ILLINOIS NATURAL HISTORY SURVEY

CENTER FOR AQUATIC ECOLOGY

ANNUAL PROGRESS REPORT

OCTOBER 1, 2003 THROUGH SEPTEMBER 30, 2004

QUALITY MANAGEMENT OF BLUEGILL: FACTORS AFFECTING POPULATION SIZE STRUCTURE

M.J. Diana, J. Stein, D.D. Aday, R.W. Oplinger,
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Aquatic Ecology Technical Report 2004/13

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Executive Summary

During the past segment, all activities outlined in the annual work plan were accomplished and within the specified budget. In previous segments, 32 lakes were identified for use in an intensive management experiment (described in job 101.3). These manipulations consist of four treatments across 32 lakes (8 lakes per treatment): control, restrictive harvest regulations, predator stocking, and a combination of restrictive harvest regulations and predator stocking. Treatments have equal representation from regional, lake size, and bluegill size structure classifications of lakes.

In this segment, as part of Job 101.1, creel data was analyzed from 12 lakes surveyed in 2003. These lakes were examined for changes in PQBG 170 (proportion of bluegill over 170 mm). Creel data from 2003 showed little changes in the percent of anglers targeting bluegill at a lake when compared to creel data from before the management experiment. Post manipulation creel surveys were conducted on 12 of the 32 experimental bluegill lakes in 2004. These surveys will be used to compare creel survey results from years prior to implementation of experimental manipulations conducted as a part of Job 101.3. Results of the 2004 creel surveys, completed in October 2004, will be available in the next annual report. We will continue to conduct creel surveys in 2005, which will complete the creel surveys for all 32 lakes in the management experiment. These results will be compared to those collected from historical creel surveys on these lakes.

In Job 101.2, we examine the four factors that determine the size structure of bluegill populations: pre-maturation growth rate, the age at maturation, post-maturation growth rate, and

longevity. In this segment, we conducted two analyses to examine factors influencing the size structure of bluegill in Illinois. The first set included estimates of bluegill growth, maturity, size structure, and lake latitude from 50 lakes throughout the state collected in earlier segments. Field data suggested growth (as indicated by body size at age 5) was a positive predictor of bluegill size structure; mean length of male bluegill at age 5 (MAGE5) was strongly correlated with PSD. Our second analysis included prey estimates on 19 of the original 50 lakes. Prey data included zooplankton and benthic invertebrate densities by taxa. Correlations from the 19 lakes with prey data available revealed that density of Daphnia spp. positively influenced bluegill growth.

We also conducted pond experiments in order to examine the importance of food availability and presence/absence of large adult bluegill in the growth and maturation of juvenile bluegill. Bluegill were placed in ponds with either high or low food and presence or absence of large adult bluegill. Previous analyses examined growth differences, in the current segment we examined the energetic tradeoff between growth and maturation. Length and weight of immature fish that matured were compared to those that remained immature. Across both sexes and all ponds, individuals remaining immature were significantly longer and heavier than those that matured, demonstrating a size cost of maturation. A cost of maturation was also more apparent for juvenile males than juvenile females, and this cost was influenced by the level of resources available.

In Job 101.3, we began the collection of final samples to examine the outcome of the management experiment. Electrofishing was performed on all lakes in the study and bluegill were collected and frozen. These samples will be dissected and examined for maturity status, GSI score, age, and growth. Additional collections of bluegill will be conducted in spring of 2005 to supplement collections made during the past year. This data will then be used in the final analyses of the bluegill management experiment in order to determine the affect of regulations and predator stockings on bluegill population size structure.

We continued our monitoring and assessment of bluegill growth, reproductive characteristics, and age-at-maturation in response to the management manipulations. Data collected throughout the spring and fall of 2003 was used to determine if bluegill size structure had shifted from its condition in previous years. Changes in bluegill population size structure were variable within and among treatments, and little increase in relative abundance of larger sized bluegill was observed in study lakes. We did, however, observe some increases in size in some lakes. Also, lakes that were designated quality at the beginning of the study remained quality populations.

In this segment, we continued to summarize data on the contribution of stocked largemouth bass to existing predator populations. We found that thus far the contribution of stocked largemouth bass was variable across lakes. Stocked largemouth bass are contributing to the natural bass population in most study lakes, but overall population numbers have not shown an increase in a majority of study lakes. Stocking as a management strategy for increasing bluegill growth may not work if the bass population is not successfully increased.

To assess angler compliance, conservation officers conducted interviews on lakes with the experimental regulation imposed. Compliance checks also raise angler awareness of the regulation and the study purpose on the experimental lakes. In the past, compliance checks showed that a large majority of anglers were compliant with the regulation. In this segment, compliance checks were completed on 12 of the 16 lakes receiving the experimental regulation. Overall, compliance was high on most lakes. We plan to continue compliance checks for one additional year and use this information in the final analysis of the experimental regulation.

We examined biotic and abiotic characteristics of the experimental lakes, such as prey resources, predation pressure, and lake-habitat characteristics. Prey resources were examined in order to observe if any changes were occurring in zooplankton or benthos densities during the course of the study that might influence the results of the management experiment. Data collected in the current segment was combined with those from previous ones in order to evaluate if there were any long-term trends. We found some variation in zooplankton and benthos densities across years, however the fluctuation was small and overall densities remained unchanged. In addition, we found no overall differences in prey resources between lakes with stunted and quality populations. These results suggest that macrozooplankton and benthic invertebrates are not expected to cause any changes in bluegill growth rates that will mask any changes in size structure due to the management manipulations.

In Job 101.4, data collected in 2003 - 2004 was entered into the appropriate data sets, analyzed and used to produce the findings in this report.

Job 101.1. Categorization of bluegill populations in Illinois impoundments.

OBJECTIVE

To use existing creel and standardized sampling databases to categorize bluegill populations based on adult size structure.

INTRODUCTION

Bluegill are a key component of Illinois sport fisheries, both serving as an important prey species and providing anglers with harvestable size fish. In Illinois lakes where creel surveys documenting harvest and total catch have been conducted, bluegill were consistently caught and harvested in great numbers. Bluegill are susceptible to high levels of exploitation, which can shift size structures toward populations dominated by small fish (Coble 1988). Size structures of bluegill populations have deteriorated in many lakes within the Midwest over the past 40 years (Drake 1997). Anglers harvest fewer large bluegill from many exploited lakes that now only support large populations of small bluegill and the number of trophy-sized bluegill have also declined across the region (Olsen and Cunningham, 1989).

If we are to manage bluegill populations effectively, we need to understand how exploitation and/or various management activities alter these life-history characteristics. Only by understanding these complex interactions can the success of bluegill regulations and management strategies be predicted and realized effectively.

PROCEDURES

The current year's efforts were designed to use creel surveys, conducted under project F-69-R-17, to evaluate the implementation of various management actions under Job 101.3. Creel surveys were conducted on 12 study lakes each in 2003 and 2004; lakes were selected according to one of four experimental treatments (control, regulation, predator stocking, regulation &

predator stocking; see Table 1-3 and 1-4).

Creel surveys provide a means for measuring changes in fish populations over time. Creel surveys were conducted over the course of several seasons on all study lakes prior to implementation of experimental treatments. These surveys provide baseline information on bluegill population size structure as well as angler success. Creel surveys are conducted from March through October of each year, and results are reported in May of the following year. Therefore, results from creel surveys on bluegill project lakes in 2004 will not be available as an assessment of project treatments until the 2005 annual report. Creel survey results for the 2003 season are presented here, although data only provide an initial indication of the effectiveness of various treatments in altering bluegill population size structure.

FINDINGS

Preliminary results of various treatments on the proportion of quality size bluegill reflected in the creel are reported in Table 1-3. Among the control lakes surveyed in 2003 (McLeansboro, Glendale, Sterling, and Hillsboro), McLeansboro (quality) and Glendale (stunted) showed a notable decrease in PQBG.170 values, while Hillsboro (stunted) showed a notable improvement. Sterling Lake (stunted) showed little change in bluegill population size structure as measured by PQBG.170.

Among the lakes with a restrictive size limit, only Walnut Point (quality) showed a significant increase in PQBG.170; Red Hills (quality), Mingo (quality), and Dolan (stunted) showed little or no change. For lakes where stocking was used to increase predator densities, Woods (quality) showed a tremendous decrease in PQBG.170, while Mermet (stunted) showed a significant increase. Lastly, on lakes where both restrictive size limit and predator stocking were combined, only Homer Lake (quality) showed a moderate improvement in PQBG.170, while Bloomington (quality) and Pierce (stunted) showed little or no change.

Creel survey results indicate little or no change in the percentage of anglers targeting bluegill before and after treatments (Table 1-4). Additionally, catch and harvest rates for bluegill showed no significant pattern of change from pre-treatment years (Table 1-5, 1-6). Any final conclusions about the effectiveness of one particular treatment will need to be made once all 32 experimental lakes have been assessed post-treatment.

RECOMMENDATIONS

Creel surveys should continue on bluegill study lakes in the 2005 season so that the entire complement of 32 experimental lakes will have been surveyed post-treatment. Lakes should be chosen so that experimental treatments are equally represented each year, facilitating inter- and intra-treatment comparisons each year. Long-term trends in creel data on bluegill study lakes should also be presented as post-treatment creel survey data becomes available.

Job 101.2. Evaluation of bluegill life-history variation in Illinois impoundments.

OBJECTIVE

To determine the extent of variation in important bluegill life-history characteristics in selected impoundments throughout Illinois

INTRODUCTION

Numerous research projects have been dedicated to investigating how to increase growth among many of the sportfish, and even how to produce a trophy fishery. One of the more popular Midwest sport fisheries is the bluegill (Lepomis macrochirus), with total harvest exceeding that of most other sportfish. Anglers are often dissatisfied with the high number of small bluegill in recreational lakes. A stunted bluegill population (most adult bluegill measuring 150mm or less) is considered a primary management problem. In Illinois, as in many other states, the demand is growing for populations with quality-sized bluegill. For management biologists to be able to make sound decisions in an attempt to provide those quality bluegill populations, we need to understand the factors that are driving population size structure.

Before effective management strategies for increasing the size structure of "stunted" bluegill populations can be developed, we need more information about the factors controlling growth and maturation of bluegill. Competition can occur among sunfishes when high numbers of small fish are forced into refuges to avoid predation (Mittelbach 1984; Mittelbach 1986). How the effect of this phenomenon on growth might extend to population structure, however, likely varies among reservoirs depending upon prey availability and predator densities. Although the availability of food resources for bluegill can impact growth, it remains unclear as to whether or not density dependent growth rates (juvenile or post-maturation) affect the ultimate size structure of bluegill populations.

