$$

In the estimates of mean standard deviation, PSD is PSD_f or PSD_e, and n is the number of bluegills that were ≥ stock length (Moore and McCabe 1998).

The bias-corrected slope of the relationship between PSD_f and PSD_e was tested for a significant difference (P ≤ 0.05) from 1.0 using a *t*-test:

$$t = \frac{\hat{b}_1 - 1}{SE\left(\hat{b}_1\right)}.$$

In the *t*-test, $\hat{b}_1$ is the bias-corrected slope of the relationship defined above, and $SE\left(\hat{b}_1\right)$ is the standard error of the bias-corrected slope, as defined by Fuller (1987). Similarly, the bias-corrected intercept of the relationship was tested for a significant difference (P ≤ 0.05) from 0.0 using a *t*-test, with terms defined by Fuller (1987).

Multiple comparisons using un-paired t-tests were used to determine if the bias-corrected slopes and intercepts differed among seasons. The t-statistic was estimated as (Zar 1999):

$$t = \frac{b_1 - b_2}{\sqrt{s_1^{\,2} + s_2^{\,2}}}.$$

In the *t*-test, b_1 and b_2 are estimated slopes or intercepts, and s_1^2 and s_2^2 are estimated variances of slopes or intercepts, as described by Fuller (1987). The Bonferroni method was used to test each comparison using a significance level of 0.05 divided by the number of comparisons (Sokal and Rohlf 2003).

Size Structure, Body Condition, and Growth of Bluegill

Data.—Surveys were included if: (1) data entry was complete and proofed; (2) bluegill length and weight or age were measured or estimated from fish collected by electrofishing (via boom shocker) and fyke netting; and (3) at least 16 stock length (≥ 3 inches) bluegills were captured. The final dataset to compare bluegill size structure to growth rate included 441 surveys (210 fyke-net surveys and 231 electrofishing surveys) on 332 Wisconsin lakes (Figure 3). The final dataset to compare bluegill size structure to body condition included 53 surveys on 44 Wisconsin lakes (Figure 4).

Proportional stock density (*PSD*) was used to index population size structure as described above and relative weight (W_r) was used to index body condition of bluegills 3.4 inches and longer (Wege and Anderson 1978; Murphy et al. 1990):

$$W_r = \frac{W}{W_s} \times 100.$$

In the W_r model, W is the weight of an individual and W_s is the standard weight for a specimen of measured length. The standard weight was estimated from the standard equation for bluegill (Wege and Anderson 1978; Murphy et al. 1990):

$$\log_{10}(W_s) = a' + b \times \log_{10}(L).$$

In the W_s model, a' is the intercept (-3.371) and b is the slope (3.316) of the $\log_{10}$ (weight) versus $\log_{10}$ (length) regression equation and L is the total length of the fish (Hillman 1982). Standard weight is the 75th percentile weight at a given length for all populations surveyed. A relative weight index of 100 or greater indicates a specimen in excellent condition. Mean relative weight ($\overline{W}_r$) was estimated for each bluegill population.

Growth was indexed using mean length at age-4 of bluegills in each survey $(\overline{X}_4)$. Mean length at age-4 was used to index growth because age-4 bluegills were assumed to be fully recruited to sampling gears when comparing growth among lakes in Wisconsin and Michigan and mean length at age was useful for classifying bluegill populations according to their overall growth potential in Wisconsin lakes (Nate 2004).

Data analysis.—Relationships between *PSD* and $\overline{W}_r$ and between *PSD* and $\overline{X}_4$ were modeled using linear regression:

$$PSD = b_0 + b_1 X \ + \varepsilon .$$

In the linear model, b_0 is the intercept, b_1 is the slope, X is $\overline{W}_r$ or $\overline{X}_4$, and ε is residual error. Mean length at age-4 and relative weight are measured with error, so ordinary least-squares parameter estimates are biased (Ricker 1975). Therefore, measurement errors in

X were incorporated by estimating the slope and intercept using an EIV model, as described above. The measurement-error ratio (MER) δ was estimated as:

$$\delta = \frac{\overline{CV}\,PSD}{\overline{CV}\,X}.$$

In the MER, $\overline{CV}$ is the mean coefficient of variation of *PSD,* W_r, and $\overline{X}_4$. The mean coefficient of variation for *PSD,* $\overline{W}_r$, and $\overline{X}_4$ was estimated as:

$$\overline{CV} = \frac{\sum_{i=1}^{n} CV_i}{n}.$$

In each estimate of *CV*, CV_i is the i^{th} population's *CV* estimate of *PSD,* W_r, or $\overline{X}_4$ and n is the number of populations in the sample. The coefficient of variation for each survey *PSD,* $\overline{W}_r$, or $\overline{X}_4$ estimate was estimated as:

$$CV_i = \frac{\sigma}{Y}.$$

In each estimate of CV_i, σ is the standard deviation of the *PSD,* $\overline{W}_r$, or $\overline{X}_4$ estimate and Y is the *PSD,* $\overline{W}_r$, or $\overline{X}_4$ estimate. Standard deviation of *PSD* was estimated as described above, and standard deviation for $\overline{W}_r$ and $\overline{X}_4$ was estimated as:

$$\sigma = \sqrt{\frac{1}{n-1}\sum_{i}^{n}\left(X_i - \overline{X}\right)^2}.$$

In the estimate of standard deviation, n is the number of bluegills sampled, X_i is estimated W_r and $\overline{X}_4$ of an individual fish, and $\overline{X}$ is the mean W_r and $\overline{X}_4$ of the population.

The bias-corrected slope of the relationship between *PSD* and $\overline{W}_r$ and *PSD* and $\overline{X}_4$ was tested for a significant difference (P ≤ 0.05) from 0.0 using a *t*-test:

$$t = \frac{\hat{b}_1}{SE\left(\hat{b}_1\right)}.$$

In the *t*-test, $\hat{b}_1$ is the bias-corrected slope of the relationship, as defined above, and $SE\left(\hat{b}_1\right)$ is the standard error of the bias-corrected slope, as defined by Fuller (1987). Similarly, the bias-corrected intercept of the relationship was tested for a significant difference (P ≤ 0.05) from 0.0 using a *t*-test, with terms defined by Fuller (1987).

To determine if the relationship between *PSD* and $\overline{X}_4$ differed among seasons (spring, early summer, late summer, and autumn) and between gear types, models were created for each season with each gear type. Un-paired t-tests were used to determine if slopes and intercepts differed among seasons for each gear type and between gear types:

$$t = \frac{b_1 - b_2}{\sqrt{{s_1}^2 + {s_2}^2}}$$

In the *t*-test, b_1 and b_2 were estimated slopes or intercepts, and ${s_1}^2$ and ${s_2}^2$ were estimated variances of the slopes or intercepts, as described by Fuller (1987). The Bonferroni method was used to test each comparison using a significance level of 0.05, divided by the number of comparisons (Sokal and Rohlf 2003). Sample sizes were not large enough to evaluate if the relationship between *PSD* and W_r differed among seasons and between gear types.

Results

Population size structure of bluegill did not differ significantly between fyke netting and boom shocking surveys in spring, early summer, late summer, or all seasons combined. For relationships between PSD from fyke netting and boom shocking, bias-corrected slopes did not differ significantly from 1.0 and bias-corrected intercepts did not differ significantly from 0.0 (Table 1). In addition, bias-corrected slope and intercept estimates of relationships between fyke netting and boom shocking PSD did not differ significantly among seasons (Table 2). Therefore, the full model with surveys from all seasons combined was used to describe the relationship between PSD estimates from fyke netting and PSD estimates from boom shocking for bluegill collected in Wisconsin lakes (Figure 2).

Population size structure was linearly related to growth, but not body condition, of bluegill in Wisconsin lakes. Slopes of relationships between PSD and mean length at age-4 differed significantly from 0.0 for all seasons and gear types except for boom shocking in early summer (Table 3). Slopes and intercepts of relationships between PSD and mean length at age-4 for each season (spring, early summer, late summer, and autumn) and gear type did not differ significantly among seasons or between gear types (Tables 4–5). Therefore, a full model including data from both gear types was used to describe the relationship between PSD and mean length at age-4 for bluegill in Wisconsin lakes (Table 3; Figure 5). The slope and intercept of the full model differed significantly from 0.0, thereby indicating a positive linear relationship between PSD and mean length at age-4 for bluegill in Wisconsin lakes (Table 3), though the relationship was noisy and therefore imprecise (Figure 5). Proportional stock density was not significantly related to

relative weight for bluegill populations because bias-corrected slopes and intercepts did not differ significantly from 0.0 (Table 6; Figure 6).

Discussion

I found that proportional stock density (PSD) estimates for bluegill did not differ significantly between electrofishing and fyke netting in spring, early summer, late summer and all seasons combined for Wisconsin inland lakes. Therefore, capture methods sampled stock-length (≥3 inches) and quality-length (≥6 inches) bluegills similarly in Wisconsin lakes. In contrast, bluegill PSD estimates in the spring were significantly higher for trap-net than electrofishing samples in one large heated impoundment in Kansas (Shultz and Haines 2005). My results may have differed from Shultz and Haines' (2005) results because of differences in sample size. Shultz and Haines' (2005) study was based on one large heated impoundment, where my study included multiple lakes throughout Wisconsin. In addition, Shultz and Haines (2005) attributed the capture of larger bluegills in trap-nets to gear placement. Trap-nets were not in vegetated littoral habitat where smaller bluegills are found, where electrofishing occurred in the vegetated habitats. Bluegill size structure indexed by PSD did not differ between 13-mm and 16-mm mesh trap-nets in autumn in four Nebraska lakes (Jackson and Bauer 2000). PSD estimates of white crappie *Pomoxis annularis* caught in trap nets and gillnets were positively correlated between the two gears (Guy et al. 1996). Guy et al. (1996) concluded that size structure could be indexed by using either gear type.

Though I found that bluegill PSD estimates did not differ significantly between electrofishing and fyke netting, the two capture methods are not necessarily selecting the same sizes of bluegills. Others have found that trap-nets selected larger bluegills (Cross

et al. 1995; Schultz and Haines 2005) and electrofishing selected for intermediate sizes of bluegills (Simpson 1978; Bayley and Austen 1987). The PSD index summarizes length frequency data as the percentage of stock-length fish that are also of quality length (Anderson and Weithman 1978). The Relative Stock Density (RSD) index developed by Wege and Anderson (1978) would allow comparison of gear types for larger sizes of bluegill, such as preferred length (8 inches), memorable length (10 inches), and trophy length (12 inches). However, my study was focused on comparing PSD between capture methods to address other questions and PSD is a size structure index being considered as an index for use in managing bluegill fisheries in Wisconsin.

I found a positive linear relationship between PSD and growth of bluegills in Wisconsin lakes. Similarly, bluegill population size structure was positively related to bluegill growth for Minnesota lakes and Missouri lakes (Tomcko and Pierce 2005; Novinger and Legler 1978). A positive relationship between PSD and growth was also found for Northern pike *Esox lucius* in 8 states (Willis and Scalet 1989) and black crappies *Pomoxis nigromaculatus* in South Dakota waters (Guy and Willis 1995). Although I found a significant relationship between PSD and growth of bluegills, the relationship was not precise. Variation in PSD estimates not explained by bluegill growth may be explained by other bluegill population dynamics not examined in my study, such as recruitment and mortality, which can influence population size structure (Ney 1999).

I did not find a significant relationship between bluegill body condition and population size structure. I did not find other studies that examined the relationship between bluegill body condition and population size structure. However, northern pike

PSD was positively related to relative weight in eight states when sampled in the spring (Willis and Scalet 1989). I expected to find a relationship between bluegill body condition and population size structure, because body condition is thought to reflect conditions for feeding and growth (Anderson and Neumann 1996) and growth was positively related to size structure for bluegill populations in Minnesota, Missouri, and Wisconsin lakes (Tomcko and Pierce 2005; Novinger and Legler 1978). Unfortunately, I did not have enough data to examine the relationship between bluegill growth and body condition.

I may not have found a relationship between bluegill body condition and size structure because of a lack of robustness in the relative weight model for bluegill and population dynamics (reproduction and mortality) affecting PSD estimates. Relative weight differed significantly among seasons for walleyes *Sander vitreus* in Wisconsin lakes (Hansen and Nate 2005) and white crappies *Pomoxis annularis* in a Kansas Reservoir (Gablehouse 1991). Relative weight models do not account for seasonal changes in body condition due to reproduction, so may not account for changes in body condition with length due to feeding conditions or reproduction (Hansen and Nate 2005). Bluegills have a protracted spawning season from April to August with peak spawning in June (Becker 1983). Mature females at the onset of spawning can have ovaries that are 10% of their body mass in northern latitudes (Keast 1978). Therefore, populations with good or poor population size structure could have good or poor body condition depending on time of sampling. If bluegills are sampled early in the spawning season, high gonad weight would bias body condition high, whereas bluegills sampled after spawning would have low body condition. Hansen and Nate (2005) developed a new index, adjusted

relative weight, to adjust relative weight for life-history based seasonal trends (i.e. reproduction) in body condition with length for walleye in Wisconsin lakes. However, an adjusted relative weight model has not yet been developed for bluegill in Wisconsin lakes.

Management Implications

My results show that proportional stock density (PSD) estimates for bluegill do not differ between electrofishing and fyke netting capture methods, so both capture methods are equivalent for estimating PSD of bluegill populations, though imprecise. Therefore, statewide summaries of bluegill size structure from Wisconsin lakes can be developed using survey information from both gear types combined. Combining gear types increases the size of the data set, and thereby enables further investigation of factors influencing bluegill populations at multiple spatial and temporal scales. More analyses that examine factors that influence the catchability of the gear types may help our understanding of unexplained variation in the relationship between PSD estimates.

I found a positive linear relationship between PSD and growth of bluegills in Wisconsin lakes, which suggests that growth may be indexed from size structure. Collection of age structures and age estimation requires more time and effort than indexing size structure. Therefore, cost-savings could be demonstrated by reducing the number of metrics collected during sampling. However, the relationship between bluegill population size structure and growth was imprecise, so one population attribute cannot be used to precisely predict the other attribute for populations in individual lakes. Imprecision in the relationship between population size structure and growth and the lack of a relationship between population size structure and body condition could be due to

biological mechanisms not accounted for in my study. More analyses are needed to identify factors affecting precision of estimates and factors that can influence the metrics. One index by itself may not provide adequate understanding of the dynamics of a bluegill population.

Table 1. Sample size (*N*), measurement error ratios (*Y/X*), bias-corrected slopes (b_1) and intercepts (b_0) estimates using linear errors-in-variables models describing the relationship between fyke-net and boom shocker proportional stock density estimates for bluegill surveyed in the same lake during the same year and season for Wisconsin lakes from 1967-2006 (95% C.I. = 95% confidence interval). Test statistics from t-tests describe if b_1 differs from 1.0 and b_0 differs from 0.

Season	*Y/X*	Parameter	Estimate	*N*	95% C.I.	*t*	df	*P*
Spring	0.811	b_1	1.093	45	0.625-1.562	0.401	43	0.625
		b_0	5.637		-37.444	0.547	43	0.547
Early Summer	0.814	b_1	0.984	10	0.395-1.574	0.068	8	0.953
		b_0	15.622		-34.201	2.111	8	0.068
Late Summer	0.826	b_1	1.211	14	-2.985	0.308	12	0.763
		b_0	0.702		-63.137	0.048	12	0.962
All Seasons	0.814	b_1	1.081	69	0.758-1.404	0.502	67	0.617
		b_0	6.589		-22.793	1.154	67	0.253

Table 2. Test statistics from un-paired t-tests comparing the bias-corrected slopes (b_1) and intercepts (b_0) estimates using linear errors-in-variables models describing the relationship between proportional stock density of bluegills sampled during the seasons of spring (January-May), early summer (June-July), and late summer (August-September) using fyke-nets or a boom shocker in Wisconsin lakes from 1967-2006 .

Season Comparison		b_1			b_0	
		t	*P*	df	*t*	*P*
Spring	Early Summer	0.315	0.754	53	0.840	0.405
Spring	Late Summer	0.163	0.871	57	0.287	0.775
Early Summer	Late Summer	0.310	0.760	22	0.917	0.369

Table 3. Sample size (*N*), measurement error ratios (*Y/X*), bias-corrected slopes (b_1) and intercepts (b_0) estimates using linear errors-in-variables models describing the relationship of proportional stock density and mean length at age-4 for bluegill surveyed during the seasons of spring (January-May), early summer (June-July), late summer (August-September), and autumn (October-December) using fyke-nets or boom shocker in Wisconsin lakes from 1946-2005 (95% C.I. = 95% confidence interval). Test statistics from t-tests used to examine if bias- corrected b_1 and b_0 estimates differed from 0.

						95% C.I.				
Gear Type	Season	*N*	*Y/X*	Parameter	Estimate	Lower	Upper	*t*	df	*P*
Boom	Spring	50	2.6	b_1	47.81	30.17	65.45	5.45	48	<0.001
Shocker				b_0	-214.62	-308.91	-120.34	-4.58	48	<0.001
	Early Summer	37	2.26	b_1	60.75	-0.53	122.03	2.01	35	0.052
				b_0	-277.37	-586.59	31.84	-1.82	35	0.077
	Late Summer	94	2.65	b_1	30.68	20.14	41.21	5.79	92	<0.001
				b_0	-129.96	-183.96	-75.95	-4.78	92	<0.001
	Autumn	49	2.4	b_1	59.45	9.38	109.52	2.39	47	0.021
				b_0	-304.54	-589.99	-19.08	-2.15	47	0.037
Fyke Net	Spring	80	1.29	b_1	104.11	9.57	198.68	2.19	78	0.031
				b_0	-563.3	-1124.2	-2.4	-2.16	78	0.02
	Early Summer	69	1.89	b_1	59.7	26.84	92.57	3.63	67	0.001
				b_0	-311.79	-508.6	-114.99	-3.05	67	0.003
	Late Summer	62	1.75	b_1	43.91	22.84	64.98	4.18	60	<0.001
				b_0	-218.99	-340.78	-97.2	-3.68	60	0.001
Both	All Seasons	441	2.07	b_1	49.8	40.8	58.81	10.87	439	<0.001
				b_0	-239.02	-289.3	-188.73	-9.34	439	<0.001

Table 4. Test statistics from unpaired t-tests comparing between seasons the bias-corrected slopes (b_1) and intercepts (b_0) estimates of linear errors-in-variables models describing the relationship between bluegill proportional stock density and mean length at age-4 for bluegill surveyed during spring (January-May), early summer (June-July), late summer (August – September), and autumn (October-December) using a boom shocker or fyke-nets in Wisconsin lakes from 1946-2005.

			b_1			b_0	
Gear Type	Season Comparison		*t*	*P*	df	*t*	*P*
Boom Shocker	Spring	Early Summer	0.412	0.682	85	0.394	0.695
	Spring	Late Summer	1.672	0.097	142	1.562	0.121
	Spring	Autumn	0.441	0.660	97	0.602	0.549
	Early Summer	Late Summer	0.981	0.328	129	0.953	0.342
	Early Summer	Autumn	0.033	0.974	84	0.130	0.897
	Late Summer	Autumn	1.131	0.260	141	1.208	0.229
Fyke Net	Spring	Early Summer	0.896	0.372	148	0.854	0.395
	Spring	Late Summer	1.236	0.219	132	1.192	0.235
	Early Summer	Late Summer	0.809	0.420	120	0.802	0.424

Table 5. Test statistics from un-paired t-tests comparing between gear types the biased corrected slopes (b_1) and intercepts (b_0) estimates of linear errors-in-variables models describing the relationship between proportional stock density and mean length at age-4 for bluegill surveyed during spring (January-May), early summer (June-July), late summer (August-September), and autumn (October-December) using a boom shocker or fyke-nets in Wisconsin lakes from 1946-2005.

Boom Shocker	Fyke-net	b_1			b_0	
Season	Season	*t*	*P*	df	*t*	*P*
Spring	Spring	1.166	0.246	129	1.217	0.226
Early Summer	Early Summer	0.030	0.976	104	0.190	0.850
Late Summer	Late Summer	1.125	0.262	145	1.339	0.183
Autumn	Late Summer	0.576	0.566	100	0.554	0.581
Spring	Early Summer	0.638	0.525	117	0.890	0.375
Spring	Late Summer	0.285	0.776	101	0.057	0.955
Early Summer	Late Summer	0.527	0.600	88	0.356	0.723
Late Summer	Spring	1.522	0.130	173	1.515	0.132
Late Summer	Early Summer	1.678	0.095	161	1.778	0.077
Autumn	Spring	0.848	0.398	128	0.833	0.406
Autumn	Early Summer	0.008	0.993	118	0.042	0.967

Table 6. Sample size (*N*), measurement error ratios (*Y/X*), bias-corrected slopes (b_1) and intercepts (b_0) estimates using a linear errors-in-variables model describing the relationship between proportional stock density and relative weight for bluegill surveyed with fyke-nets or a boom shocker in Wisconsin lakes from 1944-2005 (95% C.I. = 95% confidence interval).

N	*Y/X*	Parameter	Estimate	95% C.I.	*t*	df	*P*
53	1.211	b_1	4.346	-0.320-9.011	-1.649	51	0.105
		b_0	-360.905	-800.330-78.520	1.870	51	0.067

Figure 1. Locations of 67 Wisconsin bluegill populations surveyed using fyke-nets and electrofishing (via boomshocker) for which length data was used to determine if proportional stock density estimates differed between gear types and among seasons.