The size structure of a bluegill population is determined by the combination of four factors: the growth rate before maturation (when all energy investment is directed toward somatic growth), the age at maturation (which is highly plastic in Lepomis spp.), growth rate after maturation (when much energy investment is directed toward reproduction), and longevity. Thus, growth trajectories for parental male bluegill (and most other fish as well) follow a pattern in which growth slows significantly following sexual maturation (Wootton 1985). Given that bluegill reproduction includes behaviors such as nest construction, territorial defense, courtship of females, fanning the eggs, and defense against brood predators, they commit large energetic investments into reproduction. Because bluegill are also sexually dimorphic, male and female growth patterns and maturation schedules may differ within a population.

Bluegill have been shown to exhibit complex reproductive behaviors such as colonial nest construction, territorial defense, courtship of females, and defense against brood predators (Gross and Charnov 1980). Furthermore, male bluegill exhibit alternative reproductive strategies, whereby some individuals mature precociously and become cuckolders at a younger age and a smaller size than their brothers, who delay maturation to become parental males (Gross and Charnov 1980). The process of maturation has significant impacts upon growth trajectories in bluegill and likely all other fish species as well, because the physiological changes and mating behaviors associated with reproduction require high energetic investment, making that energy unavailable for somatic growth (Claussen 1991, Fox and Keast 1991, Jennings 1991, Jennings and Philipp 1992). Although the impact of sexual maturation and spawning activities on the growth of *Lepomis* individuals is well established, little is known about the reverse, i.e., how the growth and size structure within a population affects age at maturation and the expression of reproductive behaviors.

In Illinois, a comparison of size structure from 60 populations of bluegill throughout the state revealed that age at maturation differed among males and females within a population, sometimes as much as by two years (F-128-R, Annual Report, 2000). Furthermore, this comparison also determined that the size structure of a population is influenced heavily by when males in the population mature (i.e., stunted populations occur when males mature at a younger age/smaller size). In addition to establishing hypotheses related to stunting, it is also useful to examine factors that influence inter-population variation in size structure. Numerous prior investigations have demonstrated that both biotic and abiotic variables can influence individual growth rates (e.g., Nibblink and Carpenter 1998; Tomcko and Pierce 2001). In addition (as indicated in previous reports), life-history parameters such as timing-of-maturation can have a significant influence on adult body size, and new evidence indicating the influence of socially mediated maturation schedules on population size structure has recently emerged (e.g., Jennings et al. 1997; Aday et al. 2003). To better understand the multivariate nature of factors that can ultimately influence individual body size, therefore, it is important to consider biotic, abiotic, ecological, and behavioral parameters in a single analysis.

We manipulated both the food resources (high or low) and the social structure (presence or absence of large, mature males) of bluegill populations established in experimental ponds to assess the interaction between growth rates and timing of maturation. The pond experiment asked two questions, how does variation in resource availability and the social structure of the population influence growth rates and maturation schedules of immature male and female bluegill, and how do growth rates interact with timing of maturation to influence individual size and population size structure in variable environments? Because bluegill, like many fish species, exhibit sex-specific differences in life-history strategies, we evaluated growth and maturation rates for each sex independently.

PROCEDURES

We conducted two analyses to examine factors influencing the size structure of bluegill in Illinois. The first set included estimates of bluegill growth, maturity, size structure and lake latitude from 50 lakes throughout the state. Latitude was used as a surrogate for growing degree-days. To evaluate size structure, we calculated proportional stock density (PSD) for each bluegill population by dividing the number of bluegill over 150-mm by the number of bluegill over 80-mm. We also calculated a relative stock density (RSD) by dividing the number of bluegill over 180-mm by the number of bluegill over 80-mm. Our second analysis included prey estimates on 19 of the original 50 lakes. Prey data included zooplankton and benthic invertebrate densities by taxa. Bluegill and prey samples were collected as described in Job 101.3.

Individual correlations were examined to determine variables to include in our overall model of bluegill growth and size structure. A best subset multiple regression model was used for both data sets. We chose mean size at age-5 as the measure of growth for our dependent variable. We did not use size at age-2 (as in previous reports) because we wanted to factor in age-at-maturity and none of our populations matured before age 2.

Experiments were also conducted in eight, 0.04-ha ponds located at the Sam Parr Biological Station. To create differences in resource availability, ponds were either fertilized to encourage zooplankton growth and production (high food treatment ponds) or treated with copper sulfate ($CuSO_4$) to decrease algal production (low food treatment ponds). In addition to fertilization, bluegill in the high food treatment ponds received supplemental feeding of 3-mm pelleted food (40% protein, 10% fat, 6% fiber, 10% moisture, 10% fish) throughout the experiment at a rate of 1.2 kg/ha per day. Ponds in the low food treatment group received no supplemental feeding. Ten mature female bluegill and fifty immature bluegill were added to all experimental ponds. Ten mature male bluegill were added randomly to half of the ponds, thus creating a factorial design (two ponds each: high food plus large, mature males; low food plus large, mature males; high food without large, mature males; low food without large, mature males). Ponds were individually drained in late August (approximately eight weeks after introduction of fish) and all fish were collected, weighed (g), measured (TL, mm) and frozen for later analysis. In the laboratory, fish were thawed and their gonads were dissected and weighed (g). As an indication of the extent of gonad development and sexual maturation, we calculated a gonadosomatic index (GSI; the ratio of gonad weight to total body weight) for each bluegill.

FINDINGS

Field data suggested growth (as indicated by body size at age 5) was a positive predictor of bluegill size structure; mean length of male bluegill at age 5 (MAGE5) was strongly correlated with PSD (Figure 2-1; $r = 0.44$; $P = 0.001$). Because of the strong influence of growth on population size structure, we then modeled factors influencing growth. Similar to previous conclusions (see previous annual reports), age-at-maturity was positively related to growth (Figure 2-2;r = 0.29; P = 0.04). Latitude was negatively correlated with MAGE5 (Figure 2-3; r = -0.43; P = 0.002) with lakes in the northern portion of the state having slower growth. This result is likely a function of longer growing seasons in southern lakes.

Correlations from the 19 lakes with prey data available revealed that density of Daphnia spp. positively influenced bluegill growth (Figure 2-4; r = 0.59;P = 0.008). Given that latitude and age at maturity were important in the full model, we added these two variables in our subset model along with Daphnia spp. density. This multiple regression model explained 57 percent of the variability in growth at age 5 for male bluegill (R^2 = 0.57; P = 0.005).

To examine the energetic tradeoff between growth and maturation in pond experiments, length and weight of immature fish that matured were compared to those that remained immature. Across both sexes and all ponds, individuals remaining immature were significantly longer (ANOVA; $F_{1,321}$ = 3.6, P = 0.05) and heavier ($F_{1,321}$ = 8.7, P = .003) than those that matured, demonstrating a size cost of maturation. The size difference between mature and immature individuals, however, was both sex-specific and dependent on food resources. For juvenile males, individuals in the low food ponds that became mature were significantly smaller ($F_{1,84}$ = 7.15, P = 0.009) than those that remained immature, indicating that individuals in this treatment incurred a size cost associated with gonad maturation (Figure 2-3). In the high food treatment, however, there was no difference ($F_{1,82}$ = 1.55 , P = 0.22) in size of mature and immature individuals (Figure 2-3); food resources were apparently abundant enough to allow continued somatic tissue growth during and immediately after gonad maturation. For females, there was no difference ($\underline{F} < 1.98$, $\underline{P} > 0.16$) in length or weight of individuals that became mature and those that remained immature for either food treatment (Figure 2-2).

A cost of maturation was more apparent for juvenile males than juvenile females, and this cost was influenced by the level of resources available. Individual males in the low food treatment that matured early were significantly smaller than those that remained immature, whereas there was no decrease in size of early-maturing fish in the high food treatment (Table 2-1). These results demonstrate the interaction between socially-mediated early maturation and resource availability. When resources levels are high enough, individuals may have sufficient energy to simultaneously allow gonad maturation and somatic tissue growth (at least in the short-term). When resources are limited, as in the low food treatment, individuals face an energetic tradeoff between growth and maturation; gonad maturity will come at the expense of somatic tissue growth. Implications for these energetic tradeoffs are apparent; timing of maturation influences bluegill population size structure, and it is reasonable to infer that an excessive growth cost associated with early maturation may lead to stunted body size.

RECOMMENDATIONS

Clearly, there are many ways to measure growth rates. Our analysis of size at age 5, however, indicates the important role that both biotic and abiotic factors can play in shaping population size structure. We will continue to examine these data and conduct additional analysis of mechanisms associated with variable adult size structure. To do that, we must consider more than just body size-at-age. Rather, we must also determine which variables influence growth rates (both pre- and post-maturation) and timing-of-maturation, and how. We will continue to analyze prey abundance and availability data to determine how zooplankton and benthic macroinvertebrate communities influence individual growth rates. We will also quantify factors such as predation (primarily by largemouth bass) and competition (primarily with gizzard shad) to determine how these important biotic factors interact with food availability, latitude (temperature), and timing-of-maturation to shape population size structure. Although we will continue to use multiple regression and MANOVA to analyze these data, we may also take an information-theoretic approach. For example, the Akaike Information Criterion (AIC) has been used successfully in natural systems such as these to assess the ways that multiple, interacting factors influence a set of response variables (Burnham and Anderson 2002). This analysis (or similar) may be required if all of the potential causative variables are to be considered simultaneously.

Additional experiments are also needed to determine the mechanism(s) by which bluegill assess their population's social structure and accordingly make decisions on whether to mature early or delay maturation. In addition, it is important to determine if increased food resources (even through additional feeding) can alter size structure patterns and if so, how that can be accomplished on a large lake scale.

Results of the pond experiment demonstrate that growth rates and timing of maturation interact in sex-specific and resource-dependent ways to influence the ultimate size that individual fish achieve. As such, we believe that traditional, single-dimensional paradigms regarding stunting do not accurately reflect the complex nature of ecological (e.g., resource availability) and evolutionary (plastic timing of maturation) mechanisms that can ultimately cause smaller-than-average body size, and our results illustrate why management approaches based solely on growth rates have often failed. If early maturation is the cause of stunting, manipulations that focus only on resource availability would fail to address the underlying problem. Rather, harvest regulations would be required that restrict the take of large, mature males such that the size- and stage-structured interactions are maintained, forcing juveniles to delay maturation. We suggest a two-pronged approach to management, in which biologists both foster conditions in which individuals can obtain adequate food resources and simultaneously protect large, vulnerable individuals from harvest. We believe that this comprehensive approach, which more accurately reflects the mechanisms responsible for stunting, will likely be met with greater success when attempts are made to both modify population size structure in the short term and maintain populations with large individuals on a long-term basis.

Job 101.3 Pre- and post-regulation characterization of experimental study lakes.

OBJECTIVE

To gather detailed baseline data on bluegill life-history characteristics as well as the biotic and abiotic variables that may affect bluegill recruitment, growth, and maturation in the chosen experimental study lakes.