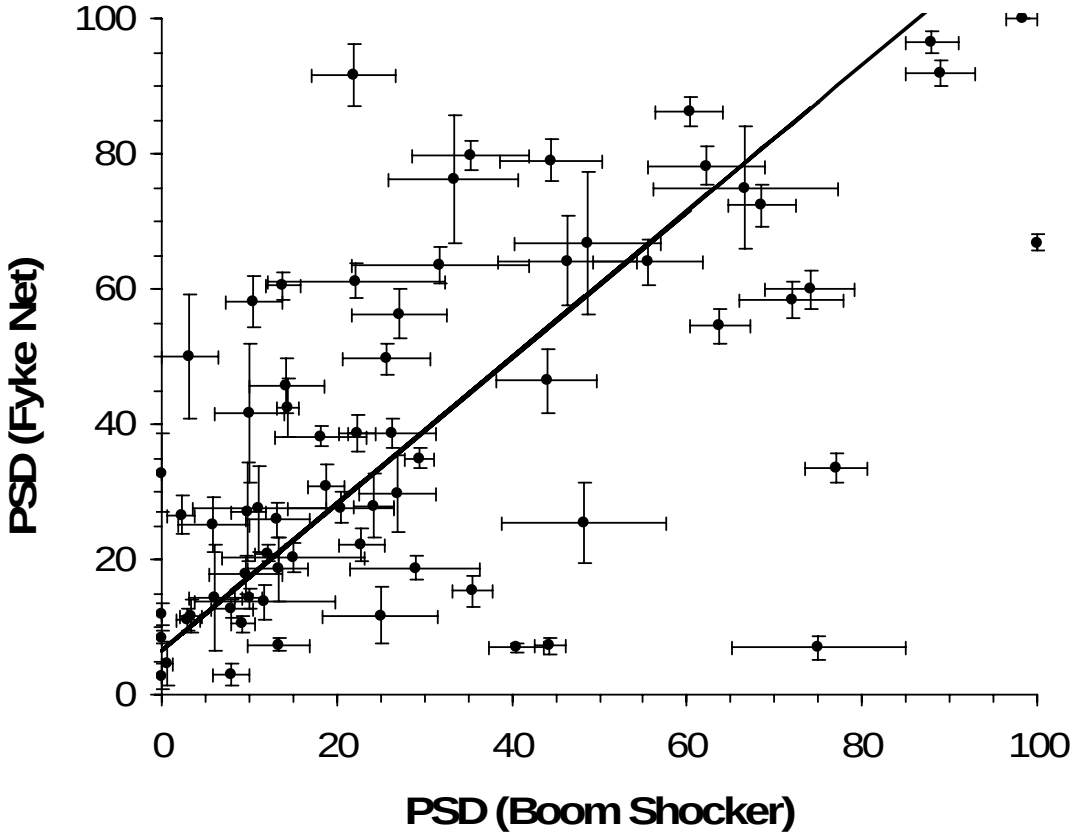

Figure 2. Proportional stock density (PSD) with upper and lower 95% confidence intervals (CI) estimated for bluegill populations surveyed using fyke-nets vs. PSD with upper and lower 95% CI estimated for bluegill populations surveyed using a boom shocker, where surveys occurred in the same lake during the same season and year in Wisconsin inland lakes (N=69) from 1967-2006. The solid line is the predicted relationship from a linear errors-in-variables model.

Figure 3. Locations of 332 Wisconsin bluegill populations for which length and age data were used to examine the relationship between bluegill proportional stock density and mean length at age-4.

Figure 4. Locations of 44 Wisconsin bluegill populations for which length and weight data were used to examine the relationship between bluegill proportional stock density and relative weight.

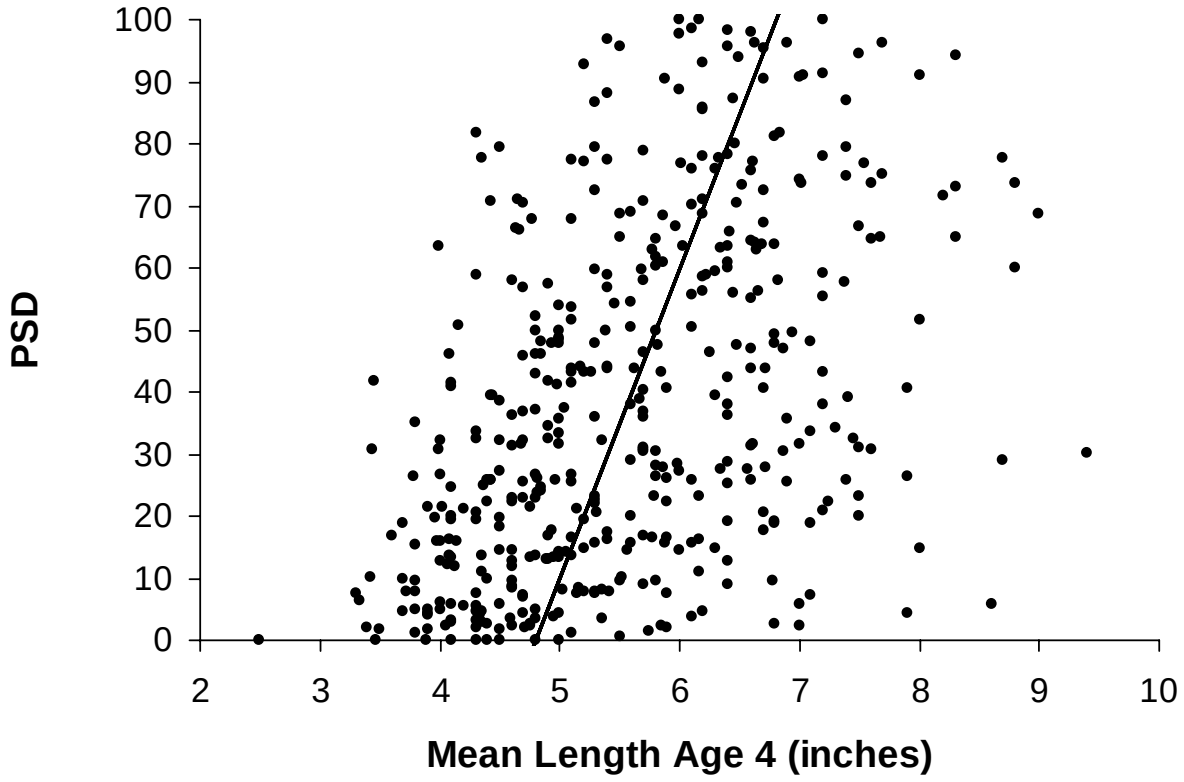

Figure 5. Proportional stock density (PSD) versus mean length at age-4 for bluegill populations surveyed using fyke-nets or a boom shocker in Wisconsin lakes from 1946-2005. The solid line is the predicted relationship of a linear errors-in-variables model.

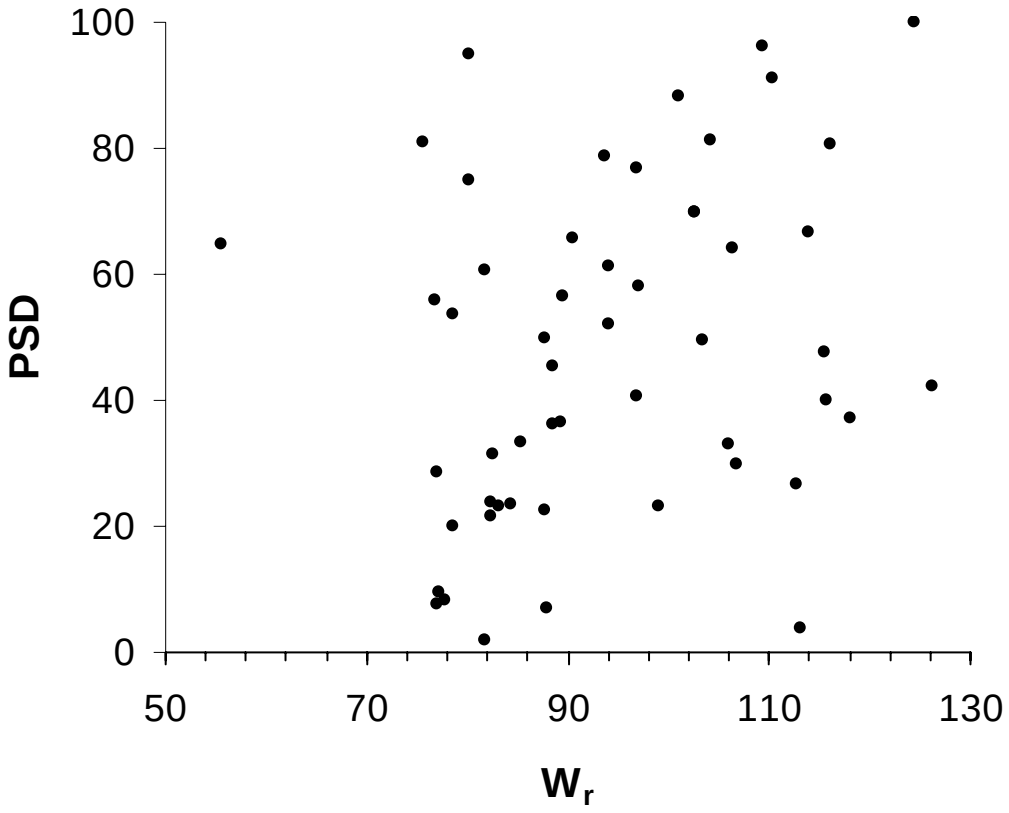

Figure 6. Proportional stock density versus relative weight for bluegill populations surveyed using fyke-nets or a boom shocker in Wisconsin lakes from 1944-2005.

CHAPTER 2: PREDICTING THE OCCURRENCE OF STUNTED BLUEGILL POPULATIONS FROM WISCONSIN LAKE FEATURES

Abstract

Bluegill stunting (poor growth and small size) is a fishery management problem in Wisconsin. Wisconsin has over 15,000 lakes and surveying each lake is not feasible due to lack of resources (personnel, money and time). Classifying lakes based on ecological and limnological similarities may provide a way to account for differences among lakes without having to survey all lakes. My objective was to classify stunted and non-stunted bluegill populations using features of Wisconsin lakes. Stunted bluegill populations were defined as having a PSD < 20 and a mean length at age-4 < 5 inches. I used linear discriminant analysis (LDA) to classify stunted and non-stunted bluegill populations based on lake features. A linear discriminate function (LDF) that included latitude, trophic state index, alkalinity, distance to nearest urban center, percent of surface area shallower than 20 ft, shoreline length, lake surface area, percent gravel, and percent sand correctly discriminated lakes with stunted bluegill populations from lakes with non-stunted bluegill populations. Overall, the LDF was 82% accurate in model creation and 85% accurate with validation. Stunted bluegill populations were predicted with 77% accuracy in model creation and 79% accuracy with validation. Non-stunted bluegill populations were predicted with 85% accuracy in model creation and 90% accuracy with model validation. My model using easy to measure lake features can be used to classify stunted bluegill populations in Wisconsin lakes and allow managers to set broad-scale regulations to optimize angling opportunities for bluegills.

Introduction

The bluegill *Lepomis macrochirus* is an important fish species ecologically and recreationally in freshwater lakes across the United States. The bluegill often dominates the fish community of many small lakes throughout the eastern and mid-western parts of the United States and plays an important role as a predator and prey in the trophic dynamics of a fish community (Mittelbach and Osenberg 1993). The bluegill is a highly sought species in many recreational fisheries (Drake et al. 1997). According to the National Survey of Fishing, Hunting, and Wildlife Associated Recreation, of 28.0 million anglers who participated in freshwater fishing (excluding the Great Lakes), panfish anglers (i.e. those who target *Lepomis* species and yellow perch) were the second most numerous, 7.9 million, and fished 103 million days (USFWS 2002). In Wisconsin, the bluegill is the second most sought fish species, behind the walleye *Sander vitreus*, but the bluegill had the highest catch, 26 million, and harvest, 14 million (McClanahan 2003). In many recreational fisheries, bluegills have the highest total catch in numbers and weight, and often exceed that of all other species combined (Drake et al. 1997).

Stunting of bluegill is a major management problem in the upper Midwestern United States (Beard et al. 1997). Stunting is the inability of fish to reach their size potential because of slow growth. Small, slow-growing individuals dominate stunted populations of fish (Swingle and Smith 1942). Stunting of bluegill populations occurs in many waters throughout Wisconsin, and is the most serious fishery management problem in the state (Becker 1983). Stunted bluegills are of little value because they are often too large for predators to eat and too small for anglers to keep.

Stunting (slow growth) of the bluegill has been attributed to insufficient food resources (Gerking 1962) or to a life-history strategy to mature early in response to the social structure of the population (Aday et al. 2003). Stunted bluegill populations can develop under high intraspecific competition of limited food resources (Mittelbach 1983). In life history stunting, parental male bluegills delay maturation until a larger size when they can compete for nest sites and defend their brood (Gross 1979). The presence of large parental males inhibits maturation of juvenile bluegills in the population (Jennings et al. 1997; Aday et al. 2003). However, the bluegill's life-history strategies are plastic and respond strongly to the social structure of the population (Aday et al. 2003). Angling can cause a change in the social structure of a bluegill population by selectively removing large bluegill (Drake et al. 1997; Jennings and et al. 1997). If large parental males are removed by angling, juvenile bluegills initiate gonad development, thereby resulting in decreased size and age at maturity and reduced growth rates and maximum size.

Many factors affect bluegill growth, but food availability and water temperature are the main determinants (Hayes et al. 1999). Food availability for fish depends on the presence of intraspecific and interspecific competitors, and on lake productivity. Food availability is complicated by the presence of predators, which influence habitat choice of vulnerable prey. For example, predators can force young bluegill to live in weedy vegetation where survival is high and food supply is low, thereby leading to slow growth of young bluegills (Werner 1983). Growth rate varies with temperature, where fish found in their optimum temperature range with unlimited amounts of food have their highest growth rate (Wootton 1992).

Because of the large number of inland lakes in Wisconsin (15,057 inland lakes; WDNR 2001), management of individual lakes is not feasible. Resources (money, time, and personnel) are limited in relation to the number of lakes requiring surveys. Therefore, management schemes that classify lakes based on ecological and limnological similarities among lakes provide a way to account for differences in lakes without surveying each lake (Nate 1999). Lake features are easy to use and readily available, so classifying Wisconsin lakes as having potentially stunted or non-stunted bluegill populations without needing to survey the population would help fisheries managers manage bluegill fisheries in Wisconsin. For example, fisheries managers could prescribe necessary management actions based on the predicted growth status of the population.

Physical, biological, and chemical characteristics of lakes have been used in classification schemes to explain variation in fish communities and abundance (Nate 1999). For example, lake surface area, mean depth, fetch, and three substrate descriptors were useful for classifying 120 northern Wisconsin lakes for the presence and absence of walleye (Nate et al. 2003). Similarly, patterns of fish assemblages and lake-habitat characteristics in 18 small lakes in northern Wisconsin were useful for predicting fish assemblages in 11 other lakes based on area, maximum depth, pH, watershed size, and conductivity (Tonn et al. 1983).

Physical, biological, and chemical lake features could be used to classify stunted and non-stunted bluegill populations because lake features are often related to food availability, food productivity, and water temperature and therefore may reflect growth potential of fish. Lake morphometry affects food productivity by determining the extent of littoral, benthic, and pelagic habitats, and also physical, chemical and biological

attributes of lakes (Wetzel, 2001; Reynolds 2004). For example, littoral area has been found to be positively related to bluegill growth (Tomcko and Pierce 2001), and lake morphometry was related to abundance and size of zooplankton (*Daphnia*) and the abundance and size of *Daphnia* was related to bluegill growth (Mittelbach and Osenberg 1993). Lakes that were deep, stratified, and had well-oxygenated hypolimnia produced abundant large *Daphnia* and fast-growing bluegills, whereas lakes that had limited hypolimnia produced few large *Daphnia* and slow-growing bluegills (Mittelbach and Osenberg 1993). Solar radiation is a major energy source that drives the productivity of aquatic ecosystems (Wetzel 2001). For example, secchi-disk transparency, a measure of solar radiation, and density of phytoplankton populations was negatively related to bluegill growth in Minnesota lakes (Tomcko and Pierce 2001. Slow-growing bluegill populations occurred in clear unproductive lakes in northwestern Wisconsin (Snow and Staggs 1994). Bluegill growth is also related to macrophyte density (Werner 1983; Theiling 1990), where lake morphology affects macrophyte distribution (Theiling 1990). Alkalinity, the buffering capacity of the carbonate system in water, is determined by soil type and the equilibrium between photosynthesis and decomposition of plants, factors that are related to productivity (Reynolds 2004). Total alkalinity was positively related to bluegill growth in Minnesota lakes (Tomcko and Pierce 2001) and slow-growing bluegill populations occurred in northwestern Wisconsin lakes with low alkalinity and low conductivity (Snow and Staggs 1994).

My objective was to determine if the occurrence of non-stunted and stunted bluegill populations could be predicted using features of Wisconsin Lakes. I used linear discriminate analysis to classify non-stunted and stunted bluegill populations using map-

based or temporally stable features of Wisconsin lakes. Lake features were related to food productivity, food availability, water temperature, recruitment potential, and angling pressure and therefore bluegill stunting.

Methods

Fisheries survey data were obtained from the Wisconsin Department of Natural Resources (WDNR) Fish and Habitat Database and a WDNR historic database. Fisheries surveys in the analysis were conducted by fyke netting or electrofishing on Wisconsin inland lakes in spring (January – May), early summer (June-July), late summer (August-September), and fall (October-December) during 1946 – 2005. Fisheries survey data were included in the analysis if: (1) data entry was complete and proofed; (2) bluegill length data was measured; and (3) bluegill age was estimated.

Stunted bluegill populations were defined using growth indexed by mean length at age-4 and size structure indexed by proportional stock density (PSD). Size structure alone was not used to define a stunted bluegill population because the relationship between PSD and mean length at age-4 for bluegill in Wisconsin lakes was noisy (Chapter 1). Age-4 bluegills were assumed to be fully vulnerable to fyke-nets and boom shockers in Michigan lakes (Nate 2004). In addition, mean length at age-4 was useful for classifying bluegill populations according to their overall growth potential in Wisconsin lakes (Nate 2004). In 16 Michigan lakes, the average length of age-4 stunted bluegills was less than 5 inches (Schneider and Lockwood 1997). The average length of an age-4 bluegill was 6.3 inches in Michigan (Schneider and Lockwood 1997) and 5.9 inches in Wisconsin (Becker 1983).

The *PSD* index summarizes length-frequency data as the percentage of stock-length fish that are also of quality length (Anderson and Weithman 1978; Willis et al. 1993):

$$PSD = \frac{Number\ of\ \ fish \geq quality\ length}{Number\ of\ \ fish \geq stock\ length} \times 100 .$$

In the *PSD* index, quality length is 6 inches and stock length is 3 inches for bluegill (Gabelhouse 1984). A minimum sample size of 16 stock length bluegills was required to estimate PSD with a 5% probability that the predicted CI will exceed 0.25 on each side of the hypothesized proportion of 50 (Miranda 1993). Bluegill populations with a PSD of 20–60 are in balance in bluegill-largemouth bass fisheries Anderson (1978). A PSD of 20–40 for bluegill provided the best number of fish for anglers and prey for bass in small impoundments (Novinger and Legler 1978). Therefore, I defined lakes as having a stunted bluegill population if mean length at age-4 was less then 5 inches and proportional stock density (PSD) was less then 20.

Confidence intervals (CI) were estimated for PSD and mean length at age-4 and were used in defining a stunted and non-stunted bluegill population. The CI must have only included my definition of a stunted bluegill population (PSD < 20 and mean length at age-4 < 5 inches) for a population to be defined as stunted. An exact 95% CI was estimated for PSD with an alpha of 0.05 where the lower CI was estimated using the equation (Zar 1999):

$$L_1 = \frac{X}{X + (n - X + 1)F_{\alpha(2),v_1,v_2}} .$$

For the lower CI, X is the number of quality length bluegill, n is the number of bluegills that are at least stock length, $v_1 = 2(n - X + 1)$, and $v_2 = 2X$. The upper CI was estimated using the following equation (Zar 1999):

$$L_2 = \frac{(X+1)F_{\alpha(2),v'_1,v'_2}}{n - X + (X+1)F_{\alpha(2),v'_1,v'_2}}.$$

For the upper CI, $v'_1 = 2(X+1)$, $v'_2 = 2(n - X)$, and other terms are the same as for the lower CI. A two-sided t-interval with an alpha of 0.05 was used to generate approximate 95% CIs for the mean length at age-4 estimates using the equation (Hayter 2007):

$$\hat{\mu} \in \left(\bar{x} - \frac{t_{\alpha/2,n-1}s}{\sqrt{n}}, \bar{x} + \frac{t_{\alpha/2,n-1}s}{\sqrt{n}} \right).$$

For the *t*-interval, n is the sample size and s is the sample standard deviation. For mean length at age-4 estimates that were from summary data (raw data unavailable), sample standard deviation was approximated using the mean s of mean length at age-4 estimates with the same sample size. A lake was excluded from analysis if the CI of both metrics overlapped with the definition of a stunted population and non-stunted population, because the status of the lake could not be determined. The CI of both metrics may have overlapped because precision of one or both metrics was low. If a lake was surveyed multiple times and the status of the lake changed, the lake was defined as stunted if more then one generation existed between surveys.

Lake features used to predict the occurrence of stunted and non-stunted bluegill populations were map based and temporally stable, and were selected to reflect growth potential (water temperature, food availability and productivity) and life history based

stunting (fishing effort and recruitment potential). Latitude, maximum depth (ft), surface area (A = acres), percent of surface area < 20 ft deep, percent of surface area < 3 ft, shoreline length (L = mi), shoreline development index (L/(2*SQRT(π*A))), alkalinity (mg/L), drainage area (acres), watershed area (acres), percent gravel, and percent sand were obtained from the Wisconsin Surface Water Inventory database and Surface Water Resource publications (Wisconsin Conservation Department 1961–1966; Wisconsin Department of Natural Resources 1967–1983). Trophic State Index (TSI) describes the productivity of a lake and was estimated using the average secchi disk measurements for the lake with all available data collected during summer (July – early-September) from the Wisconsin Department of Natural Resources (Lillie et al. 1993; Lillie and Mason 1983.) The distance from each lake to the nearest urban center was used to index fishing effort, which is rarely available for lakes in Wisconsin. Urban centers were defined by the United States Census Bureau (2000) as a census block with a population density of at least 1,000 people per square mile and at least 500 people per square mile in surrounding census blocks. I used ArcView Geographic Information System with a tool that measures the Euclidean distance of each lake (polygon) to an urban center (polygon) (Pinteric 2007; ESRI 2004).