INTRODUCTION

An important goal of this study is to examine the impact of various management actions (i.e., harvest regulations and predator stocking) on bluegill growth rates and size- and age-at-maturation, and determine how each acts to improve size structure among stunted bluegill populations in Illinois. Four aspects of a species' life-history trajectory determine the ultimate size structure of the adult population in a given water body: pre-maturation (larval/juvenile) growth rate, age at maturation, post-maturation (adult) growth rate, and longevity. These four aspects can be affected by a variety of variables within a water body. Age-at-maturation and longevity are directly affected by the social relationships among surviving adults and can be greatly impacted, therefore, by harvest. Both pre- and post-maturation growth rates are directly affected by density-dependent processes (i.e., slower growth rates when there is an overabundance of bluegill or underabundance of prey) at all bluegill life stages. Additionally, biotic (e.g., interspecific competition, predation) and abiotic (e.g., temperature, dissolved oxygen saturation) factors can also influence all four aspects of a life-history trajectory. This job is designed to elucidate how these processes may act and interact to alter bluegill population size structure under different management options.

Results from Job 101.2 indicate that factors controlling the age-at-maturation may have the greatest influence in determining size structure of bluegill populations throughout the state. Quality populations were characterized by a later age- and larger size-at-maturity than stunted populations. Manipulative experiments associated with this project continue to suggest that the social structure of the population, specifically the presence or absence of large, mature males, has a direct impact on age-at-maturation of juvenile male bluegill in the population and, therefore, a direct impact on population size structure. Management actions designed to increase the size structure of wild bluegill populations (i.e., convert stunted populations to quality populations) need to increase PQM170. From an evolutionary standpoint, that requires reaching a new life history state, in which age-at-maturation is increased; i.e., males delay to older ages and larger sizes prior to maturing and entering the slower post-maturation growth phase. Moving a population from a stunted to a quality life history state, however, might be accomplished by increasing pre-maturation growth rates, increasing post-maturation growth rates, extending longevity, or increasing age-at-maturation directly. Which route successful management actions will use is unclear. As a result, it is important that we continue to collect juvenile and mature bluegill from study lakes to monitor size, age, and maturity status.

Both pre- and post-maturation growth rates may be increased by an underabundance of bluegill or an increase of prey. This density-dependent alteration in growth rate can occur at any or all life stages of the bluegill. Bluegill feed on both zooplankton and benthic invertebrates throughout their life. Competition for food resources (intra- and interspecific) can occur at each life stage (i.e., larval, juvenile, adult) and could affect growth. Identifying the importance of altering competition for limited resources relative to other potential mechanisms designed to increase growth rates will be important for evaluating the success of any management regulation designed to alleviate stunting. Monitoring prey resources and bluegill densities in the study lakes is necessary to assess the role that density-dependent mechanisms may play in altering size structure of our test bluegill populations and influencing the results of the management experiment.

PROCEDURE

In this segment, we began collecting samples at the end of the management experiment of bluegill in each of the 32 experimental lakes for determination of age and size at maturity. Lakes were electrofished once in May - June and all bluegill collected were brought to the laboratory for processing. Some lakes were sampled a second time to ensure that enough bluegill were collected from each age group. Collected bluegill will be dissected and gonads weighed and examined for maturity status. To analyze the bluegill collected in each lake sampled, individuals are thawed and total length, weight, and sex determined. In addition, gonads are identified as to stage of development, and mature gonads weighed. Scales and otoliths were removed for age and growth analysis. We will use these data to determine age-specific growth curves, age at maturation, and abundance of cuckolders. All otoliths will be read in whole view unless there was a disagreement between two readers, or if crowding of annuli occurred. If so, the otolith will be sectioned by one of two methods: by either cracking the otolith in half and reading transverse section with fiber optic light or by mounting the mid-section on a slide and reading it with transmitted light. Individuals will be given a gonad score of 1 - 5 (immature - mature) based on the degree of maturation of the testes or ovaries (Aday et al. 2002). Individuals with scores of 1 - 3 are immature, having no or very little gonad development, whereas individuals with scores of four and five exhibit mature gonads; yolked eggs are present (females; Justus and Fox 1994) or testes are fully developed and running sperm (males). This data will then be used to determine the age of maturity for the bluegill population in each study lake.

In this job, we also continued monitoring of experimental populations to determine influences of the management manipulations on bluegill population size and age structure. The management experiment, which began in April, 1999, involves 32 lakes across the state of Illinois, divided into four treatments (8 lakes per treatment): restrictive harvest regulations (8-inch minimum size limit, 10 fish daily creel limit); predator stockings (largemouth bass added to increase predation on juvenile bluegill); restrictive harvest regulations and predator stockings in combination; control (for complete details of the management experiment see Claussen et al. 1999; Table 3-1). Three components of each study lake are important for current monitoring: 1) bluegill population parameters (adult abundance, size structure, age-at-maturation, and larval and juvenile growth and abundance); 2) biotic variables (e.g., prey availability, predation); and 3) abiotic variables (e.g., temperature, lake productivity, lake-habitat characteristics). The sampling protocol that was established at the initiation of the management experiment (Aday et al. 1999) was followed during the summer of 2003 and 2004: all 32 experimental lakes were sampled for bluegill (juvenile and adults) and largemouth bass (as a predator) abundance. In addition, prey resources (zooplankton and macro invertebrates) were collected in 16 (7 stunted and 9 quality) of the 32 experimental lakes, and larval bluegill were collected in 8 of them. We will continue to monitor these and other biotic and abiotic variables in the experimental lakes throughout the management experiment.

Bluegill Population Parameters

In this segment we continued to monitor changes in bluegill populations by examining length-frequencies of bluegill collected in spring and fall electrofishing samples of populations from each experimental treatment group. This consisted of comparing data collected in the current segment to those from previous ones. We also continued to examine potential density-dependent mechanisms to understand the role that they may play in altering population size structure. We determined larval, juvenile, and adult bluegill abundance in the experimental study lakes. Larval fish were collected from each offshore site by pushing an icthyoplankton net (0.5m diameter, 500 mm mesh) for 5 minutes. Volume of water filtered was calculated with a calibrated flow meter mounted inside the mouth of the net. Inshore bluegill density (primarily juveniles) was assessed by shoreline seining (9.2 x 1.2 m bag seine, 3.2 mm mesh) at four fixed sites within each lake. Effort was calculated as the length of the haul (nearest m). All fish were counted and a minimum of 50 individuals of each species collected was measured (total length in mm). Density (#/m of seine haul) was calculated for bluegill throughout the study period. Adult bluegill were collected by shoreline seining (6.7 x 1.2 m bag seine, 3.2 mm mesh) and electrofishing. Electrofishing samples were performed on each study lake using an AC powered, boat mounted electrofishing unit in the spring and fall in order to compare length frequencies between pre- and post-regulation populations. A fall sample was collected in September or October from all 32 experimental lakes to examine population length frequencies.

Prey Availability

Prey availability may interact with relative abundance of bluegill to affect growth at all life stages. Macro invertebrates and zooplankton are important food items to larval, juvenile, and adult bluegill. We determined the abundance of these food resources in 16 of the experimental lakes. To quantify zooplankton abundance, collections were taken using vertical tows with a 0.5 m diameter, 64 mm mesh zooplankton net at four inshore and four offshore sites (one tow per site). Zooplankton were preserved in a Lugols solution (4%) for later processing. Inshore macro invertebrates were collected using a stovepipe sampler (20 cm diameter) at 6 sites (one sample per site) within each lake. Depth of each sample collection was measured. Samples were cleaned in a 250 mm mesh benthos bucket and preserved in an ethanol/rose bengal solution (70%) for processing.

In previous segments we examined correlations between juvenile bluegill growth rates and prey resources (total zooplankton and benthic invertebrate densities). We also examined the relationship between food resources and bluegill growth and maturity as well as relative abundance of quality sized fish in the population. In this segment we continued these analyses by examining changes in total zooplankton, macro zooplankton, and total benthos densities throughout the management experiment. Monitoring the densities of bluegill prey will allow us to determine if changes in bluegill size structure are related to changes in prey availability rather than the management manipulations. Across lake, we also determined differences in prey availability between stunted and quality populations.

Predator Abundance

Predator abundance may also influence bluegill size structure and may be important at each life stage. Largemouth bass are the primary predator in these centrarchid-dominated experimental lakes and can consume large numbers of larval and juvenile bluegill. In addition, bass may compete with bluegill for available resources at the larval and juvenile stages. To quantify largemouth bass abundance, spring and fall electrofishing surveys were conducted on all experimental lakes. Largemouth bass were measured for total length and identified for fin clips.

As part of the management experiment, 16 lakes were stocked with advanced fingerling largemouth bass to increase predator numbers. As in previous years, fingerlings were stocked in mid-August 2003, and each bass was given a distinct clip for future identification. We monitored growth and survival of stocked bass through the first fall after they were stocked and in subsequent years. Largemouth bass were collected by day AC electrofishing in the fall by INHS and Division of Fisheries personnel. All largemouth bass were examined for marks, measured, and weighed. In this segment, we summarized the contribution the stocked bass are making to the standing stock of largemouth bass in the experimental lakes. We examined CPUE for all bass in the system as well as determining the proportional contribution of natural and stocked bass.

Other Biotic and Abiotic Factors

Abiotic variables may also influence bluegill population parameters. We measured water transparency, dissolved oxygen, temperature, total dissolved phosphorous, and chlorophyll *a* on 16 lakes. Water transparency was measured with a secchi disc. Temperature and dissolved oxygen profiles were measured at one-meter intervals. Water samples were collected monthly with an integrated water sampler for analysis of total phosphorous and chlorophyll *a*.

Angler Compliance

To assess compliance of anglers to the experimental regulations, compliance cards were given to conservation officers at all lakes with experimental regulations. Conservation officers were asked to record the number of anglers fishing for bluegill along with the number of legal and sub-legal length bluegill harvested by each group of anglers. Conservation officers then completed these cards each time they performed a bluegill regulation check on an experimental lake.

FINDINGS

Bluegill were collected from all experimental lakes during the spring of 2004 for determining final age at maturity. Overall, a total of 8197 bluegill were collected (Table 3-2). The lab processing of these samples has not been completed at this time and will be conducted in subsequent segments. At this time preliminary samples from 13 of the 32 study lakes have been dissected and gonads were scored. Otoliths were removed and will be aged during subsequent segments.

In this segment, length frequency data was compiled for 2004 spring electrofishing for all experimental lakes. This data was then added to previous length frequency data and examined for changes in the bluegill population size structure. As in previous segments, length frequency analysis revealed variable changes among study lakes in response to experimental regulations (Figures 3-1 to 3-8). Only bluegill over 100 mm were included in these analyses because we were interested in shifts in adult bluegill that were both large enough to be effectively sampled with electroshocking gear and were large enough to be included in the fishery. Smaller bluegill would also be more strongly influenced by year-to-year variation in spawning success. Lakes in the control treatment have continued to show little changes in length frequency distribution with some year-to-year variation (e.g., Apple Canyon, Figure 3-1; Round, Paris, Figure 3-2). Control treatment lakes that were designated quality bluegill populations at the start of the experiment continued to be quality in 2004 (Figure 3-1). The same was true for control treatment lakes that were designated stunted (Figure 3-2).

Lakes receiving experimental treatments however, continued to show highly variable results. In general, lakes that were designated quality before the experiment maintained their quality size structure. Regulation treatment lakes showed few changes in bluegill size structure. There may be some evidence for size structure beginning to shift in some lakes such as Busse South where there is a shift from high numbers of 100-133 mm bluegill to 134-166 mm bluegill and the presence of some larger bluegill (201+) that were not found in earlier years (Figure 3-3). Lakes undergoing predator stocking alone did not show any increases in bluegill size structure, the exception being Le Aqua Na, which showed a decrease in the proportion of fish in the smallest size class (100-133 mm) and increases in 134-166 mm and 167-200 mm size classes (Figure 3-6). Some stocking treatment lakes showed decreases in proportions of larger bluegill (Spring Lake South, Figure 3-5). Lakes where the regulation is combined with predator stocking that were designated quality at the beginning of the experiment showed very little change throughout the experimental period. Lakes that were designated stunted and were in the regulation and stocking treatment showed some increases in size structure in 2004 (Figure 3-8). These lakes are showing some increases in the proportion of fish in the larger size classes. Because these are stunted lakes, these increases are occurring in the 134-166 mm (Bullfrog and Jacksonville) or 167-200 mm (Pierce) size class. We are also beginning to observe some fish in the larger size classes at these lakes. Because there were no major shifts in size structure, we must focus on examining changes in age of maturation.

We continued to monitor prey resources in 2004, and will present those data in subsequent reports. During 2004, we processed and analyzed samples collected in 2003 (Figure 3-13). Multiple years of data (1998-2003) were included from each population to examine differences in prey resources throughout the management experiment. Incorporating multiple years of data will help control for high variation among study lakes and was used to further evaluate effects of prey resources. There was some fluctuation in zooplankton and benthic invertebrate densities from 1998–2003. These fluctuations were small and no change in bluegill growth is expected from this natural variation. The lack of changes in prey resources would imply that any changes in the bluegill size structure are due to the management manipulations. Bluegill diet data will help us continue to assess the importance of certain groups of prey to growth and maturation rates of bluegill within and among populations. Information on what prey types bluegill may be feeding on will help us understand limitations to growth and influences on age at maturity.

In this segment, we continued to evaluate whether or not the experimental treatment has been set up successfully. This was done through assessing angler compliance to the regulation and success of the stocked largemouth bass contributing to natural populations. The treatments must be implemented successfully, for predicted change to be observed in the bluegill population size structure.

Contribution of stocked largemouth bass was again variable in 2004 during the first fall after stocking (Table 3-3). In fall 2004, CPUE for age-0 stocked bass was low in electrofishing samples (0-12 fish/hr) and no stocked fish were observed in a number of lakes (Table 3-3). Numbers for stocked bass were low the following spring as well (0-20 bass/hour; Table 3-3). The contribution of largemouth bass in stocked lakes varied greatly by lake (Figures 3-9 to 3-12). Many lakes had low numbers of stocked bass contributing to the total bass population. A few stocked lakes are showing increases in the numbers of adult largemouth bass due to the stockings (Sam Parr, McLeansboro, Forbes, and Walton Park). Many lakes showed declines in the total number of bass caught (Spring Lake South, Murphysboro). There has been varied success with increasing the number of predators in the study lakes and this may cause varied success with the stocking treatments. Largemouth bass stocked in the initial years of the treatment are now reaching a size where they can effectively prey on larger sized bluegill. Stocking treatment lakes may still be building supplemental largemouth bass populations. Continued assessment of the largemouth bass population is required to evaluate if the stocking of YOY largemouth bass is increasing the standing stock of predators that can feed on multiple sizes of bluegill in the study lakes.

In this segment, angler compliance was assessed on 12 of the 18 lakes in the regulation treatment. Compliance was high on 10 lakes and ranged from 60 to 100 percent of anglers complying with the regulation (Table 3-4). Certain lakes did have lower compliance levels (Jacksonville and Dolan) that may be due to the low numbers of larger bluegill in a lake or lack of awareness of the regulation.

Throughout the first two years of the study compliance was lower as anglers were most likely unaware of the new regulation. Monitoring of lakes for compliance not only allows us to assess the effectiveness of the regulation, but it helps educate anglers of the regulation and enforce it.

RECOMMENDATIONS

In the next segment, we will finish examining bluegill population parameters, prey and predator abundances, and fish community variables in the study populations to determine mechanisms responsible for alteration in bluegill population size structure expected to result from the experimental management actions. These assessments will be critically important to determine the mechanisms by which each management action alters growth and maturity schedules, and, hence, size structure of the population. We plan to again sample the bluegill populations next spring for length frequency, sex ratio and maturity status. In particular we are planning additional collection of bluegill at lakes that have low sample sizes (eg. Sterling, Kakusha). Data collected in 2004 and 2005 will be combined to generate final conclusions regarding the success of the experimental regulations. Samples collected during 2004 and 2005 will be dissected, gonads measured, and otoliths will be aged during the next segment. This data will then be used to calculate age of maturity, PQM170, and growth data for bluegill in the experimental lakes. This data will be compared to data collected before the start of the experiment in 1996 and 1997. This analysis will reveal if any changes in maturity and growth occurred as a result of the management manipulations. Length frequency analysis from 2004 revealed that stunted lakes receiving both stocked bass and the experimental regulation were showing some signs of increasing bluegill size structure. Overall, lakes showed a high amount of variability in size structure and few lakes showed increases in size structure.

We will need to further examine changes in prey availability in the experimental lakes to verify that changes in bluegill size structure is not being caused by changes in prey abundance. Diet data should be processed and analyzed during the next segments to determine differences in prey selection by bluegill at each life stage. In addition, differences in prey selection and prey availability within populations should be determined to provide insight into optimal food resources for bluegill in these eutrophic and hypereutrophic populations.

We will continue to follow stocked fingerling largemouth bass in the predator manipulation treatment lakes. Stocking bass has had varied success across the 16 study lakes. By monitoring these various biotic and abiotic variables before and after implementation of the experimental management actions, we will be able to assess the cause of changes in age-at-maturation and growth rates that may result. Understanding the conditions under which changes in bluegill population size structure occur will be important in determining the future utility of these management options across a range of lakes.

Based on data collected from conservation officers, compliance was high across all of the regulation lakes. Compliance will be evaluated for one more year on regulation lakes in order to better understand the effects of the regulation. The low level of compliance on certain lakes may be due to smaller bluegill populations being present in a lake. Compliance must be high at a lake for an expected increase in the size of bluegill available for anglers. Analysis of changes in bluegill size structure must take the level of compliance and success of the bass stockings into account in order to fully understand changes in bluegill size structure.

Job 101.4. Analysis and reporting.

Objective

To prepare annual and final reports that provide guidelines for bluegill management in Illinois impoundments.

Findings

Relevant data were analyzed and reported in individual jobs of this report (see Job 101.1-101.3).

Segment 9

Job	Proposed Cost	Actual Cost
Job 1	$21,200	$21,200
Job 2	$10,600	$10,600
Job 3	$127,200	$127,200
Job 4	$53,000	$53,000

Acknowledgments

The authors of this report would like to acknowledge the help and input from the current and past staff of the Kaskaskia and Sam Parr Biological Stations, including, T. Edison, L. Einfalt, A. Larsen, K. Mann, K. Schnake, E. Smolik, M. Harrington, K. Ostrand, P. Port, J Godbout, and M. Anderson. We would also like to thank all of the conservation police officers that collected compliance data on bluegill regulations.

A special note of thanks to the regional and district biologists that assisted in collections, participated in project discussions, and provided advice on various portions of this project. Steve Pallo, Larry Dunham, and Mike Conlin coordinated activities with the Division of Fisheries, Illinois Department of Natural Resources.

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Table 1-1. Experimental lakes where creel surveys were conducted in 2003.

Lake	Class	Treatment
Glendale	Quality	Control
Woods	Quality	Predator Stocking
Red Hills	Quality	Regulation
Walnut Point	Quality	Regulation
Bloomington	Quality	Regulation/Predator Stocking
Homer	Quality	Regulation/Predator Stocking
Hillsboro	Stunted	Control
Sterling	Stunted	Control
Mcleansboro	Stunted	Predator Stocking
Mingo	Stunted	Predator Stocking
Dolan	Stunted	Regulation
Pierce	Stunted	Regulation/Predator Stocking

Table 1-2. Experimental lakes where creel surveys were conducted in 2004.

Lake	**Class**	**Treatment**
Lincoln Trail	Quality	Control
Murphysboro	Quality	Predator Stocking
Busse South	Quality	Regulation
Mermet	Quality	Regulation
Kakusha	Quality	Regulation/Predator Stocking
Round	Stunted	Control
Paris	Stunted	Control
Spring Lake North	Stunted	Predator Stocking
Le-Aqua-Na	Stunted	Predator Stocking
Tampier	Stunted	Regulation
Walton Park	Stunted	Regulation/Predator Stocking
Jacksonville	Stunted	Regulation/Predator Stocking

Table 1-3. PQBG.170 values for experimental lakes surveyed in 2003.

Lake	Class	Treatment	Pre-Treatment	Post-Treatment
Glendale	Quality	Control	0.55	0.39
Hillsboro	Stunted	Control	0.05	0.22
McLeansboro	Quality	Control	0.46	0.25
Sterling	Stunted	Control	0.02	0.03
Dolan	Stunted	Regulation	0.10	0.11
Mingo	Quality	Regulation	0.08	0.13
Red Hills	Quality	Regulation	0.52	0.52
Walnut Point	Quality	Regulation	0.30	0.66
Bloomington	Quality	Reg & Stock	0.75	0.77
Homer	Quality	Reg & Stock	0.22	0.05
Pierce	Stunted	Reg & Stock	0.07	0.09
Mermet	Stunted	Stocking	0.50	0.91
Woods	Quality	Stocking	0.58	0.00

Table 1-4. Percent creel interviews with anglers targeting bluegill in 2003.