Linear discriminant analysis (LDA) was used to determine if lake features could be used to classify lakes as having stunted or non-stunted bluegill populations based on known group membership. LDA was used because my objective was to discriminate between two groups (stunted and non-stunted bluegill lakes) and use the resulting classification scheme to classify new observations. LDA has been used to link fish populations to their habitats (Tonn and Magnuson 1982; Nate el al. 2003).

To meet assumptions of LDA and develop an accurate and precise model, I excluded non-stunted lakes from the model that were surveyed before 1980. LDA requires samples to be of known group membership (stunted or non-stunted bluegill lakes) (McGarigal et al. 2000). Because the cause of stunting has been attributed to some non-temporally stable factors, such as removal of large male bluegills, population surveys from many years ago may not reflect the current status of the bluegill population. The year 1980 was chosen arbitrarily to ensure an appropriate sample size for the non-stunted group required for LDA. In addition, LDA requires sample sizes of both groups to be relatively equal (Tabachnick and Fidell 1983). If all non-stunted bluegill surveys were included in the analysis, the sample sizes would have greatly differed. The sample size for stunted and non-stunted bluegill populations were 44 and 66 respectively (Figure 1).

I evaluated assumptions and requirements of linear discriminant analysis: sample size, multivariate normality, multicollinearity, equality of variance-covariance matrices, and prior probabilities. First, LDA requires samples sizes to be large to ensure means and dispersions used to discriminate groups are estimated accurately and precisely (McGarigal et al. 2000). I assumed that the sample size for each group was appropriate because the sample size was greater than or equal to three times the number of discriminating variables in the model (Williams and Titus 1988). Second, LDA assumes that the underlying distribution of the data for each group is multivariate normal (McGarigal et al. 2000). To determine if variables were normally distributed, residuals were examined from a Univariate Analysis of Variance (ANOVA) on each discriminating variable with the grouping variable as the main effect (McGarigal et al. 2000). To help meet the assumption of multivariate normality, continuous variables were

transformed into natural logarithms (Gotelli and Ellison 2004) and percentages were transformed into arcsines (Gotelli and Ellison 2004). LDA is robust to non-multivariate normality if sample sizes are large for each group (>20 in each class) and relatively equal (Tabachnick and Fidell 1983). Third, LDA requires that discriminating variables not be correlated (McGarigal et al. 2000). To test for collinearity of discriminating variables, pairwise correlations among all discriminating variables were tested (McGarigal et al. 2000). A separate univariate ANOVA for each variable with a high pairwise correlation (Pearson's $r \geq 0.7$) were used with the grouping variable as the main effect and each discriminating variable as a dependent variable (McGarigal et al. 2000). Discriminating variables with the highest F-value among those with high pairwise correlations were retained in the data set as better predictors (McGarigal et al. 2000). The variables retained for the LDA were: latitude, trophic state index, alkalinity, distance to the nearest urban center, depth above 20 ft, shoreline length (miles), surface area of the lake (acres), percent gravel and percent sand. Fourth, Box's M-test showed that the assumption of equal variance-covariance between groups (McGarigal et al. 2000) was violated, so the LDA was run using separate group covariance matrices (Tabachnick and Fidell 1983). However, classification results did not change, which suggests that violation of the equal variance-covariance assumption did not affect the LDA. LDA is robust to violation of the assumption of equal variance-covariance with equal or large sample sizes (Tabachnick and Fidell 1983). Therefore, I retained the original analysis using the same variance-covariance between the groups. I assumed an equal prior probability of stunted and non-stunted bluegill lakes (i.e. 50% in each class).

The linear discriminant function (LDF) was created by randomly choosing 70% of the data for each group and validated by holding out the remaining 30% of the data. Utility of the LDF was judged based on the canonical correlation coefficient (R) and the squared canonical correlation coefficient (R^2). The canonical correlation coefficient is a measure of the multiple correlations between the set of discriminating variables and the LDF (McGarigal et al. 2000). An R of 0 would indicate no association between the groups and the LDF, whereas larger values of R would represent increasing degrees of association. The squared canonical correlation coefficient describes how much of the variation in the LDF is due to group differences. Chi-square statistics were used to test if means of the discriminant function were equal across groups. The discriminant function separated stunted and non-stunted bluegill lakes better than chance if the p-value was less then or equal to 0.05. Proportional chance criterion (C_{pro}) was used to assess accuracy of the discriminant function (Morrison 1969):

$$C_{pro} = p\alpha + (1-p)(1-\alpha)\,.$$

In the C_{pro} statistic, p is the true proportion of stunted bluegill lakes in the sample and α is the proportion of lakes categorized by the discriminant function as a stunted bluegill lake. The C_{pro} statistic compares the proportion of correctly classified observations with the proportion expected to be correctly classified by chance, and is appropriate when discriminant analysis is used to identify membership of both groups and when sample sizes of the groups are unequal (Morrison 1969). Structure coefficients of the discriminant function were used to assess how predictor variables were related to the function (McGarigal et al. 2000). A large absolute value for the structure coefficient (close to 1.0) indicates that the variable and function are related. In addition, structure

coefficients are useful for interpreting ecological meaning of the discriminant function (McGarigal et al. 2000).

Results

A linear discriminate function (LDF) that included latitude, trophic state index, alkalinity, distance to nearest urban center, percent of surface area shallower than 20 ft, shoreline length, lake surface area, percent gravel, and percent sand (Table 1) correctly discriminated lakes with stunted bluegill populations from lakes with non-stunted bluegill populations ($\chi^2 = 45.83$; $df = 9$; $p < 0.001$; Table 2). The relatively large canonical correlation ($R = 0.694$) indicated that stunted and non-stunted bluegill populations were associated with the LDF. About 48% ($R^2 = 0.48$) of variation in the LDF was due to group differences. Of 76 bluegill populations used to create the LDF, the model correctly classified 77% of stunted populations, 85% of non-stunted populations, and 82% of all populations (Table 3). Of 34 bluegill populations used to validate the model, the LDF correctly classified 79% of stunted populations, 90% of non-stunted populations, and 85% of all populations (Table 3). The proportional chance criterion ($C_{pro} = 52\%$) indicated that 52% of bluegill populations were expected to be correctly classified by chance alone, so the model classified lakes with stunted and non-stunted bluegill populations at a higher rate than chance alone.

Structure matrix coefficients for variables in the LDF indicated that stunted bluegill populations were in lakes with lower alkalinity, higher latitude, less surface area, shorter shoreline, lower trophic state index (TSI; less productive), more sand, less gravel, shallower depth, and closer to urban centers than in lakes with non-stunted bluegill populations (Table 4). Variables that were most related to the LDF (absolute value of the

coefficients were closest to one) included alkalinity, latitude, surface area, and shoreline length (Table 4). Variables that were least related to the LDF included (from most related to least) TSI, percent sand, area above a depth of 20 ft, distance to nearest urban center, and amount of gravel (Table 4).

Discussion

My results show that stunted (slow growth) bluegill populations in Wisconsin lakes were in lakes of low productivity, similar to other studies that identified relationships between lake productivity and bluegill growth. In my study, bluegill stunting was associated with lakes that were colder (higher latitude), had lower alkalinity, and a lower trophic state index. Slow bluegill growth was also associated with lakes of low productivity in Minnesota (Tomko and Pierce 2001). Bluegill mean back-calculated lengths at ages 1–6 in Minnesota were negatively correlated with secchi depth (higher water clarity and less productivity) and positively correlated with alkalinity and mean maximum July air temperature (Tomko and Pierce 2001). Lake productivity was positively related to bluegill growth in 115 lakes in northwestern Wisconsin (Snow and Staggs 1994). Secchi depth was negatively related to bluegill mean length at age, while alkalinity and morphoedaphic index (ratio of total dissolved solids to mean depth) was positively related to bluegill growth (Snow and Staggs 1994).

I found that stunted (slow growth) bluegill populations were in lakes with small surface area and short shoreline length, similar to another study of bluegill growth in Wisconsin Lakes (Nate 2004). Bluegill growth, indexed as mean length at age 4, was higher in lakes with larger surface areas (> 446 ha) than in lakes with smaller surface areas (<446 ha; Nate 2004). Photosynthesis per unit of lake surface area increases with

lake size (Fee et al. 1992), so lakes with large surface area may be more productive and thereby increase fish growth rate.

I found that non-stunted (fast growth) bluegill populations were in deep lakes, similar to another study in southwestern Michigan lakes (Mittelbach and Osenberg 1993). Lakes that were deep, stratified, and well-oxygenated in the hypolimnion produced abundant large *Daphnia* and fast-growing bluegills, whereas lakes with limited hypolimnia produced few large *Daphnia* and slow-growing bluegills (Mittelbach and Osenberg 1993). In contrast, bluegill growth was higher in shallow lakes in Minnesota (Tomcko and Pierce 2001). Bluegill growth, indexed by mean back-calculated length at ages 1–6, was negatively related to maximum depth and positively related to percent littoral area (percent of lake area < 4.6 m deep; Tomcko and Pierce 2001). Therefore, bluegill growth was higher in lakes with more littoral area. In contrast, I found that stunted (slow growth) bluegill populations were found in lakes with more littoral area (percent of lake < 20 ft deep). These contradictory findings may be due to the fact that littoral habitat provides food resources for growth but may also provide refugia for bluegills to avoid predation and thereby lead to dense slow growing populations.

Overall, I found that stunted bluegill populations were in lakes of low productivity, which is consistent with other studies that attributed bluegill stunting to a lack of food resources. Stunted bluegill populations can develop under high intraspecific competition of limited food resources (Mittelbach 1983). For example, growth of bluegills declined with bluegill density and net energy gains were positively related to bluegill growth in an experimental lake in Michigan (Mittelbach 1988). Mittelbach (1988) concluded that bluegills were competing for food resources and prey availability

directly influenced growth rates. Growth rates of small bluegills were negatively related to density in nine lakes in southwestern Michigan (Osenberg et al.1988). Food availability in littoral habitat was positively correlated with bluegill growth at ages 2–4 in five lakes in central and southern Wisconsin (Nibbelink and Carpenter 1998). Resource availability (low and high food ration) and timing of maturation (presence and absence of large bluegills) interact to influence body size of bluegill (Aday et al. 2006). Juvenile bluegills were significantly longer and heavier in high food treatment ponds than in low food treatment ponds (Aday et al. 2006). Juvenile males that became mature in low food ponds were significantly smaller than those that remained immature (Aday et al. 2006). However, in high food ponds, mature and immature juvenile male bluegills did not differ in weight or length (Aday et al. 2006).

I found that lakes with stunted (slow growth) bluegill populations were closer to urban centers and therefore may have experienced higher fishing effort. Lakes in Ontario that were closer to major population centers suffered heavily from high fishing pressure (Lester et al. 2003). Because large bluegills are often selected by Wisconsin anglers (Beard and Kampa 1999), and exploitation is directly related to effort (Coble 1988), Wisconsin bluegill populations experiencing higher fishing effort may be more vulnerable to stunting. Life-history based stunting occurs when juvenile male bluegills mature after large parental male bluegills are removed from a population (Aday et al. 2003; Drake et al. 1997). Early maturing, young bluegill divert energy into gonadal development instead of somatic growth, thereby resulting in decreased size and age at maturity, and reduced growth rates and maximum size (Aday et al. 2003; Drake et al. 1997). Small male bluegills in experimental ponds occupied nests in the absence of large

male bluegills, but when large male bluegills were present, most nests were occupied by large males (Jennings et al. 1997). Lakes with lower fishing effort had parental male bluegills that were older, faster growing, and larger at maturity than parental males in lakes with low fishing effort in five Minnesota lakes and one Ontario lake (Drake et al. 1997). In experimental ponds, 60% of juvenile male bluegills matured in the absence of large parental male bluegills, whereas only 13% of juvenile male bluegills matured in the presence of large male bluegills (Aday et al. 2003). Social structure had a strong influence on the percentage of juvenile bluegills that matured in experimental ponds, where the rate of maturation for juvenile male bluegills in the absence of large male bluegills was four times higher than in the presence of large males (Aday et al. 2006).

Other lake measures not examined in my study, such as predation, may have helped to classify stunted bluegill populations. Predators may increase bluegill growth rate by reducing bluegill density, thereby increasing per capita resource availability (Belk and Hales 1993). However, increasing predator density may confine small bluegills to vegetated refugia and allow bluegill density to increase, thereby increasing competition for limited food resources and decreasing growth rates (Werner and Hall 1988). Bluegill density can also remain high if size structure of predators is reduced (reduced gape size), thereby allowing bluegills to outgrow the threat of predation (Belk and Hales 1993).

My model had a relatively low error rate (18% for creation and 15% for validation), so can be used to classify stunted bluegill populations in Wisconsin lakes. The risk of misclassifying bluegill populations is outweighed by the cost of surveying all lakes in Wisconsin. The accuracy of the model may have improved by adding difficult to measure variables, such as predation, but obtaining difficult-to-measure variables would

require intensive lake-by-lake sampling, and may not be useful for creating a simple classification scheme to help manage thousands of Wisconsin Lakes.

Management Implications

My linear discriminant function can be used to classify stunted bluegill populations in Wisconsin lakes based on easily measured attributes, including latitude, trophic state index, alkalinity, distance to the nearest urban center, percent of surface area shallower than 20 ft, shoreline length, lake surface area, percent gravel, and percent sand. Managers can use the model to classify lakes and then set broad-scale regulations that are designed to optimize angling harvest opportunities for bluegill. A classification scheme that is based on easily measured lake characteristics is easier and cheaper to implement than more intensive and costly lake surveys.

Fisheries manager can use a variety of management actions to improve characteristics (growth, size structure, or size at maturity) of stunted bluegill populations. For example, a one-time stocking of fingerling walleyes improved bluegill population size structure after a four-year lag (Schneider and Lockwood 2002). Similarly, a one-time treatment of lakes with antimycin increased bluegill population size structure after a 1–2 year lag, but lasted only 2–8 years (Schneider and Lockwood 2002). In contrast, a combination of antimycin treatment and catch-and-release angling for all species resulted in immediate and prolonged increased bluegill growth, adult survival, and population size structure. After reducing the daily bag limit from 30 bluegills per day to 10 bluegills per day, length at maturity of parental male bluegills increased significantly and mean length of bluegills increased significantly in Minnesota lakes (Jacobson 2005). Based on a

simulation study, closure of angling during the spawning season produced a noticeable increase in mean length of bluegills (Beard et al. 1997).

Table 1. Summary of lake features used to discriminate the occurrence of stunted bluegill populations ($N = 44$) and non-stunted bluegill populations ($N = 66$) in 110 Wisconsin lakes.

Variables	Stunted bluegill lakes			Non-stunted bluegill lakes		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum
Latitude	45.6	44.3	46.2	45.5	43.3	46.7
Trophic State Index	45.1	34.0	60.1	48.3	33.1	67.1
Alkalinity (ppm)	56.3	3.0	188.0	71.0	4.0	186.0
Distance to urban center (miles)	16.9	0.0	33.9	12.5	0.0	32.8
Depth above 20 feet (%)	78.7	20.0	100.0	84.5	12.0	100.0
Shoreline length (miles)	4.2	0.5	22.6	4.9	0.8	34.1
Surface area of lake (acres)	315.8	11.0	6063.0	383.6	20.0	3585.0
Depth below 20 feet (%)	20.2	0.0	75.0	16.3	0.0	88.0
Depth <3 feet deep (%)	16.2	3.0	40.0	17.7	1.0	70.0
Shoreline Development Index (SDI)	1.6	1.1	3.0	2.1	1.0	6.7
Drainage area (acres)	1.6	1.0	12.0	5.3	0.0	33.0
Watershed area (acres)	2.1	1.0	18.0	44.9	0.0	740.0
Maximum depth (feet)	32.7	5.0	105.0	29.9	8.0	82.0
Amount of gravel (%)	16.8	0.0	82.0	12.5	0.0	70.0
Amount of sand (%)	43.7	0.0	99.0	49.8	0.0	99.0

Table 2. Linear discriminant function coefficients for determining the occurrence of stunted bluegill populations (proportional stock density < 20 and mean length at age-4 < 5.0 inches; N =30) and non-stunted bluegill populations (N = 46) using 9 features of 76 Wisconsin lakes.

	Coefficent	
Variables	Stunted	Non-stunted
Constant	-70285.100	-69992.000
Latitude	36021.419	35942.308
Trophic State Index	912.084	911.521
Alkalinity (ppm)	145.052	146.648
Distance to urban center (miles)	-180.073	-178.930
Depth above 20 feet (%)	-349.386	-348.280
Shoreline length (miles)	-45.824	-45.154
Surface area of lake (acres)	-53.825	-53.559
Amount of gravel (%)	182.453	183.021
Amount of sand (%)	-83.625	-84.698

Table 3. Classification with validation (hold-out sample) summary for a linear discriminant function using alkalinity, latitude, surface area, shoreline length, trophic state index, littoral area (percent of lake above 20 ft), distance to nearest urban center, percent gravel, and percent sand to discriminate 110 Wisconsin lakes for the occurrence of stunted bluegill populations ($N = 44$) and non-stunted bluegill populations ($N = 66$). The table shows the number and percent of observations classified into each group during model creation and validation.

		Predicted Group Membership			
		Stunted	Yes	No	Total
Model Building	Count	Yes	23	7	30
		No	7	39	46
	%	Yes	76.7	23.3	100.0
		No	15.2	84.8	100.0
Model Validation	Count	Yes	11	3	14
		No	2	18	20
	%	Yes	78.6	21.4	100.0
		No	10.0	90.0	100.0

Table 4. Structure matrix coefficients describing the pooled within-groups (stunted bluegill populations and non-stunted bluegill populations) correlations between 9 lake features and the linear discriminant function used to determine the occurrence of stunted bluegill (proportional stock density < 20 and mean length at age-4 < 5.0 inches; $N = 30$) and non-stunted bluegill populations ($N = 46$) in 76 Wisconsin lakes. The discriminant function's centroids for the stunted and non-stunted bluegill populations were -1.181 and 0.770 respectively.

Variables	Coefficent
Alaklinity (ppm)	0.700
Latitude	-0.464
Surface area of lake (acres)	0.395
Shoreline length (miles)	0.368
Trophic State Index	0.214
Amount of sand (%)	-0.185
Depth above 20 feet (%)	0.064
Distance to urban center (miles)	0.030
Amount of gravel (%)	0.030

Figure 1. Map showing the locations of 44 stunted bluegill populations (circles) and 66 non-stunted bluegill populations (triangles) in Wisconsin that were used to develop a linear discriminate function to predict occurrence of populations based on the lakes' features.

CONCLUSIONS

I found that proportional stock density (PSD) estimates for bluegill do not differ between electrofishing and fyke netting capture methods, so both capture methods are equivalent for estimating PSD of bluegill populations. Therefore, statewide summaries of bluegill size structure from Wisconsin lakes can be developed using survey information from both gear types combined. Combining gear types increases the size of the data set, and thereby enables further investigation of factors influencing bluegill populations at multiple spatial and temporal scales.

I found a positive linear relationship between PSD and growth of bluegills in Wisconsin lakes, which suggests that growth may be indexed from size structure. Collection of age structures and age estimation requires more time and effort than indexing size structure. Therefore, cost-savings could be demonstrated by reducing the number of metrics collected during sampling. However, the relationship between bluegill population size structure and growth was imprecise, so one population attribute cannot be used to precisely predict the other attribute for populations in individual lakes. Imprecision in the relationship between population size structure and growth and the lack of a relationship between population size structure and body condition could be due to biological mechanisms not accounted for in my study. More analyses are needed to identify factors affecting precision of estimates. One index by itself may not provide adequate understanding of the dynamics of a bluegill population.

My linear discriminant function can be used to classify stunted bluegill populations in Wisconsin lakes based on easily measured attributes, including latitude, trophic state index, alkalinity, distance to the nearest urban center, percent of surface area

shallower than 20 ft, shoreline length, lake surface area, percent gravel, and percent sand. Managers can use the model to classify lakes and then set broad-scale regulations that are designed to optimize angling harvest opportunities for bluegill. A classification scheme that is based on easily measured lake characteristics is easier and cheaper to implement than more intensive and costly lake surveys.

APPENDIX A:

Year, Season, Lake, County, Water Body Identification Code, Number of bluegill that are at least stock length (≥ 3 inches) and quality length (≥ 6 inches) sampled during electrofishing (boom shocker) and fyke netting surveys in Wisconsin lakes from 1967-2006.