Lake	Class	Treatment	Pre-Treatment	Post-Treatment
Glendale	Quality	Control	2.4	2.5
Hillsboro	Stunted	Control	6.9	2.7
McLeansboro	Quality	Control	9.7	2.9
Sterling	Stunted	Control	1.9	1.7
Dolan	Stunted	Regulation	5.2	0.7
Mingo	Quality	Regulation	9.4	6.2
Red Hills	Quality	Regulation	18.1	14.8
Walnut Point	Quality	Regulation	37.9	41.6
Bloomington	Quality	Reg & Stock	2.0	2.9
Homer	Quality	Reg & Stock	3.9	2.5
Pierce	Stunted	Reg & Stock	4.7	0.9
Woods	Quality	Stocking	1.0	2.0

Table 1-5. Bluegill catch rates for 2003 study lakes.

Lake	Size	Location	Class	Treatment	# BLG/Hr	
					Pre-Treatment	Post-Treatment
Glendale	Small	South	Quality	Control	0.828	0.313
Hillsboro	Small	South	Stunted	Control	0.158	0.261
McLeansboro	Large	South	Quality	Control	0.094	0.305
Sterling	Small	North	Stunted	Control	0.212	0.154
Dolan	Small	South	Stunted	Regulation	0.388	0.123
Mingo	Large	South	Quality	Regulation	0.393	0.457
Red Hills	Small	South	Quality	Regulation	0.612	0.479
Walnut Point	Small	North	Quality	Regulation	0.302	0.996
Bloomington	Large	North	Quality	Reg & Stock	0.312	0.240
Homer	Small	South	Quality	Reg & Stock	0.300	0.522
Pierce	Large	North	Stunted	Reg & Stock	0.207	0.382
Woods	Small	North	Quality	Stocking	0.473	0.142

Table 1-6. Bluegill harvest rates for 2003 study lakes.

Lake	Size	Location	Class	Treatment	# BLG/Hr	
					Pre-Treatment	Post-Treatment
Glendale	Small	South	Quality	Control	0.308	0.096
Hillsboro	Small	South	Stunted	Control	0.057	0.080
McLeansboro	Large	South	Quality	Control	0.055	0.139
Sterling	Small	North	Stunted	Control	0.034	0.025
Dolan	Small	South	Stunted	Regulation	0.235	--
Mingo	Large	South	Quality	Regulation	0.151	0.192
Red Hills	Small	South	Quality	Regulation	0.278	0.031
Walnut Point	Small	North	Quality	Regulation	0.197	0.054
Bloomington	Large	North	Quality	Reg & Stock	0.140	0.039
Homer	Small	South	Quality	Reg & Stock	0.017	0.013
Pierce	Large	North	Stunted	Reg & Stock	0.016	0.020
Woods	Small	North	Quality	Stocking	--	--

Table 2-1: Final sizes and gonadosomatic index (GSI) for juvenile females that remained immature and those that matured in the treatment ponds with high food and no supplemental food.

	High Food			No Supplemental Food		
	Immature	Mature	P-value	Immature	Mature	P-value
Total Length (mm)	138 ± 1.0	138 ± 1.8	0.78	143 ± 1.2	147 ± 1.6	0.16
Total Weight (g)	47 ± 1.3	46 ± 2.0	0.70	54 ± 1.6	57 ± 2.4	0.28
GSI	0.98 ± 0.0	2.1 ± 0.30	0.0001	1.4 ± 0.2	2.1 ± 0.20	0.02

Table 3-1: Experimental management lakes, controlling for region (north, south), lake size (large, small), and population size structure (quality, stunted). Treatments include control, restrictive regulation (8 inch minimum size limit, 10 fish creel limit), predator stocking, and combination of restrictive regulation and predator stocking.

Type	**Region**	**Lake Size**	**Control**	**Regulation**	**Pred. Stocking**	**Regulation/Pred Stocking**
Quality	North	Large	Apple Canyon	Busse South	Spring Lake South	Bloomington
	North	Small	Siloam Springs	Walnut Point	Woods	Kakusha
	South	Large	Lincoln Trail	Mermet	Murphysboro	Forbes
	South	Small	Glendale	Red Hills	Sam Parr	Homer
Stunted	North	Large	Round	Tampier	Spring Lake North	Pierce
	North	Small	Sterling	Lake of the Woods	Le-Aqua-Na	Bullfrog
	South	Large	Paris	Pana	Mingo	Jacksonville
	South	Small	Hillsboro	Dolan	Mcleansboro	Walton Park

Table 3-2: Number of bluegill collected for each of the 32 experimental lakes during spring 2004 by electrofishing.

Treatment	Lake	Class	Bluegill Collected
Control	Apple Canyon	Quality	318
	Glendale	Quality	48
	Lincoln Trail	Quality	414
	Siloam Springs	Quality	191
	Hillsboro	Stunted	323
	Paris	Stunted	573
	Round	Stunted	245
	Sterling	Stunted	31
Predator Stocking	Murphysboro	Quality	167
	S. Spring	Quality	93
	Sam Parr	Quality	317
	Wood	Quality	128
	LeAquaNa	Stunted	188
	McLeansboro	Stunted	181
	Mingo	Stunted	250
	N. Spring	Stunted	622
Regulation	Busse South	Quality	191
	Mermet	Quality	170
	Red Hills	Quality	216
	Walnut Point	Quality	284
	Dolan	Stunted	374
	Lake of the Woods	Stunted	314
	Pana	Stunted	332
	Tampier	Stunted	160
Regulation and Predator	Bloomington	Quality	164
	Forbes	Quality	448
	Homer	Quality	342
	Kakusha	Quality	22
	Bullfrog	Stunted	226
	Jacksonville	Stunted	287
	Pierce	Stunted	267
	Walton Park	Stunted	200

Table 3-3: Contribution of largemouth bass fingerlings stocked into 14 bluegill study lakes in Fall 2003 and Spring 2004. All lake received 4-inch fingerlings, Homer also received 2, 6 and 8 inch fish. Predator addition lakes were those stocked with advanced fingerling largemouth bass, whereas predator addition plus regulation lakes were those with stocked largemouth bass, and had an 8-inch minimum size limit, and a 10 fish daily creel. Catch per unit effort (CPUE) is based on the number of fish collected per hour of AC electrofishing during the fall (Sept. - Oct.) and spring (May - June) following stocking.

Lake	Size (ha)	#/ha	Stocked Largemouth Bass		Native Largemouth Bass	
			Fall CPUE	Spring CPUE	Fall CPUE	Spring CPUE
Predator Addition Lakes						
Le Aqua Na	16	67	0	0	10	10
McLeansboro	30	61	0	12	44	14
Mingo	69	62	12	4	12	10
Murphysboro	58	62	-	3	-	12
Sam Parr	73	62	0	20	108	60
Spring North	194	74	0	-	6	-
Spring South	277	55	0	-	8	-
Woods	11	64	6	1	3	2
Regulation Plus Predator Addition Lakes						
Bloomington	250	64	0	0	8	4
Bullfrog			0	0	41	25
Forbes	212	28	6	2	74	8
Homer	32	125	1	0	27	7
Jacksonville	198	25	0	0	11	10
Kakusha	21	63	2	0	1	11
Pierce	66	61	4	0	24	27
Walton Park	12	104	3	4	12	4

Table 3-4. Percent compliance for the experimental harvest regulation for bluegill on study lakes. Compliance data was collected by Illinois Conservation Police Officers for lakes with the experimental bluegill regulation. An angler was reported as compliant if they did not harvest any bluegill under 8 inches and 10 or fewer total bluegill. Lakes not presented either had low bluegill fishing pressure or infrequent compliance checks.

Lake	**# of Checks**	**% Compliant**
Dolan	39	85
Forbes	27	100
Homer	44	100
Jacksonville	10	60
Lake of the Woods	50	94
Mermet	11	91
Pana	6	100
Pierce	97	91
Red Hills	69	94
Walnut Point	34	100
Walton Park	48	100
Kakusha	9	100

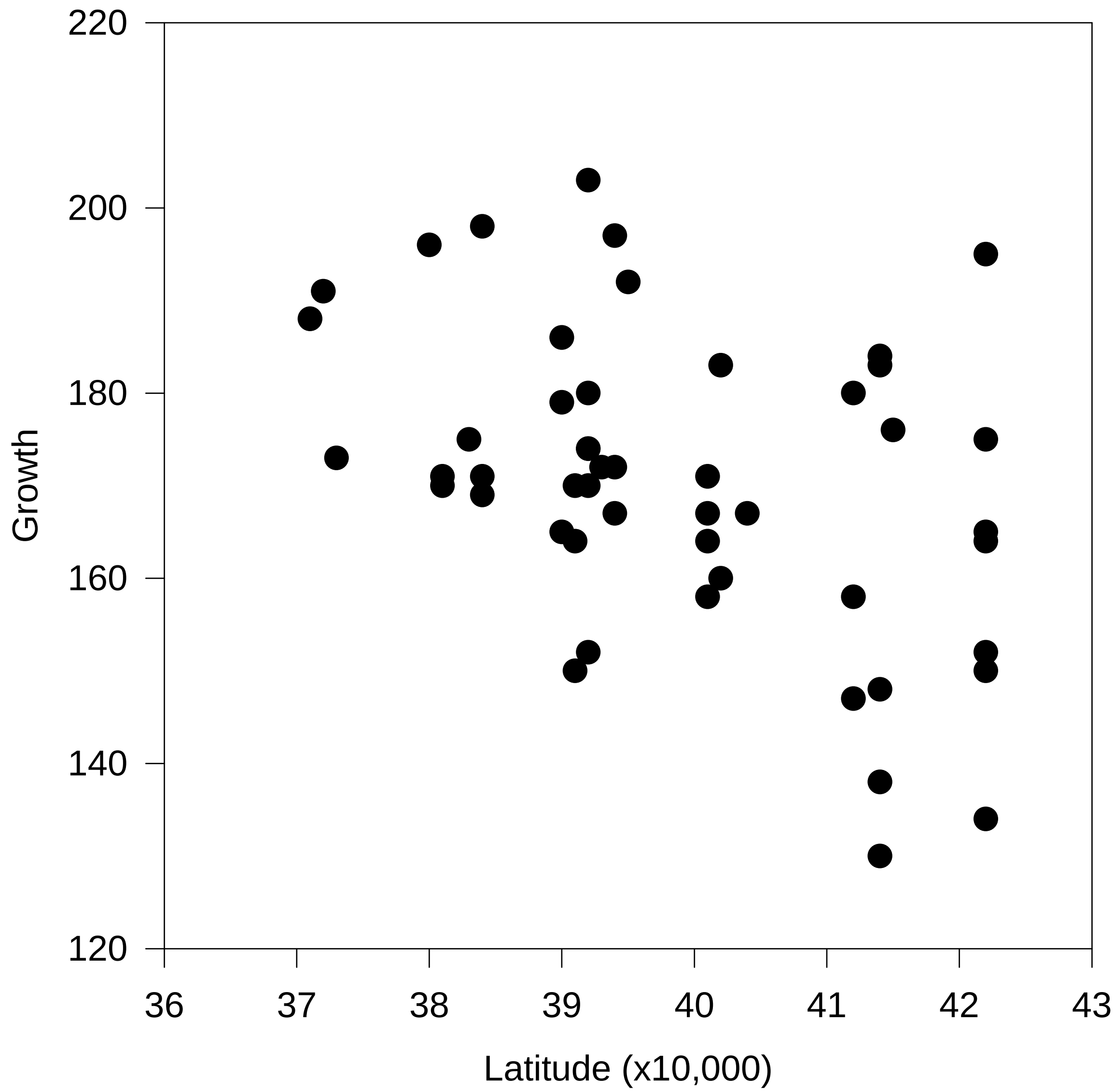

Figure 2-1: Relationship between lake latitude and mean total length of Age 5 bluegill in 50 Illinois lakes.

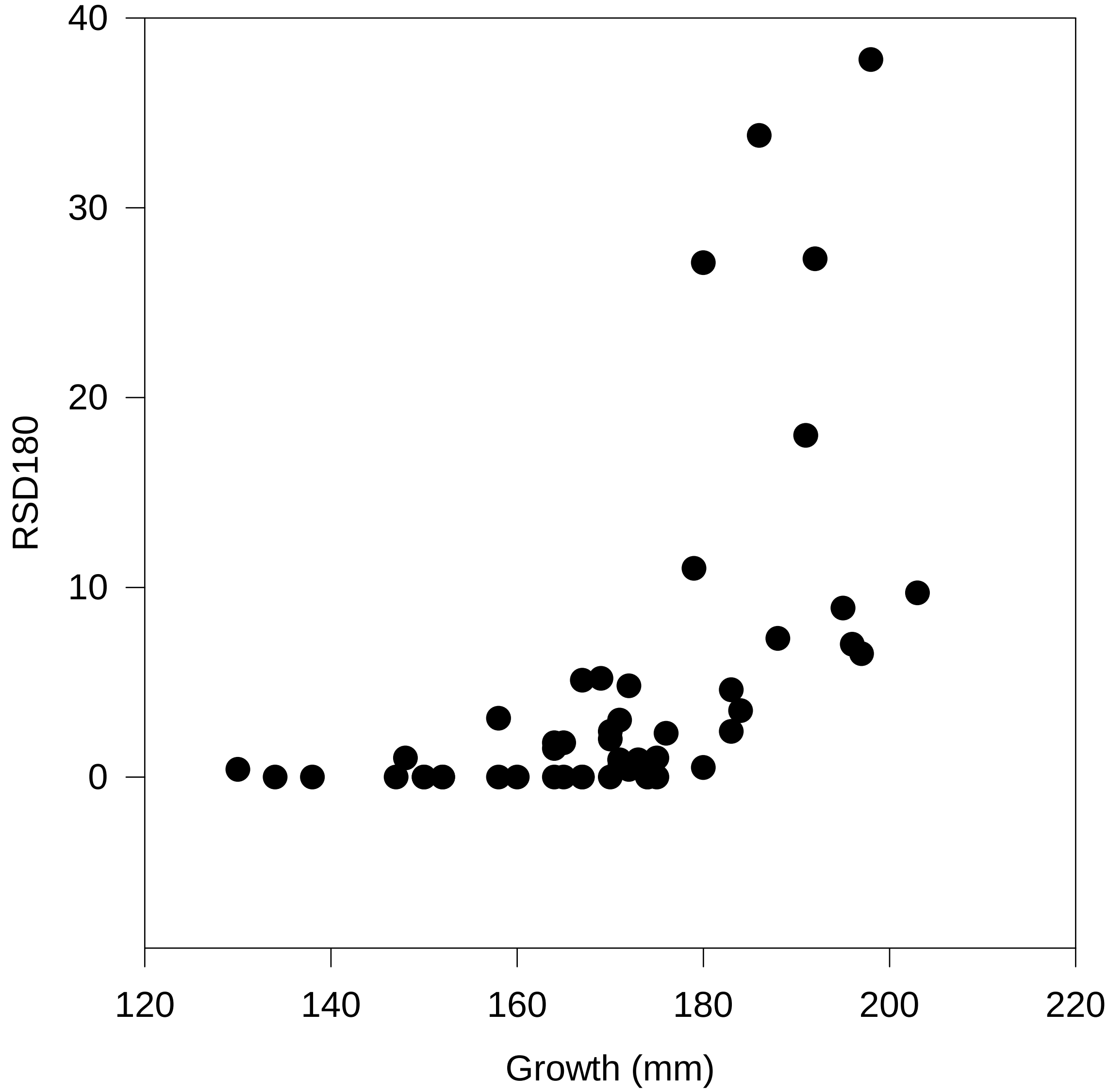

Figure 2-2: Relationship between mean total length of Age 5 bluegill and RSD180 in 50 Illinois lakes.

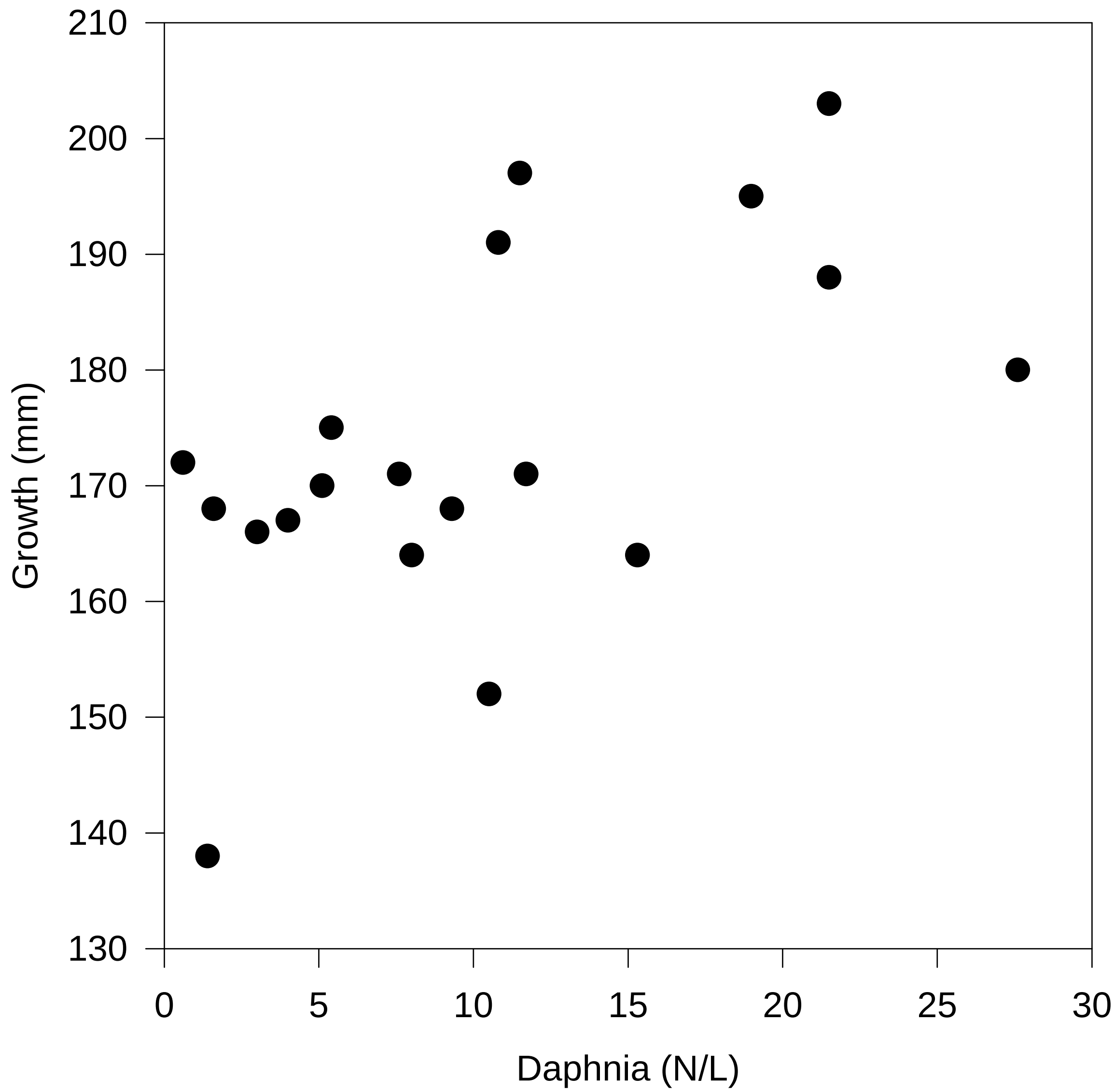

Figure 2-3: Relationship between daphnia density and mean total length of bluegill at age 5 in 19 Illinois lakes.