					Boom Shocker		FYKE NETTING	
Year	Season	Lake	County	WBIC	Stock	Quality	Stock	Quality
2001	Spring	PINE LAKE	WAUSHARA	196100	381	85	336	130
2001	Spring	LONG LAKE	BAYFIELD	2767100	740	328	471	34
2002	Spring	PIKE LAKE	MARATHON	1406300	52	5	192	34
2003	Spring	LAKE MONONA	DANE	804600	336	63	208	64
2004	Spring	LONG LAKE	FOND DU LAC	38700	76	20	546	211
2004	Spring	LAKE WINGRA	DANE	805000	165	13	105	3
2002	Spring	SAND LAKE	RUSK	2353600	361	36	582	83
2002	Spring	JERSEY VALLEY LAKE	VERNON	1191600	338	82	93	26
1992	Spring	LAC LA BELLE	WAUKESHA	848800	47	47	1483	992
2004	Spring	KANGAROO LAKE	DOOR	98600	51	18	356	284
2006	Spring	ELKHART LAKE	SHEBOYGAN	59300	20	15	217	15
1979	Spring	COMSTOCK LAKE	MARQUETTE	155570	20	3	365	74
1985	Spring	LAKE EMILY	DODGE	161600	317	44	556	336
1979	Spring	LAKE MONTELLO	MARQUETTE	164300	695	100	139	59
1991	Spring	LOON LAKE	SHAWANO	323800	83	11	282	73
1981	Spring	PENSAUKEE LAKE	SHAWANO	415000	75	33	112	52
1992	Spring	ARCHIBALD LAKE	OCONTO	417400	143	98	199	144
1988	Spring	MACHICKANEE FLOWAGE	OCONTO	448200	53	33	216	169

1983	Spring	HIGH FALLS RESERVOIR	MARINETTE	540600	22	7	302	192
1990	Spring	KEYES LAKE	FLORENCE	672900	70	19	190	107
1990	Spring	FAY LAKE	FLORENCE	677100	95	10	174	101
1984	Spring	WABASSO LAKE	VILAS	2045000	55	10	1126	430
1974	Spring	BEAVER DAM LAKE	BARRON	2081200	57	41	315	184
1978	Spring	LONG LAKE	WASHBURN	2106800	38	11	513	96
1967	Spring	SALEM LAKE	TAYLOR	2165100	42	14	21	16
1961	Spring	MONDEAUX FLOWAGE	TAYLOR	2193300	63	56	207	190
1971	Spring	MONDEAUX FLOWAGE	TAYLOR	2193300	104	28	64	19
1992	Spring	ELK LAKE	PRICE	2240000	37	18	21	14
1992	Spring	DUROY LAKE	PRICE	2240100	21	14	24	18
1990	Spring	WHITCOMB LAKE	PRICE	2266100	155	1	43	2
1986	Spring	BOOT LAKE	IRON	2297800	16	0	74	2
1978	Spring	TEAL LAKE	SAWYER	2417000	70	10	153	70
1978	Spring	LOST LAND LAKE	SAWYER	2418600	708	208	1029	360
1991	Spring	LOWER CLAM LAKE	SAWYER	2429300	98	13	70	13
1976	Spring	HORSESHOE LAKE	WASHBURN	2470000	212	21	37	10
1974	Spring	BIG LAKE	POLK	2615900	116	102	143	138
1973	Spring	WAPOGASSET LAKE	POLK	2618000	148	114	489	164
1983	Spring	BIG SAND LAKE	BURNETT	2676800	193	123	398	217
1969	Spring	TREGO LAKE	WASHBURN	2712000	72	32	176	139
1990	Spring	BLADDER LAKE	BAYFIELD	2756200	73	16	36	33
1979	Spring	WANOKA LAKE	BAYFIELD	2832400	237	96	1728	120

1992	Spring	AMNICON LAKE	DOUGLAS	2858100	210	7	173	20
1970	Spring	LAKE MINNESUING	DOUGLAS	2866200	57	56	28	28
1975	Spring	LAKE OWEN	BAYFIELD	2900200	60	6	24	10
1987	Spring	MINERAL LAKE	ASHLAND	2916900	41	19	53	34
1976	Early Summer	BEECHER LAKE	MARINETTE	617000	90	2	248	66
1975	Early Summer	LAKE RIPLEY	JEFFERSON	809600	44	9	343	95
1982	Early Summer	WELLINGTON LAKE	TAYLOR	1467800	100	0	1012	86
1981	Early Summer	STONE LAKE	PRICE	1513800	17	2	183	25
1973	Early Summer	LITTLE CLAM	ASHLAND	1861100	34	0	64	21
1967	Early Summer	BEAVER DAM LAKE	BARRON	2081200	156	94	232	200
1975	Early Summer	BASS LAKE	PRICE	2243800	18	4	368	225
1972	Early Summer	BASS LAKE	PRICE	2282200	34	2	119	30
1973	Early Summer	EAST TWIN LAKE	ASHLAND	2429000	65	4	21	3
1984	Early Summer	NELSON LAKE	SAWYER	2704200	77	57	287	172
1989	Late Summer	BEAVER DAM LAKE	DODGE	835100	31	1	30	15
1975	Late Summer	YELLOWSTONE LAKE	LAFAYETTE	903700	63	35	208	133
1988	Late Summer	SPIRIT LAKE	TAYLOR	1513000	44	11	60	7
1977	Late Summer	LITTLE KEKEGAMA LAKE	WASHBURN	1861900	137	11	668	85
1970	Late Summer	SPRING LAKE	WASHBURN	1882900	410	38	672	70
1973	Late Summer	LAKE CHETEK	BARRON	2094000	423	150	235	36
1972	Late Summer	BASS LAKE	PRICE	2279800	18	2	51	14
1977	Late Summer	ANTLER LAKE (PINE)	POLK	2449400	90	12	715	53

1970	Late Summer	LEESOME LAKE (BASS)	WASHBURN	2474800	540	65	1076	225
1967	Late Summer	SCOVILS LAKE	WASHBURN	2495900	153	0	384	46
1970	Late Summer	BIG CASEY LAKE	WASHBURN	2709100	263	60	320	71
1978	Late Summer	ANODANTA LAKE	BAYFIELD	2898200	167	5	389	43
1972	Late Summer	BUSKEY LAKE	BAYFIELD	2903800	78	20	489	243
1991	Late Summer	SPILLERBERG LAKE	ASHLAND	2936200	29	14	55	14

APPENDIX B:

Year, Season, Lake, County, Water Body Identification Code, Number of bluegill that are at least stock length (≥ 3 inches) and quality length (≥ 6 inches) sampled during fyke netting surveys, bluegill mean length at age-4 and sample size for populations surveyed in Wisconsin from 1946-2005.

					Fyke Net		Mean Length Age-4	
Year	Season	Lake	County	WBIC	Stock	Quality	(in)	n
2001	Early Summer	SWAMP LAKE	ONEIDA	1522400	253	111	5.4	11
2000	Early Summer	LITTLE RICE LAKE	FOREST	406400	289	213	7.0	28
2002	Early Summer	ELLWOOD LAKE	FLORENCE	650500	205	115	6.7	13
2002	Early Summer	EMILY LAKE	FLORENCE	651600	299	69	6.2	37
1999	Early Summer	WABIKON LAKE	FOREST	556900	64	47	6.5	7
1999	Early Summer	RILEY LAKE	FOREST	557100	188	145	6.6	10
1998	Early Summer	CHEQUAMEGON WATERS FLOWAGE	TAYLOR	2160700	283	247	6.4	9
2003	Early Summer	PINE LAKE	FOREST	406900	451	319	4.4	3
2003	Early Summer	SCATTERED RICE LAKE	FOREST	555200	232	223	6.6	30
2004	Early Summer	LONG LAKE	FLORENCE	677400	276	21	5.9	9
2004	Spring	IOLA LAKE	WAUPACA	278800	468	262	6.4	20
2003	Spring	ERLER LAKE	WASHINGTON	27500	887	726	6.8	26
2000	Spring	PIKE LAKE	WASHINGTON	858300	68	5	7.1	6
2004	Spring	LAKE DEXTER	WOOD	1369900	360	277	7.5	8
1995	Spring	WAUSAU DAM LAKE	MARATHON	1469700	539	490	7.0	13
1999	Spring	LITTLE CEDAR LAKE	WASHINGTON	25100	289	24	5.2	50

2005	Spring	WAUSAU DAM LAKE	MARATHON	1469700	302	201	6.0	33
2005	Spring	PELICAN LAKE	ONEIDA	1579900	267	81	6.9	10
1977	Spring	SILVER LAKE	COLUMBIA	107700	176	26	8.0	1
1991	Spring	LAKE PUCKAWAY	GREEN LAKE	158700	635	427	6.7	30
1981	Spring	HARRIS POND	MARQUETTE	165700	59	17	6.4	13
1993	Spring	WILSON LAKE	SHAWANO	240900	437	0	4.8	5
1990	Spring	WOLF RIVER POND	SHAWANO	322500	600	182	5.7	66
1986	Spring	SHAWANO LAKE	SHAWANO	322800	1335	1034	5.1	10
1991	Spring	LOON LAKE	SHAWANO	323800	282	73	4.4	24
1984	Spring	UPPER RED LAKE	SHAWANO	329900	1202	526	6.6	31
1981	Spring	PENSAUKEE LAKE	SHAWANO	415000	112	52	5.7	15
1983	Spring	PENSAUKEE LAKE	SHAWANO	415000	491	81	5.9	13
1978	Spring	NELLIGAN LAKE	OCONTO	425300	1480	648	6.7	30
1978	Spring	PINE RIDGE LAKE	OCONTO	426100	1714	1520	6.0	1
1981	Spring	SURPRISE LAKE	OCONTO	428100	191	26	4.1	8
1981	Spring	WAUBEE LAKE	OCONTO	439500	103	27	4.8	13
1978	Spring	KELLY LAKE	OCONTO	446600	62	20	4.7	2
1987	Spring	KELLY LAKE	OCONTO	446600	842	351	4.9	46
1987	Spring	WHITE LAKE	OCONTO	447000	747	216	5.6	41
1988	Spring	MACHICKANEE FLOWAGE	OCONTO	448200	216	169	6.4	18
1989	Spring	OCONTO FALLS POND	OCONTO	449300	92	25	6.0	2
1978	Spring	ANDERSON LAKE	OCONTO	458700	153	116	6.1	17
1989	Spring	ANDERSON LAKE	OCONTO	458700	204	162	4.5	8

1979	Spring	WISCOBEE LAKE	OCONTO	481700	487	251	5.1	14
1984	Spring	ONEONTA LAKE	MARINETTE	503300	182	136	7.4	6
1980	Spring	WHITE POTATO LAKE	OCONTO	515100	232	98	6.4	7
1983	Spring	LAKE JULIA	MARINETTE	530400	485	341	4.7	10
1983	Spring	LAKE MARY	MARINETTE	530500	466	243	4.8	12
1990	Spring	SANDSTONE FLOWAGE	MARINETTE	531300	198	1	5.5	1
1983	Spring	HIGH FALLS RESERVOIR	MARINETTE	540600	302	192	6.4	19
1991	Spring	CALDRON FALLS RESERVOIR	MARINETTE	545400	551	50	5.7	25
1978	Spring	WOLF LAKE	MARINETTE	614200	547	39	4.7	47
1989	Spring	BEECHER LAKE	MARINETTE	617000	144	93	5.8	7
1991	Spring	WHITE RAPIDS FLOWAGE	MARINETTE	634300	186	170	7.2	15
1978	Spring	TIMMS LAKE	MARINETTE	639800	276	78	5.8	18
1986	Spring	EMILY LAKE	FLORENCE	651600	470	225	5.3	13
1986	Spring	SEALION LAKE	FLORENCE	672300	107	43	5.7	24
1990	Spring	KEYES LAKE	FLORENCE	672900	190	107	6.2	17
1990	Spring	FAY LAKE	FLORENCE	677100	174	101	5.7	13
1974	Spring	LAKE WAUBESA	DANE	803700	57	37	8.3	4
1973	Spring	LAKE MENDOTA	DANE	805400	26	19	8.3	4
1969	Spring	SEELEY LAKE	SAUK	1275500	86	4	6.2	2
1974	Spring	SPRING LAKE	WASHBURN	1882900	63	19	9.4	4
1961	Spring	WINDIGO LAKE	SAWYER	2046600	64	5	5.2	6
1947	Spring	UPPER VERMILLION LAKE	BARRON	2098800	132	127	7.7	44
1949	Spring	BALSAM LAKE	BARRON	2112800	135	98	6.7	6

1987	Spring	BEARSKULL LAKE	IRON	2265100	50	47	6.5	3
1950	Spring	MASON LAKE	SAWYER	2277200	41	32	6.2	6
1961	Spring	BASS LAKE	PRICE	2279800	171	39	4.6	10
1986	Spring	BOOT LAKE	IRON	2297800	74	2	6.8	5
1981	Spring	MERCER LAKE	IRON	2313600	158	77	5.0	3
1950	Spring	ROUND LAKE	SAWYER	2395600	24	17	5.7	4
1948	Spring	TEAL LAKE	SAWYER	2417000	17	15	5.4	2
1964	Spring	DEROSIER LAKE	WASHBURN	2460900	328	233	4.7	8
1974	Spring	GREEN LAKE	WASHBURN	2467100	74	70	7.5	20
1972	Spring	TRAVERS LAKE	BAYFIELD	2502200	244	23	4.6	15
1984	Spring	STAPLES LAKE	BARRON	2631200	151	149	6.1	3
1965	Spring	SAND LAKE	BARRON	2661100	166	62	5.0	11
1964	Spring	GRENQUIST LAKE	POLK	2669300	289	236	4.3	5
1965	Spring	BURLINGAME LAKE	BURNETT	2671400	321	314	6.0	5
1949	Spring	LIPSETT LAKE	BURNETT	2678100	87	31	5.0	6
1949	Spring	MINONG FLOWAGE (LAKE NANCY)	WASHBURN	2692900	105	101	6.9	1
1959	Spring	BOND LAKE	DOUGLAS	2693700	27	21	4.4	2
1972	Spring	TOTOGATIC FLOWAGE	SAWYER	2703500	29	27	6.2	1
1949	Spring	MIDDLE MCKENZIE LAKE	WASHBURN	2706500	125	54	5.1	6
1965	Spring	DUNN LAKE	WASHBURN	2709800	357	173	5.0	12
1983	Spring	TREGO LAKE	WASHBURN	2712000	3994	818	6.7	23
1950	Spring	LOWER EAU CLAIRE LAKE	DOUGLAS	2741600	139	139	7.2	9
1971	Spring	LOWER EAU CLAIRE LAKE	DOUGLAS	2741600	28	13	6.3	2

1950	Spring	MIDDLE EAU CLAIRE LAKE	BAYFIELD	2742100	187	160	6.2	47
1989	Spring	BONY LAKE	BAYFIELD	2742500	448	285	4.0	14
1950	Spring	ROBINSON LAKE	BAYFIELD	2743300	32	31	5.4	1
1950	Spring	SMITH LAKE	BAYFIELD	2743500	30	26	5.3	5
1972	Spring	REYNARD LAKE	BAYFIELD	2772200	55	50	8.0	1
1978	Spring	ARROWHEAD LAKE	BAYFIELD	2898500	583	217	4.8	12
1989	Early Summer	BEAULIEU LAKE	SHAWANO	182000	100	2	4.3	2
1950	Early Summer	PENSAUKEE LAKE	SHAWANO	415000	356	202	5.4	16
1948	Early Summer	BOOT LAKE	OCONTO	418700	134	121	6.7	3
1979	Early Summer	MCCOMB LAKE	OCONTO	424200	191	18	6.8	9
1979	Early Summer	WAUPEE FLOWAGE	OCONTO	461300	250	195	7.2	14
1948	Early Summer	MAIDEN LAKE	OCONTO	487500	85	74	7.4	15
1978	Early Summer	EAGLE LAKE	MARINETTE	500200	17	16	8.3	8
1949	Early Summer	ELWOOD LAKE	FLORENCE	650500	88	70	7.4	13
1976	Early Summer	LOWER SPRING LAKE	JEFFERSON	820800	224	172	6.0	9
1960	Early Summer	CUSHMAN POND	JEFFERSON	823900	29	9	7.5	3
1960	Early Summer	HULLS LAKE	TAYLOR	1762700	60	48	6.5	3

1975	Early Summer	ELBOW LAKE	WASHBURN	1847000	647	201	5.7	12
1978	Early Summer	FENTON LAKE	WASHBURN	1848400	1282	400	6.6	2
1981	Early Summer	LITTLE CLAM	ASHLAND	1861100	62	47	6.3	36
1978	Early Summer	LOWER DEVILS LAKE	BARRON	1864000	481	21	7.9	5
1975	Early Summer	OAK LAKE	WASHBURN	1871300	416	199	6.8	1
1959	Early Summer	PELICAN LAKE	SAWYER	1873100	36	14	5.7	18
1966	Early Summer	PERCH LAKE	SAWYER	1873500	689	157	4.7	6
1958	Early Summer	PERCH LAKE	SAWYER	1873600	39	10	4.7	3
1964	Early Summer	SPRING LAKE (BRYER LAKE)	BARRON	1882800	196	94	5.0	5
1976	Early Summer	LAKE THIRTY	BARRON	2099900	293	208	6.2	18
1964	Early Summer	GRANITE LAKE	BARRON	2100800	87	69	5.3	5
1978	Early Summer	KEKEGAMA LAKE	WASHBURN	2106200	585	342	6.2	28
1946	Early Summer	MONDEAUX FLOWAGE	TAYLOR	2193300	21	14	7.5	14
1990	Early Summer	MERCER LAKE	IRON	2313600	36	2	4.3	8
1982	Early Summer	CHIPPEWA LAKE	BAYFIELD	2431300	25	1	3.9	6

1949	Early Summer	TIGER CAT FLOWAGE	SAWYER	2435000	104	32	7.6	13
1976	Early Summer	BASS LAKE	BURNETT	2451100	235	116	6.8	28
1978	Early Summer	BASS LAKE	BURNETT	2451200	404	146	4.6	3
1977	Early Summer	BONER LAKE	BURNETT	2454500	613	221	5.3	23
1978	Early Summer	CROOKED LAKE	BURNETT	2459100	696	220	7.0	9
1976	Early Summer	GODFREY LAKE	BURNETT	2466300	737	106	4.5	11
1976	Early Summer	LEACH LAKE	WASHBURN	2474400	118	51	7.2	2
1975	Early Summer	MURRAY LAKE	DOUGLAS	2485000	245	172	6.1	4
1975	Early Summer	NO MAN'S LAKE	WASHBURN	2486300	806	205	6.9	3
1964	Early Summer	OAK LAKE	BURNETT	2486600	49	15	4.0	16
1963	Early Summer	PRINEL LAKE (FROG)	BURNETT	2491500	20	4	4.1	2
1977	Early Summer	PRINEL LAKE (FROG)	BURNETT	2491500	598	113	6.8	56
1975	Early Summer	ROCK LAKE	DOUGLAS	2492900	116	86	7.0	22
1975	Early Summer	SAGINAW LAKE	BURNETT	2494700	784	326	5.1	22
1988	Early Summer	SAND LAKE	WASHBURN	2495200	329	259	5.7	2

1975	Early Summer	SANDHILL LAKE	POLK	2495400	123	32	5.9	5
1975	Early Summer	SCOVILS LAKE	WASHBURN	2495900	472	29	4.0	14
1975	Early Summer	SLEEPY EYE LAKE	WASHBURN	2497400	555	28	4.0	9
1976	Early Summer	WARD LAKE	POLK	2599400	151	40	7.9	2
1957	Early Summer	HALF MOON LAKE	POLK	2621100	22	14	6.7	6
1978	Early Summer	DUNHAM LAKE	BURNETT	2651800	840	163	4.3	20
1977	Early Summer	BURLINGAME LAKE	BURNETT	2671400	390	158	5.9	32
1977	Early Summer	CHICOG LAKE	WASHBURN	2692200	683	53	5.3	25
1978	Early Summer	BEAN LAKE	WASHBURN	2718500	595	78	4.9	9
1965	Early Summer	SPRING LAKE	SAWYER	2724900	87	47	5.0	5
1966	Early Summer	BASS LAKE	BAYFIELD	2733600	213	69	4.9	10
1958	Early Summer	UPPER OX LAKE	DOUGLAS	2744700	28	28	6.0	1
1965	Early Summer	BASS LAKE	BAYFIELD	2754900	193	149	5.2	12
1964	Early Summer	REYNARD LAKE	BAYFIELD	2772200	335	173	8.0	6
1983	Early Summer	PORCUPINE LAKE	BAYFIELD	2896600	291	28	5.5	6

1958	Early Summer	ENGLISH LAKE	ASHLAND	2914800	35	5	5.1	6
1977	Early Summer	SPILLERBURG LAKE	ASHLAND	2936200	366	7	5.9	10
1994	Late Summer	WILSON LAKE	SHAWANO	240900	307	44	5.0	14
1979	Late Summer	LAUTERMAN LAKE	FLORENCE	675200	49	29	7.2	5
1946	Late Summer	LITTLE CLAM L, CENTRAL BRANCH	ASHLAND	1861100	40	30	7.7	2
1977	Late Summer	LITTLE KEKEGAMA LAKE	WASHBURN	1861900	668	85	4.6	11
1976	Late Summer	RIPLEY LAKE	WASHBURN	1877000	482	40	4.6	6
1965	Late Summer	SAWMILL LAKE	WASHBURN	1880200	63	3	4.3	11
1948	Late Summer	SPIDER LAKE	BARRON	1882000	100	44	5.4	29
1978	Late Summer	SPIDER LAKE # 3	WASHBURN	1882300	246	33	5.0	3
1978	Late Summer	SPIDER LAKE # 4	WASHBURN	1882400	292	41	5.0	2
1978	Late Summer	SPIDER LAKE # 5	WASHBURN	1882500	486	129	4.8	13
1954	Late Summer	BEAVER DAM LAKE	BARRON	2081200	251	145	7.4	23
1948	Late Summer	POSKIN LAKE	BARRON	2098000	95	77	6.8	54
1978	Late Summer	POSKIN LAKE	BARRON	2098000	372	205	6.6	16

1978	Late Summer	GRANITE LAKE	BARRON	2100800	66	50	6.6	1
1978	Late Summer	KNUTESON LAKE	SAWYER	2114300	713	259	6.4	11
1977	Late Summer	ANTLER LAKE (PINE)	POLK	2449400	715	53	4.3	18
1977	Late Summer	BASS LAKE (PATTERSON)	WASHBURN	2451900	1948	387	7.5	26
1970	Late Summer	CYCLONE LAKE	WASHBURN	2459800	194	32	5.1	16
1976	Late Summer	GIBSON LAKE	POLK	2465800	511	132	7.4	16
1977	Late Summer	LITTLE BASS LAKE	WASHBURN	2475700	406	79	5.2	21
1976	Late Summer	LITTLE MCGRAW LAKE	BURNETT	2477000	501	94	3.7	16
1977	Late Summer	MCLAIN LAKE	WASHBURN	2481600	437	59	4.8	22
1965	Late Summer	NICABOYNE LAKE (NICAHOYNE)	BURNETT	2486100	227	25	4.4	9
1979	Late Summer	ROONEY LAKE	BURNETT	2493100	554	137	4.1	8
1958	Late Summer	SAND LAKE	POLK	2495000	51	3	7.0	1
1978	Late Summer	SILVER LAKE	WASHBURN	2496900	775	22	4.1	3
1965	Late Summer	SIMMS LAKE	DOUGLAS	2497100	16	7	5.6	5
1974	Late Summer	SIMMS LAKE	DOUGLAS	2497100	18	18	6.2	3