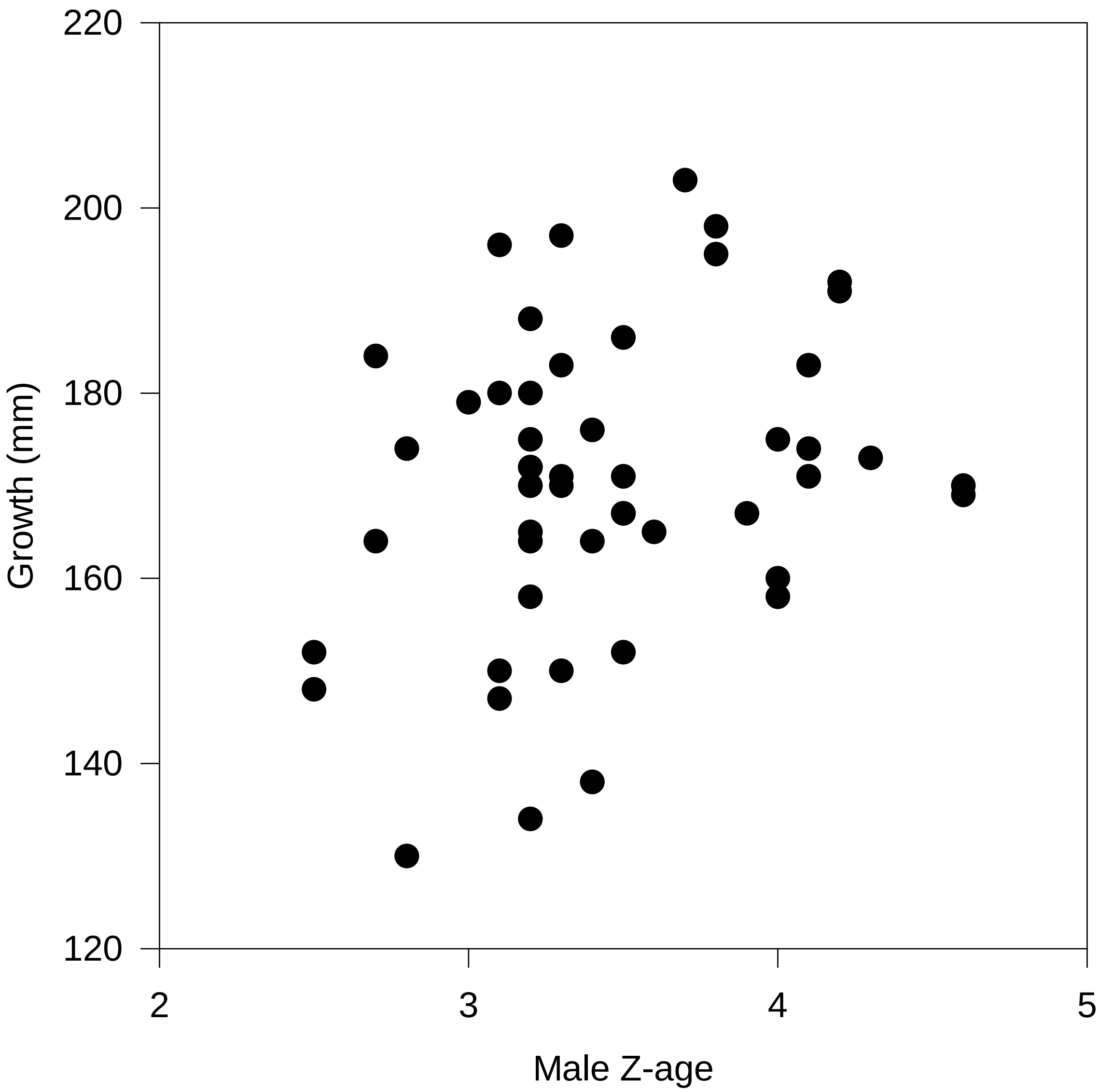

Figure 2-4. Relationship between Male Z-age and mean total length of Age 5 bluegill in 50 Illinois lakes.

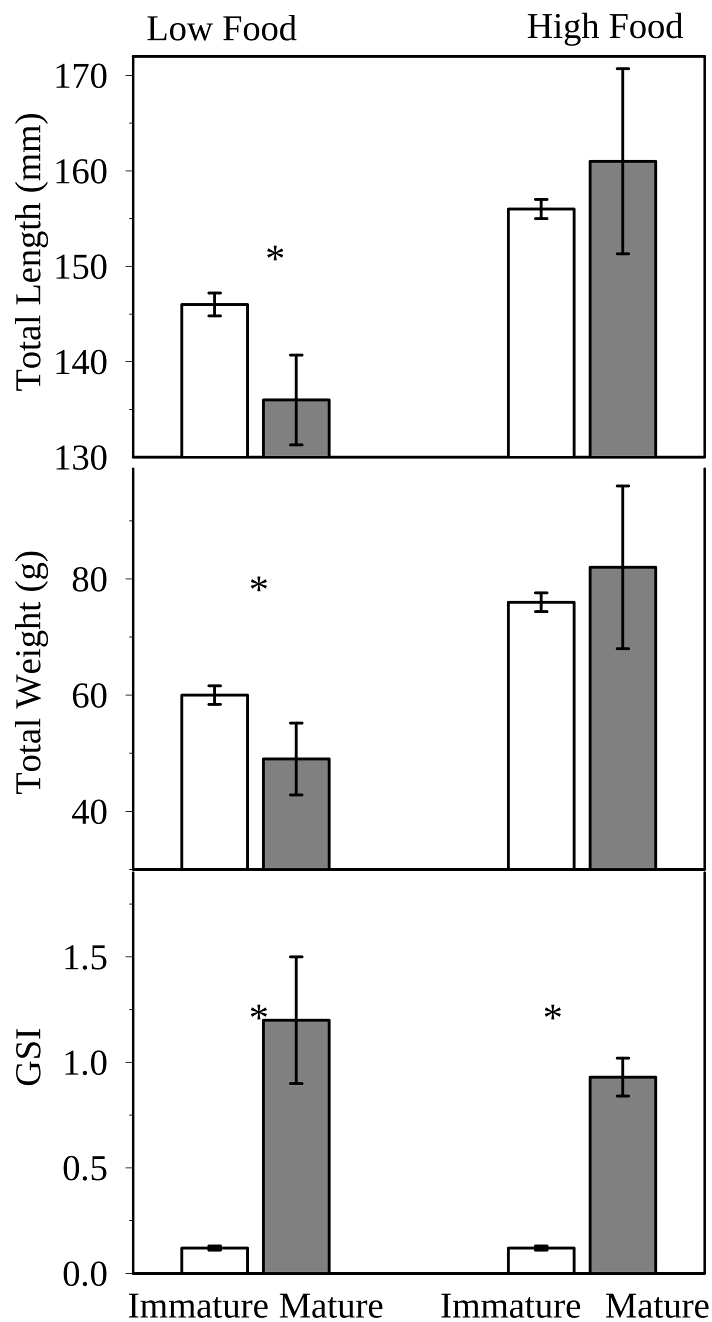

Figure 2-5. Total length, total weight and GSI scores for Ponds with high and low food ability.

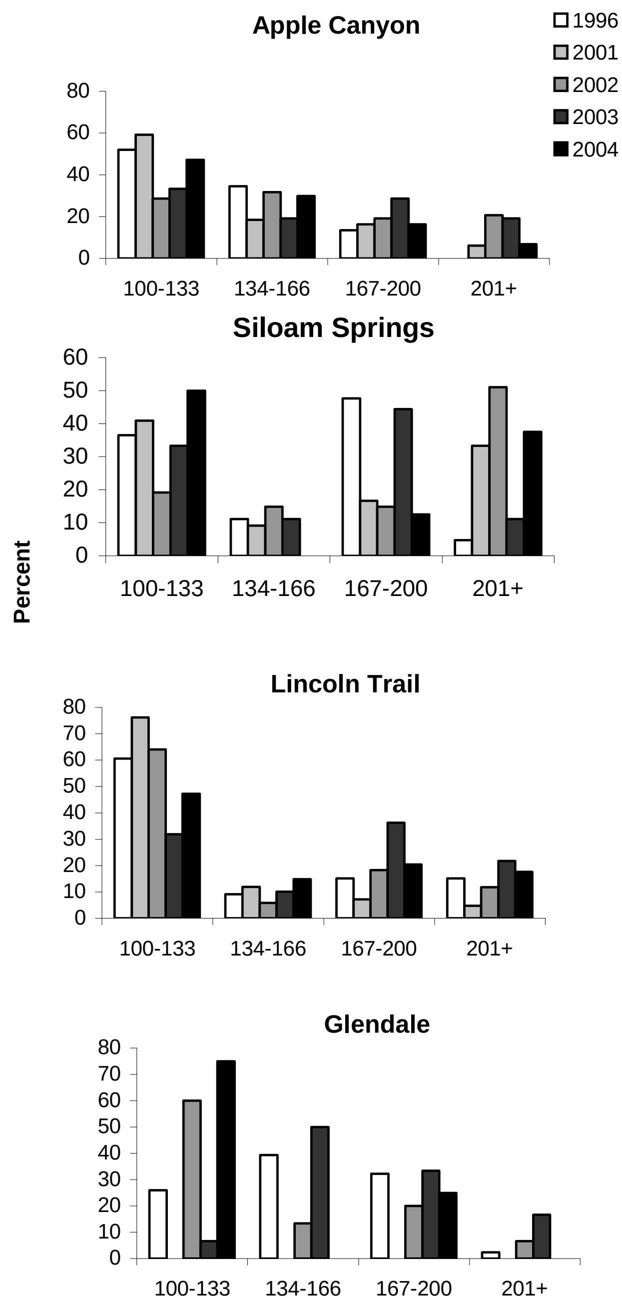

Figure 3-1: Length frequency from spring electrofishing expressed as percent of the total catch for lakes that were designated as quality bluegill lakes and are receiving the control treatment.

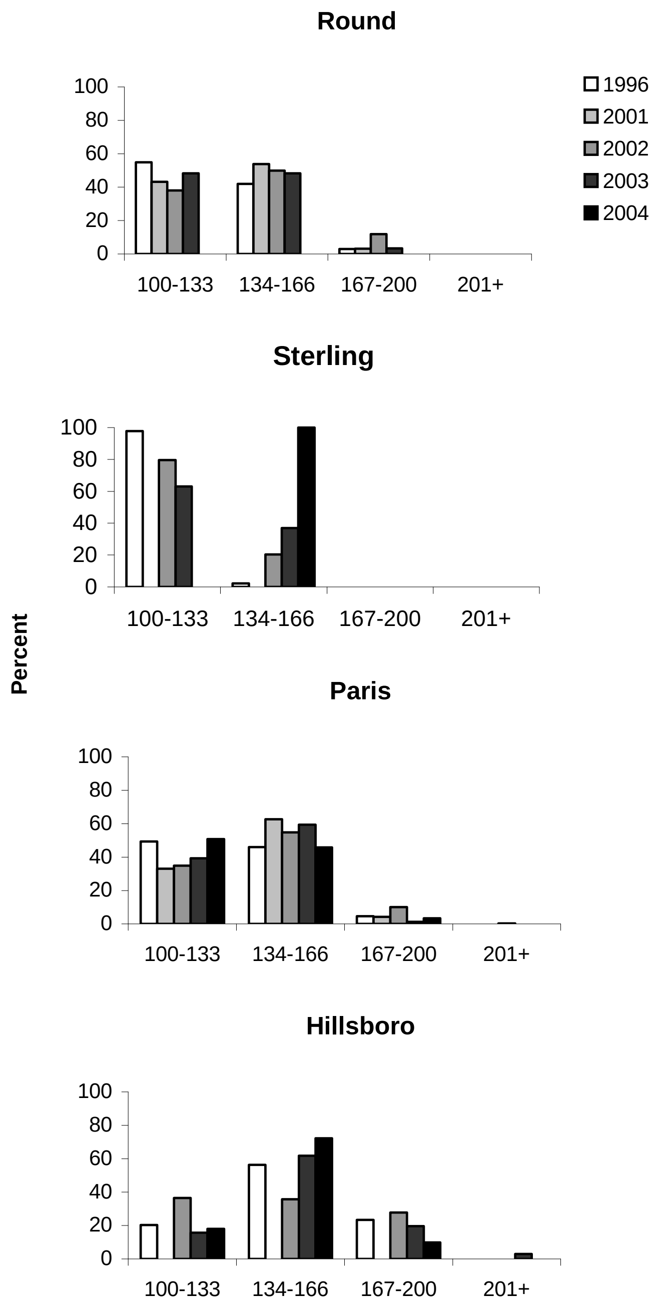

Figure 3-2: Length frequency from spring electrofishing expressed as percent of the total catch for lakes that were designated as stunted bluegill lakes and are receiving the control treatment. Sample Sizes were very low for Lake Sterling in 2004 due to high water and may not be representative.