1975	Late Summer	SUNFISH LAKE	WASHBURN	2500100	431	21	3.9	19
1975	Late Summer	TARBERT LAKE	POLK	2501000	385	283	7.6	9
1975	Late Summer	VINCENT LAKE	POLK	2598500	92	79	6.2	17
1979	Late Summer	VIOLA LAKE	BURNETT	2598600	1009	209	4.3	16
1975	Late Summer	LONG LAKE	POLK	2631600	719	438	5.9	6
1958	Late Summer	LOWER CLAM LAKE	BURNETT	2655300	42	17	6.7	1
1976	Late Summer	TAYLOR LAKE	BURNETT	2655900	813	410	6.1	9
1958	Late Summer	UPPER CLAM LAKE	BURNETT	2656200	55	33	6.4	3
1979	Late Summer	LITTLE SAND LAKE	BARRON	2661600	2286	175	5.3	22
1977	Late Summer	BASHAW LAKE	BURNETT	2662400	1260	291	7.5	16
1976	Late Summer	GRENQUIST LAKE	POLK	2669300	795	475	5.3	2
1979	Late Summer	MINERVA LAKE	BURNETT	2670600	669	104	5.6	15
1978	Late Summer	GULL LAKE	BURNETT	2671100	481	91	7.1	2
1958	Late Summer	LOON LAKE	BURNETT	2673500	68	41	5.8	11
1979	Late Summer	LONG LAKE	BURNETT	2674100	899	141	5.3	41

1958	Late Summer	YELLOW LAKE	BURNETT	2675200	26	5	6.4	1
1977	Late Summer	MCGRAW LAKE	BURNETT	2688800	677	33	4.8	10
1948	Late Summer	BOND LAKE	DOUGLAS	2693700	70	46	6.4	26
1978	Late Summer	LOWER MCKENZIE LAKE	WASHBURN	2706300	398	101	5.1	12
1970	Late Summer	BIG CASEY LAKE	WASHBURN	2709100	320	71	4.6	18
1978	Late Summer	DUNN LAKE	WASHBURN	2709800	450	41	6.4	13
1976	Late Summer	DUGAN LAKE	WASHBURN	2714200	748	168	5.9	23
1947	Late Summer	AMNICON LAKE	DOUGLAS	2858100	32	13	7.9	12
1966	Late Summer	AMNICON LAKE	DOUGLAS	2858100	218	34	6.1	9
1966	Late Summer	CISCO LAKE	BAYFIELD	2899200	118	81	5.5	4
1990	Autumn	PRAIRIE LAKE	BARRON	2094100	34	21	5.8	1
1977	Autumn	BASS LAKE	WASHBURN	2451300	444	192	5.2	24
1977	Autumn	BEAR TRACK LAKE	WASHBURN	2452300	545	194	6.9	41
1978	Autumn	PEAR LAKE	WASHBURN	2488200	224	13	4.5	10
1961	Autumn	APPLE RIVER FLOWAGE	POLK	2624200	54	26	4.8	5
1979	Autumn	POKEGAMA LAKE	BURNETT	2657200	103	37	5.7	7
1977	Autumn	LINCOLN LAKE	WASHBURN	2710300	146	32	5.3	17
1992	Spring	ARCHIBALD LAKE	OCONTO	417400	199	144	5.3	19

APPENDIX C:

Year, Season, Lake, County, Water Body Identification Code, Number of bluegill that are at least stock length (≥ 3 inches) and quality length (≥ 6 inches) sampled during electrofishing (boom shocker) surveys, bluegill mean length at age-4 and sample size for populations surveyed in Wisconsin from 1958-2005.

					Boom Shocker		Mean Length Age-4	
Year	Season	Lake	County	WBIC	Stock	Quality	(in)	n
2001	Spring	NEPCO LAKE	WOOD	1389800	87	24	6.6	8
2002	Spring	LAKE SHERWOOD	ADAMS	1377900	79	8	5.5	5
2002	Spring	MASON LAKE	MARQUETTE	175700	92	54	6.2	23
2002	Spring	COLLINS LAKE	PORTAGE	270200	26	2	5.4	6
2004	Spring	GILBERT LAKE	WAUSHARA	186400	295	79	4.0	7
2002	Spring	LAKE EMILY	PORTAGE	189800	91	10	6.2	6
2000	Spring	COLLINS LAKE	PORTAGE	270200	171	31	4.5	22
2000	Spring	LAKE EMILY	PORTAGE	189800	217	138	6.0	4
2000	Spring	LAKE SHERWOOD	ADAMS	1377900	173	49	6.0	9
2000	Spring	BIG BASS LAKE	MARATHON	1405200	211	16	5.1	7
2002	Early Summer	BIG BASS LAKE	MARATHON	1405200	79	3	6.1	9
2001	Early Summer	CUNARD LAKE	ONEIDA	1590000	31	8	5.0	3
2003	Late Summer	SWEDE LAKE	POLK	2500500	305	96	4.7	12
2003	Late Summer	LITTLE BUTTERNUT LAKE	POLK	2640700	97	42	5.3	10
2003	Late Summer	HORSESHOE LAKE	POLK	2470100	189	49	4.4	10
2003	Late Summer	GREEN LAKE	BURNETT	2467200	25	3	4.1	5
2003	Late Summer	DUNN LAKE	WASHBURN	2709800	186	19	3.4	16
2003	Late Summer	CABLE LAKE	WASHBURN	2456100	305	6	3.4	3

2003	Late Summer	BASHAW LAKE	BURNETT	2662400	230	101	5.2	11
2003	Late Summer	BIRCH ISLAND LAKE	BURNETT	2453500	216	26	4.1	3
2003	Late Summer	POTATO LAKE	WASHBURN	2714500	219	90	5.0	12
2003	Late Summer	MUD HEN LAKE	BURNETT	2649500	151	12	3.7	14
2004	Late Summer	CRYSTAL LAKE	SHEBOYGAN	45200	268	57	5.1	18
2004	Late Summer	LITTLE ELKHART LAKE	SHEBOYGAN	46000	159	25	5.9	11
2004	Late Summer	RANDOM LAKE	SHEBOYGAN	30300	272	4	5.8	8
2004	Late Summer	LAKE HURON	WAUSHARA	994900	80	2	4.8	7
2004	Late Summer	BIG LAKE	POLK	2615900	65	13	5.6	5
2004	Late Summer	UPPER TURTLE LAKE	BARRON	2079800	178	26	5.6	10
2004	Late Summer	SILVER LAKE	BARRON	1881100	19	5	3.8	7
2004	Late Summer	BIG MOON LAKE	BARRON	2079000	78	37	5.8	15
2004	Late Summer	MINERVA LAKE	BURNETT	2670600	356	57	4.0	17
2004	Late Summer	NICABOYNE LAKE	BURNETT	2486100	248	76	3.4	18
2004	Late Summer	FISH LAKE	BURNETT	2464500	146	61	3.5	15
2004	Late Summer	BIG SAND LAKE	BURNETT	2676800	63	32	4.2	15
2004	Late Summer	LILY LAKE	BURNETT	2475300	81	32	4.4	10
2005	Late Summer	MOON LAKE	BARRON	1867600	45	0	4.4	11
2005	Late Summer	COON LAKE	POLK	2642000	203	5	7.0	2
2005	Late Summer	BRIDGET LAKE	POLK	2619100	174	80	4.8	10
2003	Autumn	BERRY LAKE	OCONTO	418300	221	5	5.9	2
2003	Autumn	HARPT LAKE	MANITOWOC	84600	41	16	7.4	1
2003	Autumn	APPLE RIVER FLOWAGE	POLK	2624200	518	123	4.8	12
2003	Autumn	LONG TRADE LAKE	POLK	2640500	321	191	6.3	13

2003	Autumn	LONG LAKE	POLK	2478200	104	71	5.9	9
2003	Autumn	IOLA LAKE	WAUPACA	278800	138	23	5.8	10
2003	Autumn	PRAIRIE LAKE	BARRON	2094100	171	47	6.3	5
2003	Autumn	WOLF LAKE	WASHBURN	2046900	98	2	4.7	7
2003	Autumn	ROUND LAKE	BURNETT	2640100	188	93	6.9	15
2004	Autumn	FISH LAKE	WAUSHARA	985000	282	68	4.8	5
2004	Autumn	SAND LAKE	POLK	2495000	98	13	4.8	17
2004	Autumn	SHALLOW LAKE	BARRON	1880600	74	19	4.4	9
2004	Autumn	YELLOW RIVER FLOWAGE	WASHBURN	2681600	54	17	6.6	14
2004	Autumn	LAKE NANCY	WASHBURN	2691500	149	32	4.0	25
2004	Autumn	BIRCH LAKE	WASHBURN	2113000	118	21	4.9	36
2004	Autumn	DECORAH LAKE	JUNEAU	1304600	17	8	6.9	4
2004	Autumn	LAKE CAMELOT	ADAMS	1378100	43	7	6.2	3
2004	Autumn	GOOSE LAKE	ADAMS	103600	50	4	5.4	2
2004	Autumn	PARKER LAKE	ADAMS	106500	30	1	5.4	4
2004	Autumn	ARROWHEAD LAKE	ADAMS	1377700	17	3	6.7	1
2005	Autumn	WARD LAKE	POLK	2599400	66	13	4.0	16
1982	Spring	BEAULIEU LAKE	SHAWANO	182000	37	1	4.4	7
1991	Spring	LOON LAKE	SHAWANO	323800	83	11	4.1	2
1983	Spring	FISH LAKE	DANE	985100	94	29	5.7	14
1981	Spring	SPIRIT LAKE	TAYLOR	1513000	21	19	5.9	4
1959	Spring	NORTH SPIRIT LAKE	TAYLOR	1515200	111	71	6.6	7
1962	Spring	SILVER LAKE	BARRON	1881100	21	20	6.7	14
1981	Spring	WABASSO LAKE	VILAS	2045000	225	83	5.7	21

1982	Spring	KIDNEY LAKE	BARRON	2081700	94	0	5.0	24
1962	Spring	BUTTERNUT LAKE	BARRON	2105800	116	73	5.8	8
1962	Spring	SOUTH HARPER LAKE	TAYLOR	2204100	52	7	5.0	4
1964	Spring	SOUTH HARPER LAKE	TAYLOR	2204100	29	1	4.6	9
1983	Spring	SOUTH HARPER LAKE	TAYLOR	2204100	62	0	3.5	3
1992	Spring	LONG LAKE	PRICE	2239300	70	44	6.7	6
1978	Spring	BASS LAKE	PRICE	2279800	42	1	4.8	2
1985	Spring	BASS LAKE	PRICE	2279800	19	4	4.2	5
1970	Spring	CRYSTAL LAKE	DOUGLAS	2459400	36	12	5.0	3
1976	Spring	HORSESHOE LAKE	WASHBURN	2470000	212	21	3.7	6
1967	Spring	MYSTERY LAKE	BURNETT	2485400	461	212	4.1	4
1965	Spring	RED LAKE	DOUGLAS	2492100	88	51	4.6	13
1971	Spring	ROCK LAKE	DOUGLAS	2492900	61	34	6.1	16
1966	Spring	SLEEPY EYE LAKE	WASHBURN	2497400	20	10	5.4	7
1972	Spring	TOMAHAWK LAKE	BAYFIELD	2501700	40	9	5.3	1
1963	Spring	ECHO LAKE	BARRON	2630200	162	107	4.7	11
1966	Spring	STAPLES LAKE	BARRON	2631200	339	206	6.4	11
1981	Spring	STAPLES LAKE	BARRON	2631200	48	47	6.6	22
1987	Spring	LOON LAKE	BURNETT	2671200	348	68	4.1	18
1966	Spring	AUSTIN LAKE	BURNETT	2675700	109	19	5.4	2
1982	Spring	TREGO LAKE	WASHBURN	2712000	27	21	8.7	1
1963	Spring	PACWAWONG LAKE	SAWYER	2728700	74	51	5.6	4
1966	Spring	CABLE LAKE	BAYFIELD	2729700	136	80	5.4	11
1971	Spring	TAYLOR LAKE	BAYFIELD	2734100	114	17	5.2	3

1965	Spring	LOWER EAU CLAIRE LAKE	DOUGLAS	2741600	80	62	5.4	6
1963	Spring	BONY LAKE	BAYFIELD	2742500	28	12	4.8	3
1972	Spring	ANGUS LAKE	BAYFIELD	2754400	41	2	3.8	2
1971	Spring	BLADDER LAKE	BAYFIELD	2756200	166	114	6.2	13
1987	Spring	EAST TWIN LAKE	BAYFIELD	2761000	114	5	3.9	15
1984	Spring	LAKE RUTH	BAYFIELD	2765900	24	13	5.5	5
1964	Spring	LAKE MINNESUING	DOUGLAS	2866200	70	65	5.2	2
1970	Spring	LAKE MINNESUING	DOUGLAS	2866200	57	56	6.4	4
1978	Spring	CISCO LAKE	BAYFIELD	2899200	191	6	4.1	4
1960	Early Summer	PARK LAKE	COLUMBIA	180300	27	13	7.1	1
1978	Early Summer	WHITE LAKE	OCONTO	447000	27	7	6.6	1
1965	Early Summer	TOWNSEND FLOWAGE	OCONTO	465000	36	11	5.8	9
1965	Early Summer	RESERVOIR POND	OCONTO	466700	20	5	4.4	5
1965	Early Summer	BIG GILLETT LAKE	OCONTO	486400	16	8	4.8	1
1967	Early Summer	STORRS LAKE	ROCK	780300	41	6	6.0	4
1964	Early Summer	SPIRIT LAKE	TAYLOR	1513000	61	43	6.5	22
1966	Early Summer	CYCLE LAKE	ASHLAND	1842900	27	0	3.9	12
1962	Early Summer	MITCHELL LAKE	BARRON	1867100	71	9	6.4	7
1962	Early Summer	ROUND LAKE	BARRON	1878400	134	31	5.8	24
1960	Early Summer	WINDIGO LAKE	SAWYER	2046600	41	6	4.6	5
1962	Early Summer	LAKE THIRTY	BARRON	2099900	168	36	3.9	8
1964	Early Summer	SHEARER LAKE	TAYLOR	2197600	18	4	4.4	3
1964	Early Summer	WILSON LAKE	SAWYER	2420000	16	8	5.8	12
1960	Early Summer	TIGER CAT FLOWAGE	SAWYER	2435000	57	22	4.5	2

1966	Early Summer	BEAR TRACK LAKE	WASHBURN	2452300	107	4	5.0	12
1971	Early Summer	GEORGE LAKE	BAYFIELD	2465700	101	25	4.9	2
1966	Early Summer	HILDEBRAND LAKE	BAYFIELD	2469300	49	0	4.1	15
1966	Early Summer	MCLAIN LAKE	WASHBURN	2481600	151	6	4.3	9
1960	Early Summer	PICKEREL LAKE	DOUGLAS	2489100	28	19	4.8	7
1962	Early Summer	RED LAKE	DOUGLAS	2492100	137	44	4.0	5
1966	Early Summer	DEER LAKE	POLK	2619400	231	88	7.2	7
1987	Early Summer	DEER LAKE	POLK	2619400	190	112	4.3	5
1966	Early Summer	LONG LAKE	POLK	2631600	239	31	4.9	17
1966	Early Summer	MUD HEN LAKE	BURNETT	2649500	335	132	4.4	11
1966	Early Summer	SAND LAKE	BURNETT	2664900	231	15	3.3	13
1970	Early Summer	CRANBERRY LAKE	DOUGLAS	2693100	208	141	5.1	1
1967	Early Summer	BIG BEAR LAKE	BURNETT	2705700	247	19	3.8	1
1965	Early Summer	PERRY LAKE	BAYFIELD	2730800	142	50	3.8	3
1963	Early Summer	NORTH TWIN LAKE	BAYFIELD	2731800	49	13	5.1	2
1974	Early Summer	ROBINSON LAKE	BAYFIELD	2743300	90	29	5.4	8
1960	Early Summer	SPIDER LAKE	BAYFIELD	2876200	83	53	6.8	3
1966	Early Summer	STAR LAKE	BAYFIELD	2898400	178	102	4.9	1
1965	Early Summer	WEST TWIN LAKE	ASHLAND	2935700	16	0	4.5	1
1965	Early Summer	EAST TWIN LAKE	ASHLAND	2935800	20	0	4.3	1
1992	Late Summer	PENSAUKEE LAKE	SHAWANO	415000	172	29	5.7	11
1978	Late Summer	SURPRISE LAKE	OCONTO	428100	49	8	5.4	10
1981	Late Summer	LAKE MARY	MARINETTE	530500	168	39	5.3	7
1982	Late Summer	CALDRON FALLS	MARINETTE	545400	222	84	6.4	8

		RESERVOIR						
1978	Late Summer	BACK LAKE	MARINETTE	583700	69	3	4.7	17
1980	Late Summer	LAKE WAUBESA	DANE	803700	95	68	8.2	1
1983	Late Summer	LAKE WAUBESA	DANE	803700	16	11	9.0	2
1982	Late Summer	LAKE MONONA	DANE	804600	90	26	8.7	1
1983	Late Summer	LAKE MONONA	DANE	804600	55	33	8.8	2
1981	Late Summer	LAKE WINGRA	DANE	805000	81	38	6.6	14
1982	Late Summer	LAKE WINGRA	DANE	805000	143	79	7.2	3
1981	Late Summer	BECKMAN LAKE	GREEN	894700	61	9	6.3	2
1962	Late Summer	WELLINGTON LAKE	TAYLOR	1467800	21	10	6.5	5
1966	Late Summer	DIAMOND LAKE	TAYLOR	1757200	17	1	8.6	1
1963	Late Summer	SACKETT LAKE	TAYLOR	1764500	29	11	5.6	1
1992	Late Summer	BASS LAKE	BURNETT	1833300	222	46	5.3	19
1962	Late Summer	JOHNSON LAKE	SAWYER	1856700	275	9	4.3	7
1992	Late Summer	SHALLOW LAKE	WASHBURN	1880600	186	77	4.1	9
1966	Late Summer	LAKE MONTANIS	BARRON	2103200	259	168	5.5	6
1961	Late Summer	BUTTERNUT LAKE	BARRON	2105800	31	18	6.8	10
1992	Late Summer	KEKEGAMA LAKE	WASHBURN	2106200	117	56	4.9	21
1984	Late Summer	BIRCH LAKE	WASHBURN	2113000	371	98	5.8	26
1963	Late Summer	SOUTH HARPER LAKE	TAYLOR	2204100	36	1	4.4	6
1963	Late Summer	WILSON LAKE	PRICE	2239400	43	39	7.0	3
1989	Late Summer	TUCKER LAKE	PRICE	2269000	45	29	6.6	17
1989	Late Summer	MERCER LAKE	IRON	2313600	41	4	4.4	12
1962	Late Summer	ISLAND LAKE	SAWYER	2381800	43	2	4.3	9

1962	Late Summer	LORETTA LAKE	SAWYER	2382700	35	12	7.3	9
1958	Late Summer	SISSABAGAMA LAKE	SAWYER	2393500	18	14	6.3	9
1965	Late Summer	LITTLE SISSABAGAMA LAKE	SAWYER	2394100	370	20	4.2	6
1988	Late Summer	ANTLER LAKE (PINE)	POLK	2449400	115	4	4.8	2
1992	Late Summer	ANTLER LAKE (PINE)	POLK	2449400	172	3	4.5	24
1963	Late Summer	BEAR TRACK LAKE	WASHBURN	2452300	88	12	4.4	8
1990	Late Summer	CROOKED LAKE	BURNETT	2459200	75	12	4.0	22
1973	Late Summer	CRYSTAL LAKE	DOUGLAS	2459400	113	29	6.1	1
1966	Late Summer	LEESOME LAKE (BASS)	WASHBURN	2474800	392	144	4.7	11
1986	Late Summer	LEISURE LAKE (SKUNK)	WASHBURN	2475000	316	14	5.0	25
1992	Late Summer	LILY LAKE	BURNETT	2475300	253	168	4.6	10
1981	Late Summer	LITTLE BEAR LAKE	BURNETT	2476000	444	88	4.5	2
1963	Late Summer	LITTLE SAND LAKE	WASHBURN	2477700	22	3	5.1	4
1982	Late Summer	MALLARD LAKE	BURNETT	2480800	202	15	3.3	8
1970	Late Summer	MYSTERY LAKE	BURNETT	2485400	250	32	4.0	16
1963	Late Summer	PICKEREL LAKE	BAYFIELD	2489200	97	1	5.1	16
1983	Late Summer	POPLAR LAKE	POLK	2491000	84	4	3.7	3
1963	Late Summer	PRINEL LAKE (FROG)	BURNETT	2491500	224	0	2.5	2
1983	Late Summer	ROONEY LAKE	BURNETT	2493100	390	37	3.8	9
1981	Late Summer	SCOVILS LAKE	WASHBURN	2495900	403	7	3.5	10
1962	Late Summer	TOMAHAWK LAKE	BAYFIELD	2501700	52	18	4.9	5
1983	Late Summer	TOZER LAKE	WASHBURN	2502000	605	7	3.8	12
1983	Late Summer	BIG LAKE	POLK	2615900	57	18	5.0	9

1984	Late Summer	NORTH TWIN LAKE	POLK	2623900	107	2	3.9	7
1983	Late Summer	PIKE LAKE	POLK	2624000	105	6	4.1	7
1990	Late Summer	MUD HEN LAKE	BURNETT	2649500	192	60	4.6	25
1964	Late Summer	SPIRIT LAKE	BURNETT	2650300	70	15	4.8	2
1987	Late Summer	MCKENZIE LAKE	POLK	2667300	144	82	4.7	3
1989	Late Summer	TWENTYSIX LAKE	BURNETT	2672500	316	53	3.6	13
1963	Late Summer	LONG LAKE	BURNETT	2674100	22	9	4.1	4
1991	Late Summer	DES MOINES LAKE	BURNETT	2674200	171	28	4.1	15
1965	Late Summer	WARNER LAKE	BURNETT	2677200	249	6	4.1	6
1987	Late Summer	YELLOW RIVER FLOWAGE	WASHBURN	2681600	71	18	6.4	4
1984	Late Summer	SPOONER LAKE	WASHBURN	2685200	492	11	4.6	9
1965	Late Summer	BIG CASEY LAKE	WASHBURN	2709100	182	29	4.1	7
1970	Late Summer	BIG CASEY LAKE	WASHBURN	2709100	263	60	4.8	13
1984	Late Summer	BIG CASEY LAKE	WASHBURN	2709100	295	45	3.8	4
1965	Late Summer	MATTHEW LAKE	WASHBURN	2710800	234	152	7.7	7
1966	Late Summer	MIDDLE EAU CLAIRE LAKE	BAYFIELD	2742100	81	35	5.9	2
1963	Late Summer	ENGLISH LAKE	ASHLAND	2914800	37	17	4.9	2
1990	Late Summer	RASPBERRY LAKE	DODGE	9320006	87	7	5.0	6
1981	Autumn	LEGEND LAKE	MENOMINEE	339800	176	12	4.7	11
1973	Autumn	UPPER MUD LAKE	DANE	804000	19	14	8.8	1
1984	Autumn	LAKE WINGRA	DANE	805000	196	66	7.1	2
1960	Autumn	FISH LAKE	DANE	985100	159	15	5.8	10
1964	Autumn	PERCH LAKE	SAWYER	1873600	85	10	4.6	11
1965	Autumn	WINDIGO LAKE	SAWYER	2046600	16	7	5.1	1

1966	Autumn	UPPER TURTLE LAKE	BARRON	2079800	319	61	6.8	9
1968	Autumn	POKEGAMA LAKE	BARRON	2094300	318	66	7.2	4
1965	Autumn	SQUAW LAKE	SAWYER	2395100	18	5	5.9	5
1965	Autumn	BLACK LAKE (BIRCH LAKE)	SAWYER	2401300	119	60	5.6	14
1963	Autumn	INDIAN LAKE	SAWYER	2448700	121	33	4.5	4
1963	Autumn	BIG BASS LAKE	WASHBURN	2453300	82	44	5.1	5
1965	Autumn	LITTLE SAND LAKE	WASHBURN	2477700	138	31	7.2	8
1968	Autumn	MYSTERY LAKE	BURNETT	2485400	423	194	4.7	25
1973	Autumn	PIGEON LAKE	BAYFIELD	2489400	143	78	5.6	3
1964	Autumn	ROONEY LAKE	BURNETT	2493100	185	31	4.9	5
1962	Autumn	SAND BAR LAKE	BAYFIELD	2494900	22	11	5.0	2
1987	Autumn	SAND LAKE	WASHBURN	2495200	182	174	6.4	16
1965	Autumn	VIOLA LAKE	BURNETT	2598600	264	86	4.3	9
1964	Autumn	HALF MOON LAKE	POLK	2621100	17	11	7.6	1
1965	Autumn	BONE LAKE	POLK	2628100	68	43	6.4	12
1991	Autumn	ROUND LAKE	BURNETT	2640100	190	53	6.7	8
1977	Autumn	HANSCOM LAKE	BURNETT	2674000	252	99	6.3	24
1964	Autumn	MIDDLE MCKENZIE LAKE	WASHBURN	2706500	146	87	5.7	19
1966	Autumn	LOON LAKE	WASHBURN	2709400	276	89	4.5	5
1976	Autumn	WHALEN LAKE	WASHBURN	2715900	214	72	4.3	9
1961	Autumn	SMITH LAKE	SAWYER	2726100	118	113	5.5	6
1978	Autumn	PERCH LAKE	BAYFIELD	2770700	126	11	4.6	8
1968	Autumn	BIG LAKE	POLK	2615900	273	89	7.5	4

APPENDIX D:

Year, Season, Lake, County, Water Body Identification Code, mean length at age-4 (inches), sample size (n), standard deviation (STDEV) and coefficient of variation (CV) estimates of mean length at age-4 for electrofishing (boom shocker) and fyke netting surveys for Wisconsin lakes from 1948-2005.

Survey Year	Season	Lake	County	WBIC	Mean Length	n	STDEV Mean length	CV Mean length	Gear
2004	Spring	IOLA LAKE	WAUPACA	278800	6.4	20	0.492550	0.076424	FYKE NET
2003	Spring	ERLER LAKE	WASHINGTON	27500	6.8	26	0.463847	0.067867	FYKE NET
2000	Spring	PIKE LAKE	WASHINGTON	858300	7.1	6	0.912140	0.128470	FYKE NET
2004	Spring	LAKE DEXTER	WOOD	1369900	7.5	8	0.306769	0.040699	FYKE NET
1995	Spring	WAUSAU DAM LAKE	MARATHON	1469700	7.0	13	0.368295	0.052383	FYKE NET
1999	Spring	LITTLE CEDAR LAKE	WASHINGTON	25100	5.2	50	0.652846	0.126668	FYKE NET
2005	Spring	WAUSAU DAM LAKE	MARATHON	1469700	6.0	33	0.671413	0.112413	FYKE NET
1978	Spring	NELLIGAN LAKE	OCONTO	425300	6.7	30	0.626475	0.093272	FYKE NET
1981	Spring	SURPRISE LAKE	OCONTO	428100	4.1	8	0.225198	0.055263	FYKE NET
1981	Spring	WAUBEE LAKE	OCONTO	439500	4.8	13	0.458537	0.095072	FYKE NET
1961	Spring	BASS LAKE	PRICE	2279800	4.6	10	0.169967	0.036949	FYKE NET
1964	Spring	DEROSIER LAKE	WASHBURN	2460900	4.7	8	0.475094	0.102171	FYKE NET
1965	Spring	SAND LAKE	BARRON	2661100	5.0	11	0.369521	0.073371	FYKE NET
1959	Spring	BOND LAKE	DOUGLAS	2693700	4.4	2	0.494975	0.113787	FYKE NET
1971	Spring	LOWER EAU CLAIRE LAKE	DOUGLAS	2741600	6.3	2	0.494975	0.079196	FYKE NET

2001	Early Summer	SWAMP LAKE	ONEIDA	1522400	5.4	11	0.412311	0.076354	FYKE NET
2000	Early Summer	LITTLE RICE LAKE	FOREST	406400	7.0	28	0.446073	0.063498	FYKE NET
2002	Early Summer	ELLWOOD LAKE	FLORENCE	650500	6.7	13	0.421384	0.063256	FYKE NET
2002	Early Summer	EMILY LAKE	FLORENCE	651600	6.2	37	0.624211	0.101297	FYKE NET
1999	Early Summer	WABIKON LAKE	FOREST	556900	6.5	7	0.325137	0.049802	FYKE NET
1999	Early Summer	RILEY LAKE	FOREST	557100	6.6	10	0.255821	0.038702	FYKE NET
1998	Early Summer	CHEQUAMEGON WATERS FLOWAGE	TAYLOR	2160700	6.4	9	0.703760	0.109204	FYKE NET
2003	Early Summer	PINE LAKE	FOREST	406900	4.4	3	0.230940	0.052092	FYKE NET
2003	Early Summer	SCATTERED RICE LAKE	FOREST	555200	6.6	30	0.508502	0.076736	FYKE NET
2004	Early Summer	LONG LAKE	FLORENCE	677400	5.9	9	0.223607	0.037899	FYKE NET
2005	Early Summer	PELICAN LAKE	ONEIDA	1579900	6.9	10	0.405654	0.059047	FYKE NET
1979	Early Summer	MCCOMB LAKE	OCONTO	424200	6.8	9	0.366667	0.054098	FYKE NET
1976	Early Summer	LOWER SPRING LAKE	JEFFERSON	820800	6.0	9	0.210819	0.035007	FYKE NET
1960	Early Summer	HULLS LAKE	TAYLOR	1762700	6.5	3	0.305505	0.047243	FYKE NET
1959	Early Summer	PELICAN LAKE	SAWYER	1873100	5.7	18	0.478969	0.084524	FYKE NET

1966	Early Summer	PERCH LAKE	SAWYER	1873500	4.7	6	0.209762	0.044630	FYKE NET
1964	Early Summer	GRANITE LAKE	BARRON	2100800	6.3	5	1.156287	0.182957	FYKE NET
1964	Early Summer	OAK LAKE	BURNETT	2486600	4.0	16	0.448516	0.112481	FYKE NET
1957	Early Summer	HALF MOON LAKE	POLK	2621100	6.7	6	0.643169	0.096235	FYKE NET
1958	Early Summer	ENGLISH LAKE	ASHLAND	2914800	5.1	6	0.225832	0.044719	FYKE NET
1965	Late Summer	SAWMILL LAKE	WASHBURN	1880200	4.3	11	0.398406	0.091683	FYKE NET
1954	Late Summer	BEAVER DAM LAKE	BARRON	2081200	7.4	23	0.845121	0.114475	FYKE NET
1965	Late Summer	NICABOYNE LAKE (NICAHOYNE)	BURNETT	2486100	4.4	9	0.374537	0.085991	FYKE NET
1965	Late Summer	SIMMS LAKE	DOUGLAS	2497100	5.6	5	0.476445	0.084777	FYKE NET
1974	Late Summer	SIMMS LAKE	DOUGLAS	2497100	6.2	3	0.057735	0.009362	FYKE NET
1975	Late Summer	LONG LAKE	POLK	2631600	5.9	6	0.768548	0.131003	FYKE NET
1958	Late Summer	UPPER CLAM LAKE	BURNETT	2656200	6.4	3	0.000000	0.000000	FYKE NET
1958	Late Summer	LOON LAKE	BURNETT	2673500	5.8	11	0.207145	0.035771	FYKE NET
1948	Late Summer	BOND LAKE	DOUGLAS	2693700	6.4	26	0.634702	0.098757	FYKE NET
1961	Autumn	APPLE RIVER FLOWAGE	POLK	2624200	4.8	5	0.207364	0.042844	FYKE NET

2001	Spring	NEPCO LAKE	WOOD	1389800	6.6	8	0.333542	0.050825	BOOM SHOCKER
2002	Spring	LAKE SHERWOOD	ADAMS	1377900	5.5	5	0.833667	0.151027	BOOM SHOCKER
2002	Early Summer	BIG BASS LAKE	MARATHON	1405200	6.1	9	0.734847	0.120467	BOOM SHOCKER
2002	Spring	MASON LAKE	MARQUETTE	175700	6.2	23	0.494715	0.079458	BOOM SHOCKER
2002	Spring	COLLINS LAKE	PORTAGE	270200	5.4	6	0.598052	0.110410	BOOM SHOCKER
2003	Late Summer	SWEDE LAKE	POLK	2500500	4.7	12	0.751766	0.160519	BOOM SHOCKER
2003	Autumn	BERRY LAKE	OCONTO	418300	5.9	2	0.212132	0.036262	BOOM SHOCKER
2003	Autumn	LITTLE BUTTERNUT LAKE	POLK	2640700	5.3	10	0.353396	0.067186	BOOM SHOCKER
2003	Late Summer	APPLE RIVER FLOWAGE	POLK	2624200	4.8	12	0.708177	0.147026	BOOM SHOCKER
2003	Late Summer	LONG TRADE LAKE	POLK	2640500	6.3	13	0.386138	0.061367	BOOM SHOCKER
2003	Summer	LONG LAKE	POLK	2478200	5.9	9	0.526783	0.089793	BOOM SHOCKER
2003	Autumn	HORSESHOE LAKE	POLK	2470100	4.4	10	0.663409	0.149754	BOOM SHOCKER
2003	Autumn	IOLA LAKE	WAUPACA	278800	5.8	10	0.489444	0.084679	BOOM SHOCKER
2003	Autumn	PRAIRIE LAKE	BARRON	2094100	6.3	5	0.054772	0.008639	BOOM SHOCKER
2003	Late Summer	GREEN LAKE	BURNETT	2467200	4.1	5	0.204939	0.049742	BOOM SHOCKER

2003	Autumn	WOLF LAKE	WASHBURN	2046900	4.7	7	0.291139	0.061757	BOOM SHOCKER
2003	Summer Late	DUNN LAKE	WASHBURN	2709800	3.4	16	0.703533	0.205787	BOOM SHOCKER
2003	Summer Late	CABLE LAKE	WASHBURN	2456100	3.4	3	0.264575	0.077816	BOOM SHOCKER
2003	Summer Late	BASHAW LAKE	BURNETT	2662400	5.2	11	0.272363	0.052654	BOOM SHOCKER
2003	Summer Late	BIRCH ISLAND LAKE	BURNETT	2453500	4.1	3	0.115470	0.028394	BOOM SHOCKER
2003	Summer Late	POTATO LAKE	WASHBURN	2714500	5.0	12	0.540763	0.108514	BOOM SHOCKER
2003	Summer	MUD HEN LAKE	BURNETT	2649500	3.7	14	0.309288	0.083110	BOOM SHOCKER
2003	Autumn Late	ROUND LAKE	BURNETT	2640100	6.9	15	0.668545	0.096240	BOOM SHOCKER
2004	Summer Late	CRYSTAL LAKE	SHEBOYGAN	45200	5.1	18	0.766304	0.149119	BOOM SHOCKER
2004	Summer Late	LITTLE ELKHART LAKE	SHEBOYGAN	46000	5.9	11	0.687155	0.117008	BOOM SHOCKER
2004	Summer Late	RANDOM LAKE	SHEBOYGAN	30300	5.8	8	0.469042	0.081572	BOOM SHOCKER
2004	Summer	LAKE HURON	WAUSHARA	994900	4.8	7	0.680336	0.143014	BOOM SHOCKER
2004	Autumn	FISH LAKE	WAUSHARA	985000	4.8	5	0.531977	0.109913	BOOM SHOCKER
2004	Spring	GILBERT LAKE	WAUSHARA	186400	4.0	7	0.321455	0.080364	BOOM SHOCKER
2004	Autumn	SAND LAKE	POLK	2495000	4.8	17	0.572405	0.120432	BOOM SHOCKER

2004	Late Summer	BIG LAKE	POLK	2615900	5.6	5	0.474342	0.084704	BOOM SHOCKER
2004	Late Summer	UPPER TURTLE LAKE	BARRON	2079800	5.6	10	0.279682	0.050303	BOOM SHOCKER
2004	Late Summer	SILVER LAKE	BARRON	1881100	3.8	7	0.467007	0.123360	BOOM SHOCKER
2004	Late Summer	BIG MOON LAKE	BARRON	2079000	5.8	15	0.443149	0.076055	BOOM SHOCKER
2004	Autumn	SHALLOW LAKE	BARRON	1880600	4.4	9	0.338296	0.076499	BOOM SHOCKER
2002	Spring	LAKE EMILY	PORTAGE	189800	6.2	6	0.445720	0.072279	BOOM SHOCKER
2000	Spring	COLLINS LAKE	PORTAGE	270200	4.5	22	0.498483	0.110551	BOOM SHOCKER
2000	Spring	LAKE EMILY	PORTAGE	189800	6.0	4	0.411299	0.068265	BOOM SHOCKER
2000	Spring	LAKE SHERWOOD	ADAMS	1377900	6.0	9	0.504425	0.084383	BOOM SHOCKER
2001	Early Summer	CUNARD LAKE	ONEIDA	1590000	5.0	3	0.493288	0.099320	BOOM SHOCKER
2004	Late Summer	MINERVA LAKE	BURNETT	2670600	4.0	17	0.220127	0.055439	BOOM SHOCKER
2000	Spring	BIG BASS LAKE	MARATHON	1405200	5.1	7	0.519157	0.100947	BOOM SHOCKER
2004	Late Summer	NICABOYNE LAKE	BURNETT	2486100	3.4	18	0.372590	0.108521	BOOM SHOCKER
2004	Autumn	YELLOW RIVER FLOWAGE	WASHBURN	2681600	6.6	14	0.411109	0.062155	BOOM SHOCKER
2004	Late Summer	FISH LAKE	BURNETT	2464500	3.5	15	0.415417	0.120063	BOOM SHOCKER

2004	Late Summer	BIG SAND LAKE	BURNETT	2676800	4.2	15	0.655599	0.157849	BOOM SHOCKER
2004	Autumn	LAKE NANCY	WASHBURN	2691500	4.0	25	0.531507	0.132216	BOOM SHOCKER
2004	Autumn	BIRCH LAKE	WASHBURN	2113000	4.9	36	0.789148	0.160052	BOOM SHOCKER
2004	Late Summer	LILY LAKE	BURNETT	2475300	4.4	10	0.466190	0.105473	BOOM SHOCKER
2004	Autumn	DECORAH LAKE	JUNEAU	1304600	6.9	4	0.340343	0.049504	BOOM SHOCKER
2004	Autumn	LAKE CAMELOT	ADAMS	1378100	6.2	3	0.351188	0.056949	BOOM SHOCKER
2004	Autumn	GOOSE LAKE	ADAMS	103600	5.4	2	0.212132	0.039651	BOOM SHOCKER
2004	Autumn	PARKER LAKE	ADAMS	106500	5.4	4	0.057735	0.010792	BOOM SHOCKER
2005	Autumn	WARD LAKE	POLK	2599400	4.0	16	0.401456	0.101314	BOOM SHOCKER
2005	Late Summer	MOON LAKE	BARRON	1867600	4.4	11	0.370012	0.084268	BOOM SHOCKER
2005	Late Summer	COON LAKE	POLK	2642000	7.0	2	0.282843	0.040406	BOOM SHOCKER
2005	Late Summer	BRIDGET LAKE	POLK	2619100	4.8	10	0.343188	0.071497	BOOM SHOCKER
1965	Early Summer	RESERVOIR POND	OCONTO	466700	4.4	5	0.336155	0.077100	BOOM SHOCKER
1962	Late Summer	WELLINGTON LAKE	TAYLOR	1467800	6.5	5	0.334664	0.051646	BOOM SHOCKER
1964	Early Summer	SPIRIT LAKE	TAYLOR	1513000	6.5	22	0.662737	0.102389	BOOM SHOCKER

1981	Spring	SPIRIT LAKE	TAYLOR	1513000	5.9	4	0.386221	0.065740	BOOM SHOCKER
1959	Spring	NORTH SPIRIT LAKE	TAYLOR	1515200	6.6	7	0.564843	0.085213	BOOM SHOCKER
1992	Late Summer	BASS LAKE	BURNETT	1833300	5.3	19	0.331486	0.062421	BOOM SHOCKER
1966	Early Summer	CYCLE LAKE	ASHLAND	1842900	3.9	12	0.197523	0.050755	BOOM SHOCKER
1962	Early Summer	ROUND LAKE	BARRON	1878400	5.8	24	0.971095	0.167551	BOOM SHOCKER
1961	Late Summer	BUTTERNUT LAKE	BARRON	2105800	6.8	10	0.352924	0.051673	BOOM SHOCKER
1962	Spring	BUTTERNUT LAKE	BARRON	2105800	5.8	8	0.406202	0.070338	BOOM SHOCKER
1962	Spring	SOUTH HARPER LAKE	TAYLOR	2204100	5.0	4	0.331662	0.067003	BOOM SHOCKER
1964	Spring	SOUTH HARPER LAKE	TAYLOR	2204100	4.6	9	0.822260	0.179185	BOOM SHOCKER
1983	Spring	SOUTH HARPER LAKE	TAYLOR	2204100	3.5	3	0.305505	0.088126	BOOM SHOCKER
1992	Spring	LONG LAKE	PRICE	2239300	6.7	6	0.768765	0.115604	BOOM SHOCKER
1978	Spring	BASS LAKE	PRICE	2279800	4.8	2	0.212132	0.044659	BOOM SHOCKER
1985	Spring	BASS LAKE	PRICE	2279800	4.2	5	0.212132	0.050508	BOOM SHOCKER
1970	Spring	CRYSTAL LAKE	DOUGLAS	2459400	5.0	3	0.300000	0.060000	BOOM SHOCKER
1967	Spring	MYSTERY LAKE	BURNETT	2485400	4.1	4	0.403113	0.098923	BOOM SHOCKER

1966	Spring	SLEEPY EYE LAKE	WASHBURN	2497400	5.4	7	0.279455	0.051888	BOOM SHOCKER
1963	Spring	ECHO LAKE	BARRON	2630200	4.7	11	0.482230	0.103402	BOOM SHOCKER
1966	Spring	STAPLES LAKE	BARRON	2631200	6.5	11	0.402040	0.062026	BOOM SHOCKER
1971	Spring	TAYLOR LAKE	BAYFIELD	2734100	5.2	3	0.300000	0.057692	BOOM SHOCKER
1965	Spring	LOWER EAU CLAIRE LAKE	DOUGLAS	2741600	5.4	6	0.352136	0.065210	BOOM SHOCKER
1984	Spring	LAKE RUTH	BAYFIELD	2765900	5.5	5	0.343511	0.062914	BOOM SHOCKER
1964	Early Summer	SHEARER LAKE	TAYLOR	2197600	4.4	3	0.173205	0.039365	BOOM SHOCKER
1966	Early Summer	BEAR TRACK LAKE	WASHBURN	2452300	5.0	12	0.416697	0.084181	BOOM SHOCKER
1971	Early Summer	GEORGE LAKE	BAYFIELD	2465700	4.9	2	0.212132	0.043739	BOOM SHOCKER
1966	Early Summer	MCLAIN LAKE	WASHBURN	2481600	4.3	9	0.397213	0.091430	BOOM SHOCKER
1960	Early Summer	PICKEREL LAKE	DOUGLAS	2489100	4.8	7	0.482059	0.101030	BOOM SHOCKER
1966	Early Summer	LONG LAKE	POLK	2631600	4.9	17	0.825735	0.168720	BOOM SHOCKER
1966	Early Summer	MUD HEN LAKE	BURNETT	2649500	4.4	11	0.367052	0.082568	BOOM SHOCKER
1966	Early Summer	SAND LAKE	BURNETT	2664900	3.3	13	0.352100	0.105711	BOOM SHOCKER
1963	Early Summer	NORTH TWIN LAKE	BAYFIELD	2731800	5.1	2	0.141421	0.027730	BOOM SHOCKER

1974	Early Summer	ROBINSON LAKE	BAYFIELD	2743300	5.4	8	0.507093	0.094784	BOOM SHOCKER
1960	Early Summer	SPIDER LAKE	BAYFIELD	2876200	6.8	3	0.435890	0.064101	BOOM SHOCKER
1992	Late Summer	KEKEGAMA LAKE	WASHBURN	2106200	4.9	21	0.593577	0.120320	BOOM SHOCKER
1963	Late Summer	SOUTH HARPER LAKE	TAYLOR	2204100	4.4	6	0.250998	0.057701	BOOM SHOCKER
1963	Late Summer	WILSON LAKE	PRICE	2239400	7.0	3	0.300000	0.042857	BOOM SHOCKER
1962	Late Summer	ISLAND LAKE	SAWYER	2381800	4.4	9	0.271314	0.061507	BOOM SHOCKER
1958	Late Summer	SISSABAGAMA LAKE	SAWYER	2393500	6.3	9	0.787401	0.124326	BOOM SHOCKER
1963	Late Summer	BEAR TRACK LAKE	WASHBURN	2452300	4.4	8	0.325137	0.074744	BOOM SHOCKER
1992	Late Summer	LILY LAKE	BURNETT	2475300	4.6	10	0.235938	0.050958	BOOM SHOCKER
1963	Late Summer	PRINEL LAKE (FROG)	BURNETT	2491500	2.5	2	0.141421	0.056569	BOOM SHOCKER
1981	Late Summer	SCOVILS LAKE	WASHBURN	2495900	3.5	10	0.394405	0.112687	BOOM SHOCKER
1962	Late Summer	TOMAHAWK LAKE	BAYFIELD	2501700	4.9	5	0.685565	0.139911	BOOM SHOCKER
1964	Late Summer	SPIRIT LAKE	BURNETT	2650300	4.8	2	0.212132	0.044659	BOOM SHOCKER
1963	Late Summer	LONG LAKE	BURNETT	2674100	4.1	4	0.522813	0.127515	BOOM SHOCKER
1991	Late Summer	DES MOINES LAKE	BURNETT	2674200	4.1	15	0.704948	0.172500	BOOM SHOCKER

1965	Late Summer	WARNER LAKE	BURNETT	2677200	4.1	6	0.187083	0.046193	BOOM SHOCKER
1965	Late Summer	BIG CASEY LAKE	WASHBURN	2709100	4.1	7	0.512696	0.123754	BOOM SHOCKER
1965	Late Summer	MATTHEW LAKE	WASHBURN	2710800	7.7	7	0.446148	0.058157	BOOM SHOCKER
1966	Late Summer	MIDDLE EAU CLAIRE LAKE	BAYFIELD	2742100	5.9	2	0.636396	0.108786	BOOM SHOCKER
1963	Late Summer	ENGLISH LAKE	ASHLAND	2914800	4.9	2	0.353553	0.072898	BOOM SHOCKER
1990	Late Summer	RASPBERRY LAKE	DODGE	9320006	5.0	6	1.256450	0.249626	BOOM SHOCKER
1965	Autumn	SQUAW LAKE	SAWYER	2395100	5.9	5	0.898888	0.153394	BOOM SHOCKER
1963	Autumn	BIG BASS LAKE	WASHBURN	2453300	5.1	5	0.608276	0.119270	BOOM SHOCKER
1965	Autumn	LITTLE SAND LAKE	WASHBURN	2477700	7.2	8	1.072963	0.148251	BOOM SHOCKER
1962	Autumn	SAND BAR LAKE	BAYFIELD	2494900	5.0	2	0.000000	0.000000	BOOM SHOCKER
1965	Autumn	VIOLA LAKE	BURNETT	2598600	4.3	9	0.273861	0.063689	BOOM SHOCKER
1965	Autumn	BONE LAKE	POLK	2628100	6.4	12	0.360555	0.056780	BOOM SHOCKER
1991	Autumn	ROUND LAKE	BURNETT	2640100	6.7	8	0.731803	0.109021	BOOM SHOCKER
1964	Autumn	MIDDLE MCKENZIE LAKE	WASHBURN	2706500	5.7	19	0.735801	0.129447	BOOM SHOCKER
1968	Autumn	BIG LAKE	POLK	2615900	7.5	4	0.818535	0.109871	BOOM SHOCKER

APPENDIX E:

Year, Season, Lake, County, Water Body Identification Code, Gear type (BS = Boom shocker; FN = fyke net), number of bluegill that are at least stock length (≥ 3 inches) and quality length (≥ 6 inches) sampled, mean relative weight ($W_{r\text{-}bar}$), sample size for $W_{r\text{-}bar}$ (n), and standard deviation estimates $W_{r\text{-}bar}$ for surveys in Wisconsin lakes from 1944-2005.

Year	Season	Lake	County	WBIC	Gear Type	S	Q	$W_{r\text{-}bar}$	n $W_{r\text{-}bar}$	σWr
1990	Spring	BEAULIEU LAKE	SHAWANO	182000	FN	196	16	77.851	91	8.347
1991	Spring	BEAULIEU LAKE	SHAWANO	182000	FN	208	16	76.905	88	6.662
1992	Spring	BEAULIEU LAKE	SHAWANO	182000	FN	200	162	75.564	84	12.640
1979	Spring	WANOKA LAKE	BAYFIELD	2832400	FN	1728	120	87.995	116	16.111
1948	Spring	TEAL LAKE	SAWYER	2417000	FN	17	15	101.108	17	14.266
1999	Spring	EAST LAKE FLOWAGE	KENOSHA	739100	BS	27	1	113.178	23	15.872
1999	Spring	LAKE MARY	KENOSHA	743000	BS	85	28	105.944	80	20.440
1999	Spring	COMUS LAKE	WALWORTH	794200	BS	20	14	102.621	20	15.362
1999	Spring	LOWER PHANTOM LAKE	WAUKESHA	765800	BS	92	29	82.467	79	19.005
1999	Spring	GOLDEN LAKE	WAUKESHA	775900	BS	61	22	88.439	61	12.193
2000	Spring	LONG LAKE	WAUSHARA	191100	BS	53	12	87.619	53	14.911
2001	Spring	PINE LAKE	WAUSHARA	196100	BS	5	1	78.501	5	5.321
2005	Spring	PINE LAKE	WAUKESHA	779200	BS	247	201	104.189	239	39.712
1999	Spring	LAKE MARY	KENOSHA	743000	BS	70	21	106.833	65	21.090
1997	Spring	EAGLE SPRING LAKE	WAUKESHA	768600	BS	17	11	55.599	17	41.101
1993	Spring	EAGLE SPRING LAKE	WAUKESHA	768600	BS	34	31	110.393	34	13.635
1999	Spring	COMUS LAKE	WALWORTH	794200	BS	20	14	102.621	20	15.362
1999	Spring	POTTER LAKE	WALWORTH	753800	BS	49	13	112.803	48	23.361
2001	Spring	PINE LAKE	WAUSHARA	196100	FN	104	58	74.900	104	9.012
2004	Spring	PENSAUKEE LAKES	SHAWANO	415000	FN	241	146	82.732	241	8.293

2005	Spring	HILBERT LAKE	MARINETTE	501200	FN	107	62	82.503	107	18.336
1951	Spring	LITTLE MUSKEGO LAKE	WAUKESHA	762700	FN	63	30	132.370	62	11.272
2005	Spring	HIGH FALLS RESERVOIR	MARINETTE	540600	FN	108	61	91.374	108	8.141
2005	Spring	MARION MILLPOND	WAUPACA	294500	FN	82	41	87.378	82	9.319
1989	Early Summer	BEAULIEU LAKE	SHAWANO	182000	FN	100	2	81.708	100	10.953
1988	Early Summer	SAND LAKE	WASHBURN	2495200	FN	329	259	93.610	40	12.490
1945	Early Summer	EAST LAKE	POLK	2616900	FN	207	77	118.106	89	17.923
1945	Early Summer	LITTLE BUTTERNUT LAKE	POLK	2640700	FN	184	177	109.331	95	19.009
1974	Early Summer	LITTLE SAND LAKE	BARRON	2661600	FN	53	34	106.359	52	10.483
1947	Early Summer	LAKE OWEN	BAYFIELD	2900200	FN	39	30	96.848	38	16.138
1946	Early Summer	MONDEAUX FLOWAGE	TAYLOR	2193300	FN	21	14	113.979	20	17.351
1947	Early Summer	HALFWAY LAKE (TWO MILE LAKE)	DOUGLAS	2503500	FN	20	19	80.203	20	6.857
1947	Early Summer	BIG BUTTERNUT LAKE	POLK	2641000	FN	26	21	116.016	26	17.114
1944	Late Summer	WEST TWIN LAKE	BAYFIELD	2832200	FN	43	43	124.434	23	12.684
1947	Late Summer	AMNICON LAKE	DOUGLAS	2858100	FN	32	13	96.871	32	10.706
1946	Late Summer	LITTLE CLAM L, CENTRAL BRANCH	ASHLAND	1861100	FN	40	30	80.150	40	12.200

1948	Late Summer	BOND LAKE	DOUGLAS	2693700	FN	70	46	90.428	70	7.964
1965	Late Summer	LAZY LAKE	COLUMBIA	843400	BS	19	8	126.175	11	15.676
1991	Late Summer	COX HOLLOW	IOWA	1239400	BS	115	57	103.358	39	13.413
1992	Late Summer	COX HOLLOW	IOWA	1239400	BS	45	18	115.649	45	17.225
1992	Late Summer	TWIN VALLEY LAKE	IOWA	1245800	BS	99	53	78.653	99	26.032
2004	Late Summer	SHADOW LAKE	WAUPACA	258600	BS	43	10	83.149	38	8.374
2004	Late Summer	STRATTON LAKE	WAUPACA	259600	BS	46	11	82.405	43	8.783
1960	Autumn	FISH LAKE	DANE	985100	BS	159	15	77.147	53	7.403
2004	Autumn	MARION MILLPOND	WAUPACA	294500	BS	41	15	89.310	40	13.418
2005	Autumn	SPRING LAKE	WAUSHARA	149000	BS	30	7	99.069	27	11.855
2005	Autumn	BIG TWIN LAKE	WAUSHARA	182300	BS	37	8	82.270	34	11.491
2005	Autumn	MILL POND	WAUSHARA	152200	BS	31	19	94.099	31	18.257
2005	Autumn	CLOVERLEAF CHAIN	SHAWANO	299000	BS	84	24	76.965	78	6.598
2005	Autumn	WASHINGTON LAKE	SHAWANO	323700	BS	77	18	84.349	68	7.299
2005	Autumn	SHAWANO LAKE	SHAWANO	322800	BS	33	15	88.491	33	9.542
2005	Autumn	WOLF RIVER POND	SHAWANO	322500	BS	69	36	94.051	68	5.853
2004	Autumn	SCHOOL SECTION LAKE	WAUPACA	283600	BS	45	15	85.344	41	13.709

APPENDIX F:

Year, Season, Lake, County, Water Body Identification Code, number of bluegill that are at least stock length (≥ 3 inches) and quality length (≥ 6 inches) sampled, mean length at age-4 (inches) for Chapter 2.

Season	Year	WBIC	Lake	County	Stock	Quality	Mean length (in)
Spring	2003	27500	ERLER LAKE	WASHINGTON	887	726	6.8
Spring	1982	182000	BEAULIEU LAKE	SHAWANO	37	1	4.4
Spring	2004	186400	GILBERT LAKE	WAUSHARA	295	79	4.0
Spring	2002	189800	LAKE EMILY	PORTAGE	91	10	6.2
Spring	2004	278800	IOLA LAKE	WAUPACA	468	262	6.4
Spring	1986	322800	SHAWANO LAKE	SHAWANO	1335	1034	5.1
Spring	1991	323800	LOON LAKE	SHAWANO	282	73	4.4
Spring	1984	329900	UPPER RED LAKE	SHAWANO	1202	526	6.6
Spring	1981	428100	SURPRISE LAKE	OCONTO	191	26	4.1
Spring	1987	446600	KELLY LAKE	OCONTO	842	351	4.9
Spring	1987	447000	WHITE LAKE	OCONTO	747	216	5.6
Spring	1988	448200	MACHICKANEE FLOWAGE	OCONTO	216	169	6.4
Spring	1989	458700	ANDERSON LAKE	OCONTO	204	162	4.5
Spring	1984	503300	ONEONTA LAKE	MARINETTE	182	136	7.4
Spring	1991	545400	CALDRON FALLS RESERVOIR	MARINETTE	551	50	5.7
Spring	1978	614200	WOLF LAKE	MARINETTE	547	39	4.7
Spring	1989	617000	BEECHER LAKE	MARINETTE	144	93	5.8
Spring	1986	651600	EMILY LAKE	FLORENCE	470	225	5.3
Spring	1986	672300	SEALION LAKE	FLORENCE	107	43	5.7
Spring	1990	672900	KEYES LAKE	FLORENCE	190	107	6.2
Spring	1990	677100	FAY LAKE	FLORENCE	174	101	5.7
Spring	2000	858300	PIKE LAKE	WASHINGTON	68	5	7.1

Spring	2004	1369900	LAKE DEXTER	WOOD	360	277	7.5
Spring	2000	1377900	LAKE SHERWOOD	ADAMS	173	49	6.0
Spring	2001	1389800	NEPCO LAKE	WOOD	87	24	6.6
Spring	1983	2204100	SOUTH HARPER LAKE	TAYLOR	62	0	3.5
Spring	1992	2239300	LONG LAKE	PRICE	70	44	6.7
Spring	1987	2265100	BEARSKULL LAKE	IRON	50	47	6.5
Spring	1986	2297800	BOOT LAKE	IRON	74	2	6.8
Spring	1976	2470000	HORSESHOE LAKE	WASHBURN	212	21	3.7
Spring	1972	2502200	TRAVERS LAKE	BAYFIELD	244	23	4.6
Spring	1983	2712000	TREGO LAKE	WASHBURN	3994	818	6.7
Spring	1989	2742500	BONY LAKE	BAYFIELD	448	285	4.0
Spring	1987	2761000	EAST TWIN LAKE	BAYFIELD	114	5	3.9
Spring	1984	2765900	LAKE RUTH	BAYFIELD	24	13	5.5
Spring	1978	2899200	CISCO LAKE	BAYFIELD	191	6	4.1
Early Summer	2000	406400	LITTLE RICE LAKE	FOREST	289	213	7.0
Early Summer	2003	406900	PINE LAKE	FOREST	451	319	4.4
Early Summer	2003	555200	SCATTERED RICE LAKE	FOREST	232	223	6.6
Early Summer	1999	556900	WABIKON LAKE	FOREST	64	47	6.5
Early Summer	1999	557100	RILEY LAKE	FOREST	188	145	6.6
Early Summer	2002	650500	ELLWOOD LAKE	FLORENCE	205	115	6.7
Early Summer	2004	677400	LONG LAKE	FLORENCE	276	21	5.9
Early Summer	2002	1405200	BIG BASS LAKE	MARATHON	79	3	6.1
Early Summer	2001	1522400	SWAMP LAKE	ONEIDA	253	111	5.4
Early Summer	2005	1579900	PELICAN LAKE	ONEIDA	267	81	6.9

Early Summer	1966	1842900	CYCLE LAKE	ASHLAND	27	0	3.9
Early Summer	1998	2160700	CHEQUAMEGON WATERS FLOWAGE	TAYLOR	283	247	6.4
Early Summer	1976	2466300	GODFREY LAKE	BURNETT	737	106	4.5
Early Summer	1966	2469300	HILDEBRAND LAKE	BAYFIELD	49	0	4.1
Early Summer	1966	2481600	MCLAIN LAKE	WASHBURN	151	6	4.3
Early Summer	1975	2495900	SCOVILS LAKE	WASHBURN	472	29	4.0
Early Summer	1975	2497400	SLEEPY EYE LAKE	WASHBURN	555	28	4.0
Early Summer	1966	2664900	SAND LAKE	BURNETT	231	15	3.3
Late Summer	2004	30300	RANDOM LAKE	SHEBOYGAN	272	4	5.8
Late Summer	2004	46000	LITTLE ELKHART LAKE	SHEBOYGAN	159	25	5.9
Late Summer	1992	415000	PENSAUKEE LAKE	SHAWANO	172	29	5.7
Late Summer	1978	583700	BACK LAKE	MARINETTE	69	3	4.7
Late Summer	1962	1856700	JOHNSON LAKE	SAWYER	275	9	4.3
Late Summer	1977	1861900	LITTLE KEKEGAMA LAKE	WASHBURN	668	85	4.6
Late Summer	2005	1867600	MOON LAKE	BARRON	45	0	4.4
Late Summer	1965	1880200	SAWMILL LAKE	WASHBURN	63	3	4.3
Late Summer	2004	2079000	BIG MOON LAKE	BARRON	78	37	5.8
Late Summer	2004	2079800	UPPER TURTLE LAKE	BARRON	178	26	5.6
Late Summer	1992	2106200	KEKEGAMA LAKE	WASHBURN	117	56	4.9
Late Summer	1984	2113000	BIRCH LAKE	WASHBURN	371	98	5.8
Late Summer	1989	2269000	TUCKER LAKE	PRICE	45	29	6.6
Late Summer	1962	2381800	ISLAND LAKE	SAWYER	43	2	4.3
Late Summer	1965	2394100	LITTLE SISSABAGAMA LAKE	SAWYER	370	20	4.2

Late Summer	1992	2449400	ANTLER LAKE (PINE)	POLK	172	3	4.5
Late Summer	2003	2453500	BIRCH ISLAND LAKE	BURNETT	216	26	4.1
Late Summer	2003	2456100	CABLE LAKE	WASHBURN	305	6	3.4
Late Summer	2004	2464500	FISH LAKE	BURNETT	146	61	3.5
Late Summer	2004	2475300	LILY LAKE	BURNETT	81	32	4.4
Late Summer	1982	2480800	MALLARD LAKE	BURNETT	202	15	3.3
Late Summer	1970	2485400	MYSTERY LAKE	BURNETT	250	32	4.0
Late Summer	1965	2486100	NICABOYNE LAKE (NICAHOYNE)	BURNETT	227	25	4.4
Late Summer	1983	2491000	POPLAR LAKE	POLK	84	4	3.7
Late Summer	1963	2491500	PRINEL LAKE (FROG)	BURNETT	224	0	2.5
Late Summer	1983	2493100	ROONEY LAKE	BURNETT	390	37	3.8
Late Summer	1978	2496900	SILVER LAKE	WASHBURN	775	22	4.1
Late Summer	1975	2500100	SUNFISH LAKE	WASHBURN	431	21	3.9
Late Summer	2003	2500500	SWEDE LAKE	POLK	305	96	4.7
Late Summer	1983	2502000	TOZER LAKE	WASHBURN	605	7	3.8
Late Summer	2004	2615900	BIG LAKE	POLK	65	13	5.6
Late Summer	2005	2619100	BRIDGET LAKE	POLK	174	80	4.8
Late Summer	1984	2623900	NORTH TWIN LAKE	POLK	107	2	3.9
Late Summer	1983	2624000	PIKE LAKE	POLK	105	6	4.1
Late Summer	2003	2640700	LITTLE BUTTERNUT LAKE	POLK	97	42	5.3
Late Summer	2003	2649500	MUD HEN LAKE	BURNETT	151	12	3.7
Late Summer	2003	2662400	BASHAW LAKE	BURNETT	230	101	5.2
Late Summer	1987	2667300	MCKENZIE LAKE	POLK	144	82	4.7
Late Summer	2004	2676800	BIG SAND LAKE	BURNETT	63	32	4.2

Late Summer	1965	2677200	WARNER LAKE	BURNETT	249	6	4.1
Late Summer	1984	2685200	SPOONER LAKE	WASHBURN	492	11	4.6
Late Summer	1984	2709100	BIG CASEY LAKE	WASHBURN	295	45	3.8
Late Summer	2003	2709800	DUNN LAKE	WASHBURN	186	19	3.4
Late Summer	2003	2714500	POTATO LAKE	WASHBURN	219	90	5.0
Autumn	2003	84600	HARPT LAKE	MANITOWOC	41	16	7.4
Autumn	2004	106500	PARKER LAKE	ADAMS	30	1	5.4
Autumn	1964	1873600	PERCH LAKE	SAWYER	85	10	4.6
Autumn	2003	2046900	WOLF LAKE	WASHBURN	98	2	4.7
Autumn	2003	2094100	PRAIRIE LAKE	BARRON	171	47	6.3
Autumn	1978	2488200	PEAR LAKE	WASHBURN	224	13	4.5
Autumn	1987	2495200	SAND LAKE	WASHBURN	182	174	6.4
Autumn	2003	2624200	APPLE RIVER FLOWAGE	POLK	518	123	4.8
Autumn	2003	2640100	ROUND LAKE	BURNETT	188	93	6.9
Autumn	2003	2640500	LONG TRADE LAKE	POLK	321	191	6.3
Autumn	2004	2681600	YELLOW RIVER FLOWAGE	WASHBURN	54	17	6.6
Autumn	1992	417400	ARCHIBALD LAKE	OCONTO	199	144	5.3

APPENDIX G:

Lake, County, Water Body Identification Code, Distance to the nearest urban center (miles), Latitude, Trophic State Index (TSI), Alkalinity (ppm), depth of lake < 20 ft deep (%), Shoreline length (miles), Surface Area (acres), percent sand and percent gravel of Wisconsin lakes for Chapter 2.

WBIC	Lake	County	Distance (miles)	Latitude	TSI	Alkalinity (ppm)	< 20 ft deep	Shoreline length (miles)	Surface Area (Acres)	Sand (%)	Gravel (%)
27500	ERLER LAKE	WASHINGTON	2.359	43.478	44	180	65	0.90	37	5	0
182000	BEAULIEU LAKE	SHAWANO	9.466	44.912	49	17	98	1.00	27	70	5
186400	GILBERT LAKE	WAUSHARA	6.887	44.212	37	129	30	2.60	141	80	10
189800	LAKE EMILY	PORTAGE	9.497	44.470	44	107	40	2.90	105	30	5
278800	IOLA LAKE	WAUPACA	9.618	44.510	47	186	100	4.74	206	40	40
322800	SHAWANO LAKE	SHAWANO	0.000	44.795	49	125	82	16.50	6063	88	0
323800	LOON LAKE	SHAWANO	1.924	44.830	52	51	95	3.50	305	55	10
329900	UPPER RED LAKE	SHAWANO	8.910	44.854	49	165	100	3.00	188	70	12
428100	SURPRISE LAKE	OCONTO	28.300	45.351	44	21	60	1.90	70	20	15
446600	KELLY LAKE	OCONTO	9.575	45.013	42	113	80	3.70	361	65	10
447000	WHITE LAKE	OCONTO	10.893	45.028	38	123	20	1.60	49	90	0
448200	MACHICKANEE FLOWAGE	OCONTO	1.302	44.859	60	107	95	6.20	435	20	0
458700	ANDERSON LAKE	OCONTO	20.132	45.118	46	70	40	2.20	182	70	0
503300	ONEONTA LAKE	MARINETTE	19.345	45.717	44	4	92	1.90	66	25	8
545400	CALDRON FALLS RESERVOIR	MARINETTE	29.857	45.357	47	105	74	22.60	1018	60	15
614200	WOLF LAKE	MARINETTE	23.583	45.419	42	188	25	2.10	73	0	0

617000	BEECHER LAKE	MARINETTE	13.668	45.560	52	90	75	0.70	18	5	5
651600	EMILY LAKE	FLORENCE	13.626	45.875	49	73	88	2.50	191	60	10
672300	SEALION LAKE	FLORENCE	15.326	45.878	35	66	84	3.50	122	35	5
672900	KEYES LAKE	FLORENCE	15.443	45.896	34	49	75	3.20	202	45	45
677100	FAY LAKE	FLORENCE	29.695	45.866	48	88	100	4.30	247	15	30
858300	PIKE LAKE	WASHINGTON	0.059	43.319	48	181	70	3.80	522	20	30
1369900	LAKE DEXTER	WOOD	9.884	44.378	67	40	100	8.00	298	60	20
1377900	LAKE SHERWOOD	ADAMS	8.063	44.204	51	132	92	7.80	246	0	0
1389800	NEPCO LAKE	WOOD	0.000	44.342	49	116	91	21.00	494	95	0
2204100	SOUTH HARPER LAKE	TAYLOR	15.640	45.365	54	13	88	2.00	80	50	40
2239300	LONG LAKE	PRICE	33.363	45.682	51	30	94	11.90	418	60	30
2265100	BEARSKULL LAKE	IRON	29.676	46.002	40	12	73	2.50	77	15	55
2297800	BOOT LAKE	IRON	26.546	46.038	47	40	100	3.90	180	60	15
2470000	HORSESHOE LAKE	WASHBURN	16.417	46.087	39	23	99	3.80	194	92	8
2502200	TRAVERS LAKE	BAYFIELD	26.238	46.403	40	8	100	0.80	20	75	25
2712000	TREGO LAKE	WASHBURN	5.389	45.947	49	73	86	16.90	451	95	0
2742500	BONY LAKE	BAYFIELD	32.512	46.315	33	55	65	2.60	191	68	30
2761000	EAST TWIN LAKE	BAYFIELD	9.542	46.687	44	4	85	1.00	22	80	0
2765900	LAKE RUTH	BAYFIELD	23.967	46.505	39	42	85	1.80	66	29	70
2899200	CISCO LAKE	BAYFIELD	20.959	46.361	40	7	25	2.40	95	20	10

406400	LITTLE RICE LAKE	FOREST	16.778	45.589	61	35	100	14.10	1219	20	7
406900	PINE LAKE	FOREST	17.918	45.661	48	35	100	6.40	1670	40	15
555200	SCATTERED RICE LAKE	FOREST	32.785	45.566	51	68	100	5.30	486	0	0
556900	WABIKON LAKE	FOREST	28.295	45.556	61	98	100	6.60	594	20	10
557100	RILEY LAKE	FOREST	28.769	45.542	44	110	100	2.80	213	40	15
650500	ELLWOOD LAKE	FLORENCE	7.144	45.854	40	98	74	2.10	132	85	10
677400	LONG LAKE	FLORENCE	31.329	45.848	47	100	98	4.80	340	45	4
1405200	BIG BASS LAKE	MARATHON	10.231	44.722	50	70	100	2.00	174	28	7
1522400	SWAMP LAKE	ONEIDA	9.127	45.630	54	25	100	3.50	296	10	5
1579900	PELICAN LAKE	ONEIDA	9.652	45.528	50	39	70	16.00	3585	40	20
1842900	CYCLE LAKE	ASHLAND	24.473	46.088	43	11	97	1.20	37	90	5
2160700	CHEQUAMEGON WATERS FLOWAGE	TAYLOR	15.223	45.201	64	54	85	34.10	2714	40	20
2466300	GODFREY LAKE	BURNETT	21.613	45.728	42	21	80	1.50	56	60	25
2469300	HILDEBRAND LAKE	BAYFIELD	30.426	46.163	46	3	86	0.80	17	5	5
2481600	MCLAIN LAKE	WASHBURN	13.989	46.047	37	20	92	2.00	150	92	3
2495900	SCOVILS LAKE	WASHBURN	20.254	46.127	49	22	80	1.50	66	99	0
2497400	SLEEPY EYE LAKE	WASHBURN	17.810	46.102	48	22	100	1.20	39	70	20
2664900	SAND LAKE	BURNETT	20.953	45.757	46	81	70	1.50	80	80	0
30300	RANDOM LAKE	SHEBOYGAN	7.686	43.559	55	178	100	3.90	209	10	15
46000	LITTLE	SHEBOYGAN	1.819	43.810	43	133	99	2.30	54	10	40

	ELKHART LAKE										
415000	PENSAUKEE LAKE	SHAWANO	7.365	44.818	41	137	97	3.30	109	9	1
583700	BACK LAKE	MARINETTE	10.682	45.614	46	55	90	0.50	11	5	2
1856700	JOHNSON LAKE	SAWYER	22.155	45.909	39	7	85	1.80	62	10	80
1861900	LITTLE KEKEGAMA LAKE	WASHBURN	9.117	45.680	54	8	85	1.10	30	70	10
1867600	MOON LAKE	BARRON	0.000	45.471	44	19	100	1.90	84	40	10
1880200	SAWMILL LAKE	WASHBURN	15.998	45.753	40	5	85	0.80	15	5	0
2079000	BIG MOON LAKE	BARRON	10.478	45.344	50	91	60	2.70	191	80	20
2079800	UPPER TURTLE LAKE	BARRON	10.382	45.408	54	100	80	6.70	438	80	20
2106200	KEKEGAMA LAKE	WASHBURN	8.295	45.655	53	92	79	3.20	110	18	60
2113000	BIRCH LAKE	WASHBURN	12.048	45.661	52	56	40	6.70	368	0	15
2269000	TUCKER LAKE	PRICE	33.898	45.942	39	45	75	1.90	118	3	82
2381800	ISLAND LAKE	SAWYER	28.778	45.889	42	56	70	1.50	67	0	10
2394100	LITTLE SISSABAGAMA LAKE	SAWYER	17.184	45.775	43	11	40	6.70	299	50	40
2449400	ANTLER LAKE (PINE)	POLK	14.274	45.539	48	23	85	2.90	101	40	0
2453500	BIRCH ISLAND LAKE	BURNETT	12.939	45.946	46	30	100	12.01	838	80	0
2456100	CABLE LAKE	WASHBURN	1.204	45.867	50	25	99	2.80	185	65	25
2464500	FISH LAKE	BURNETT	13.093	45.974	41	5	95	4.20	356	92	5

2475300	LILY LAKE	BURNETT	13.285	45.986	51	13	100	2.70	176	50	10
2480800	MALLARD LAKE	BURNETT	13.378	45.900	38	44	70	2.30	113	99	0
2485400	MYSTERY LAKE	BURNETT	10.641	45.960	40	9	50	0.90	26	80	20
2486100	NICABOYNE LAKE (NICAHOYNE)	BURNETT	12.316	45.986	46	53	70	3.80	291	60	10
2491000	POPLAR LAKE	POLK	11.116	45.381	56	45	100	2.30	125	40	0
2491500	PRINEL LAKE (FROG)	BURNETT	15.336	46.033	49	20	100	1.30	64	95	5
2493100	ROONEY LAKE	BURNETT	11.004	45.960	43	25	90	4.10	322	80	5
2496900	SILVER LAKE	WASHBURN	10.344	45.989	41	19	91	3.20	188	61	17
2500100	SUNFISH LAKE	WASHBURN	6.618	45.937	42	15	78	1.90	68	30	33
2500500	SWEDE LAKE	POLK	7.961	45.255	40	20	100	1.80	68	40	20
2502000	TOZER LAKE	WASHBURN	0.964	45.806	39	77	65	1.10	36	90	5
2615900	BIG LAKE	POLK	7.294	45.298	47	96	85	3.40	259	85	5
2619100	BRIDGET LAKE	POLK	6.361	45.383	50	111	100	1.80	95	0	0
2623900	NORTH TWIN LAKE	POLK	0.000	45.312	54	129	100	2.70	135	80	5
2624000	PIKE LAKE	POLK	0.000	45.316	47	130	85	4.20	159	0	0
2640700	LITTLE BUTTERNUT LAKE	POLK	17.491	45.572	61	82	85	2.30	189	45	5
2649500	MUD HEN LAKE	BURNETT	27.034	45.781	45	85	70	4.20	563	60	0
2662400	BASHAW LAKE	BURNETT	11.269	45.767	54	84	100	3.30	171	80	0
2667300	MCKENZIE LAKE	POLK	19.216	45.613	49	118	100	1.60	60	0	0

2676800	BIG SAND LAKE	BURNETT	13.848	45.829	41	46	83	7.60	1400	0	0
2677200	WARNER LAKE	BURNETT	14.908	45.804	42	10	50	3.60	176	90	0
2685200	SPOONER LAKE	WASHBURN	1.933	45.838	56	77	100	11.20	1092	70	19
2709100	BIG CASEY LAKE	WASHBURN	7.080	45.948	46	41	93	3.20	247	28	30
2709800	DUNN LAKE	WASHBURN	6.030	45.944	42	46	48	3.60	193	40	58
2714500	POTATO LAKE	WASHBURN	9.545	45.826	49	95	99	2.70	222	20	20
84600	HARPT LAKE	MANITOWOC	9.486	44.297	46	140	12	0.90	31	5	20
106500	PARKER LAKE	ADAMS	11.157	43.776	42	142	80	1.10	59	89	10
1873600	PERCH LAKE	SAWYER	29.186	45.904	41	4	99	2.30	129	0	40
2046900	WOLF LAKE	WASHBURN	15.439	45.764	42	9	65	2.00	29	40	5
2094100	PRAIRIE LAKE	BARRON	4.910	45.324	64	45	100	16.00	1534	75	5
2488200	PEAR LAKE	WASHBURN	14.090	46.040	46	41	64	1.30	49	67	32
2495200	SAND LAKE	WASHBURN	21.334	46.149	49	18	100	2.50	198	99	0
2624200	APPLE RIVER FLOWAGE	POLK	0.000	45.309	52	126	100	19.30	639	40	10
2640100	ROUND LAKE	BURNETT	24.714	45.666	61	69	80	3.40	204	40	0
2640500	LONG TRADE LAKE	POLK	23.046	45.634	66	67	100	4.20	153	75	5
2681600	YELLOW RIVER FLOWAGE	WASHBURN	0.000	45.820	47	87	100	7.50	344	5	0
417400	ARCHIBALD LAKE	OCONTO	26.726	45.282	40	103	58	9.00	430	50	10

APPENDIX H:

Lake, County, Water Body Identification Code, depth of lake >20ft, depth of lake <3ft, shoreline development index (SDI), drainage area (acres), watershed area (acres) and maximum depth (ft) of Wisconsin lakes used for Chapter 2.

WBIC	Lake	County	> 20ft deep	< 3ft deep	SDI	Drainage area (acres)	Watershed area (acres)	Maximum depth (ft)
182000	BEAULIEU LAKE	SHAWANO	2	20	1.37	1	1	22
322800	SHAWANO LAKE	SHAWANO	18	4	1.51	25	55	42
323800	LOON LAKE	SHAWANO	5	15	1.43	4	10	23
329900	UPPER RED LAKE	SHAWANO	0	30	1.56	3	147	12
415000	PENSAUKEE LAKE	SHAWANO	3	35	2.26	2	2	26
417400	ARCHIBALD LAKE	OCONTO	42	9	3.10	4	4	58
1522400	SWAMP LAKE	ONEIDA	0	65	1.45	4	4	8
428100	SURPRISE LAKE	OCONTO	40	10	1.62	1	1	30
446600	KELLY LAKE	OCONTO	20	10	1.39	2	2	41
447000	WHITE LAKE	OCONTO	80	10	1.63	1	1	49
448200	MACHICKANEE FLOWAGE	OCONTO	5	25	2.12	31	740	23
458700	ANDERSON LAKE	OCONTO	60	10	1.16	1	7	40
503300	ONEONTA LAKE	MARINETTE	8	10	1.67	1	1	24
545400	CALDRON FALLS RESERVOIR	MARINETTE	26	10	5.05	33	482	40
583700	BACK LAKE	MARINETTE	10	8	1.08	1	1	22
614200	WOLF LAKE	MARINETTE	75	5	1.75	1	1	51
617000	BEECHER LAKE	MARINETTE	25	10	1.18	1	8	45
651600	EMILY LAKE	FLORENCE	12	14	1.29	1	3	43
672300	SEALION LAKE	FLORENCE	16	33	2.26	1	3	82
672900	KEYES LAKE	FLORENCE	25	5	1.61	2	2	77
677100	FAY LAKE	FLORENCE	0	25	1.95	2	16	13
1842900	CYCLE LAKE	ASHLAND	3	25	1.41	1	1	23
1856700	JOHNSON LAKE	SAWYER	15	15	1.63	1	1	26
1861900	LITTLE KEKEGAMA LAKE	WASHBURN	15	15	1.43	1	1	21

1873600	PERCH LAKE	SAWYER	1	9	1.45	1	1	24
1880200	SAWMILL LAKE	WASHBURN	15	15	1.47	1	1	26
2106200	KEKEGAMA LAKE	WASHBURN	21	16	2.18	1	4	24
2113000	BIRCH LAKE	WASHBURN	60	5	2.49	2	42	73
2204100	SOUTH HARPER LAKE	TAYLOR	12	20	1.60	1	1	32
2239300	LONG LAKE	PRICE	6	8	4.15	2	152	54
2265100	BEARSKULL LAKE	IRON	27	15	2.03	1	3	27
2269000	TUCKER LAKE	PRICE	25	9	1.25	1	2	32
2297800	BOOT LAKE	IRON	0	15	2.07	1	1	16
2381800	ISLAND LAKE	SAWYER	30	20	1.31	1	1	31
2394100	LITTLE SISSABAGAMA LAKE	SAWYER	60	5	2.77	1	1	75
1389800	NEPCO LAKE	WOOD	9	14	6.74	17	111	29
2449400	ANTLER LAKE (PINE)	POLK	15	15	2.06	1	1	22
2466300	GODFREY LAKE	BURNETT	20	20	1.43	1	1	41
2469300	HILDEBRAND LAKE	BAYFIELD	14	11	1.38	1	1	42
2470000	HORSESHOE LAKE	WASHBURN	1	11	1.95	2	2	21
2480800	MALLARD LAKE	BURNETT	30	15	1.54	1	1	34
2481600	MCLAIN LAKE	WASHBURN	8	7	1.17	1	1	30
2485400	MYSTERY LAKE	BURNETT	50	10	1.26	1	1	51
2486100	NICABOYNE LAKE (NICAHOYNE)	BURNETT	30	15	1.59	2	2	28
2488200	PEAR LAKE	WASHBURN	36	10	1.33	1	1	32
2491000	POPLAR LAKE	POLK	0	20	1.47	2	2	18
2491500	PRINEL LAKE (FROG)	BURNETT	0	40	1.16	1	1	12
2493100	ROONEY LAKE	BURNETT	10	20	1.63	1	1	30
2495200	SAND LAKE	WASHBURN	0	40	1.27	2	2	9
2495900	SCOVILS LAKE	WASHBURN	20	12	1.32	2	2	37

2496900	SILVER LAKE	WASHBURN	9	10	1.67	3	3	28
2497400	SLEEPY EYE LAKE	WASHBURN	0	30	1.37	1	1	10
2500100	SUNFISH LAKE	WASHBURN	22	18	1.64	1	1	33
2502000	TOZER LAKE	WASHBURN	35	9	1.31	1	1	53
2502200	TRAVERS LAKE	BAYFIELD	0	30	1.28	1	1	10
2623900	NORTH TWIN LAKE	POLK	0	25	1.66	1	1	15
2624000	PIKE LAKE	POLK	15	15	2.38	1	1	30
2664900	SAND LAKE	BURNETT	30	30	1.20	1	1	42
2667300	MCKENZIE LAKE	POLK	0	20	1.47	1	1	18
2677200	WARNER LAKE	BURNETT	50	20	1.94	1	1	74
2685200	SPOONER LAKE	WASHBURN	0	11	2.42	12	18	17
2709100	BIG CASEY LAKE	WASHBURN	7	7	1.45	2	11	27
2712000	TREGO LAKE	WASHBURN	14	6	5.68	8	290	36
2742500	BONY LAKE	BAYFIELD	35	9	1.34	1	1	55
2761000	EAST TWIN LAKE	BAYFIELD	15	15	1.52	1	1	22
2765900	LAKE RUTH	BAYFIELD	15	15	1.58	1	1	27
2899200	CISCO LAKE	BAYFIELD	75	3	1.76	1	1	105
406400	LITTLE RICE LAKE	FOREST	0	15	2.88	18	45	10
650500	ELLWOOD LAKE	FLORENCE	26	8	1.30	1	1	25
556900	WABIKON LAKE	FOREST	0	70	1.93	3	6	15
557100	RILEY LAKE	FOREST	0	15	1.37	2	3	12
2160700	CHEQUAMEGON WATERS FLOWAGE	TAYLOR	15	15	4.67	17	135	22
1405200	BIG BASS LAKE	MARATHON	0	13	1.08	1	1	13
2500500	SWEDE LAKE	POLK	0	20	1.56	1	1	20
2640700	LITTLE BUTTERNUT LAKE	POLK	15	15	1.19	2	2	26
406900	PINE LAKE	FOREST	0	20	1.12	8	14	14

84600	HARPT LAKE	MANITOWOC	88	1	1.15	1	1	49
2624200	APPLE RIVER FLOWAGE	POLK	0	20	5.45	6	134	16
555200	SCATTERED RICE LAKE	FOREST	0	5	1.72	17	29	10
2640500	LONG TRADE LAKE	POLK	0	25	2.42	1	45	11
2094100	PRAIRIE LAKE	BARRON	0	5	2.92	13	21	26
2046900	WOLF LAKE	WASHBURN	35	9	2.65	1	1	51
2709800	DUNN LAKE	WASHBURN	52	7	1.85	2	9	39
2456100	CABLE LAKE	WASHBURN	1	9	1.47	2	2	24
2662400	BASHAW LAKE	BURNETT	0	20	1.80	2	19	15
2453500	BIRCH ISLAND LAKE	BURNETT	0	40	2.96	4	4	8
2714500	POTATO LAKE	WASHBURN	1	17	1.29	2	4	20
2649500	MUD HEN LAKE	BURNETT	30	30	1.26	3	5	66
2640100	ROUND LAKE	BURNETT	20	40	1.70	3	51	27
677400	LONG LAKE	FLORENCE	2	5	1.86	10	11	23
46000	LITTLE ELKHART LAKE	SHEBOYGAN	1	10	2.23	2	2	21
30300	RANDOM LAKE	SHEBOYGAN	0	10	1.93	4	4	19
186400	GILBERT LAKE	WAUSHARA	70	2	1.56	2	2	65
2615900	BIG LAKE	POLK	15	15	1.51	2	3	25
2079800	UPPER TURTLE LAKE	BARRON	20	20	2.28	4	4	25
2079000	BIG MOON LAKE	BARRON	40	15	1.39	1	7	46
189800	LAKE EMILY	PORTAGE	60	10	2.02	1	1	36
1377900	LAKE SHERWOOD	ADAMS	8	7	3.55	0	0	27
278800	IOLA LAKE	WAUPACA	0	63	2.36	22	23	9
27500	ERLER LAKE	WASHINGTON	35	4	1.06	1	1	38
858300	PIKE LAKE	WASHINGTON	30	8	1.19	13	15	45
2681600	YELLOW RIVER FLOWAGE	WASHBURN	0	30	2.89	4	37	17
2464500	FISH LAKE	BURNETT	5	40	1.59	2	2	29

2676800	BIG SAND LAKE	BURNETT	17	10	1.45	8	6	55
2475300	LILY LAKE	BURNETT	0	20	1.45	1	1	18
1369900	LAKE DEXTER	WOOD	0	25	3.31	13	210	14
106500	PARKER LAKE	ADAMS	20	15	1.02	1	1	30
1579900	PELICAN LAKE	ONEIDA	30	20	1.91	5	10	39
1867600	MOON LAKE	BARRON	0	20	1.48	1	1	5
2619100	BRIDGET LAKE	POLK	0	25	1.32	1	16	15

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