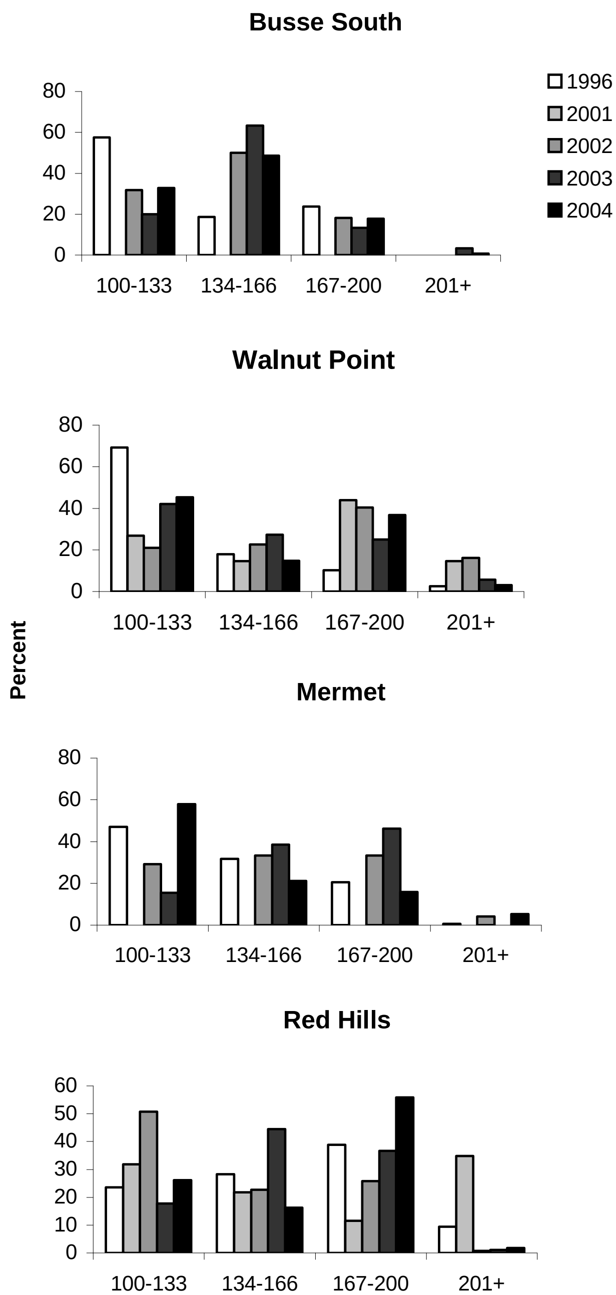

Figure 3-3: Length frequency from spring electrofishing expressed as percent of the total catch for lakes that were designated as quality bluegill lakes and are receiving the regulation treatment.

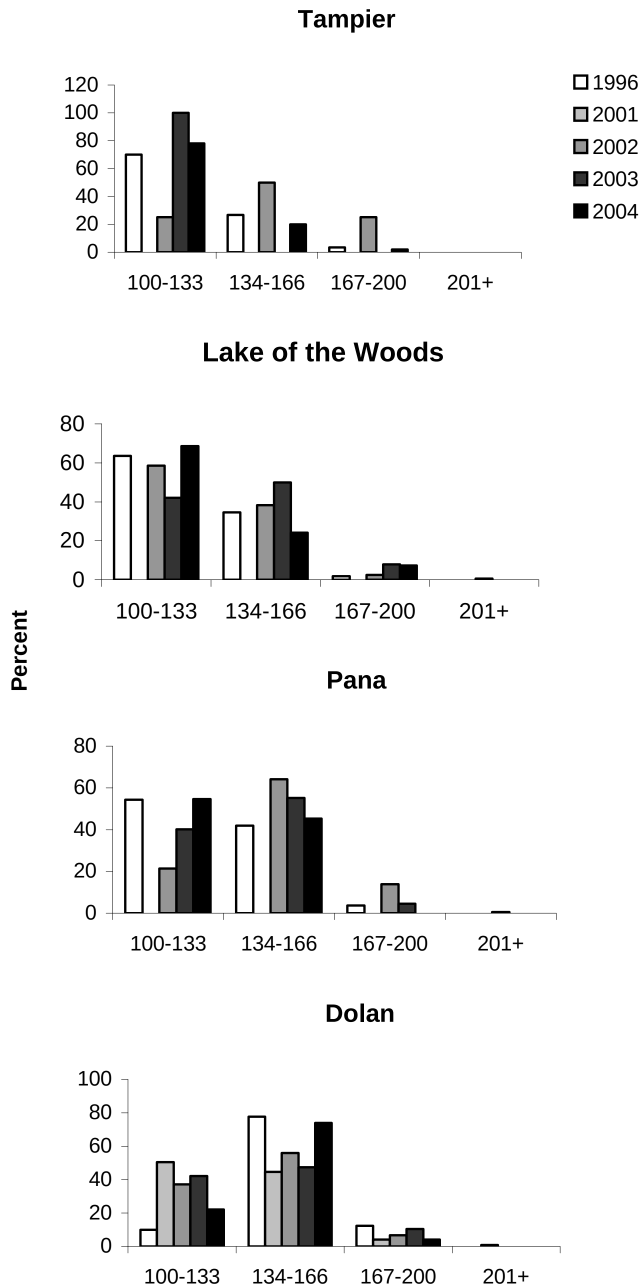

Figure 3-4: Length frequency from spring electrofishing expressed as percent of the total catch for lakes that were designated as stunted bluegill lakes and are receiving the regulation treatment.

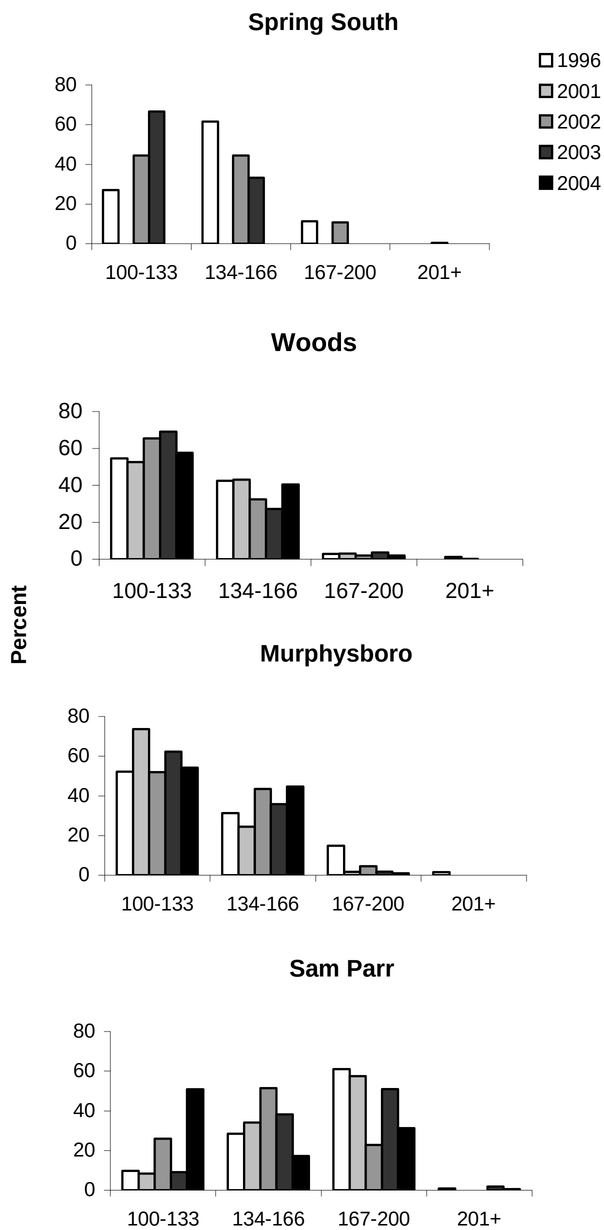

Figure 3-5: Length frequency from spring electrofishing expressed as percent of the total catch for lakes that were designated as quality bluegill lakes and are receiving the stocking treatment.

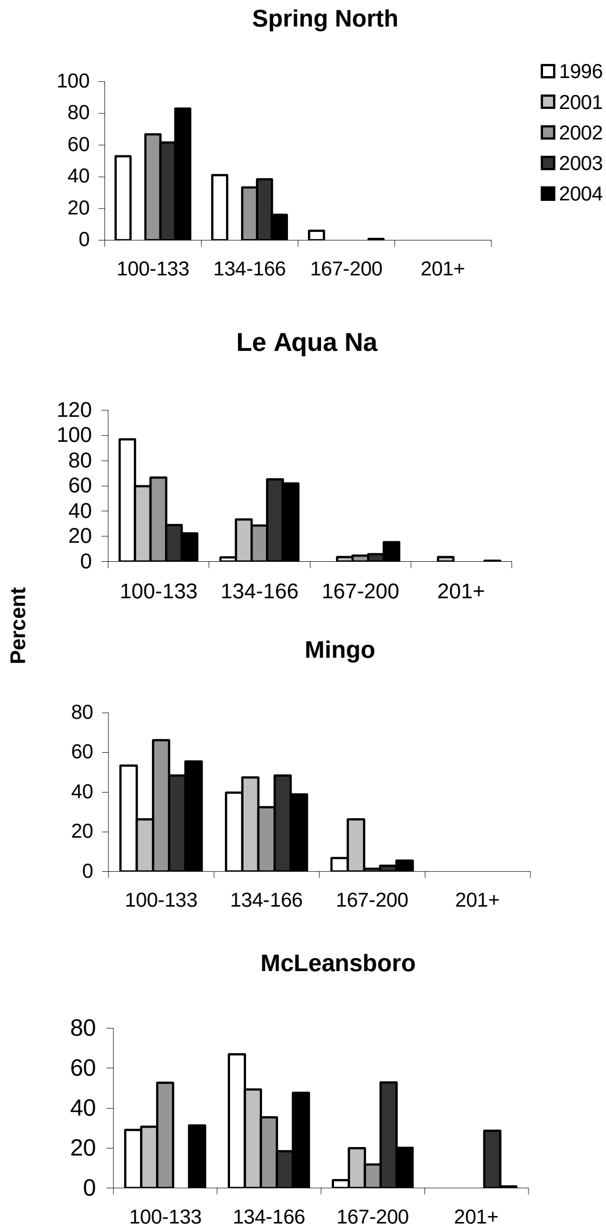

Figure 3-6: Length frequency from spring electrofishing expressed as percent of the total catch for lakes that were designated as stunted bluegill lakes and are receiving the stocking treatment.

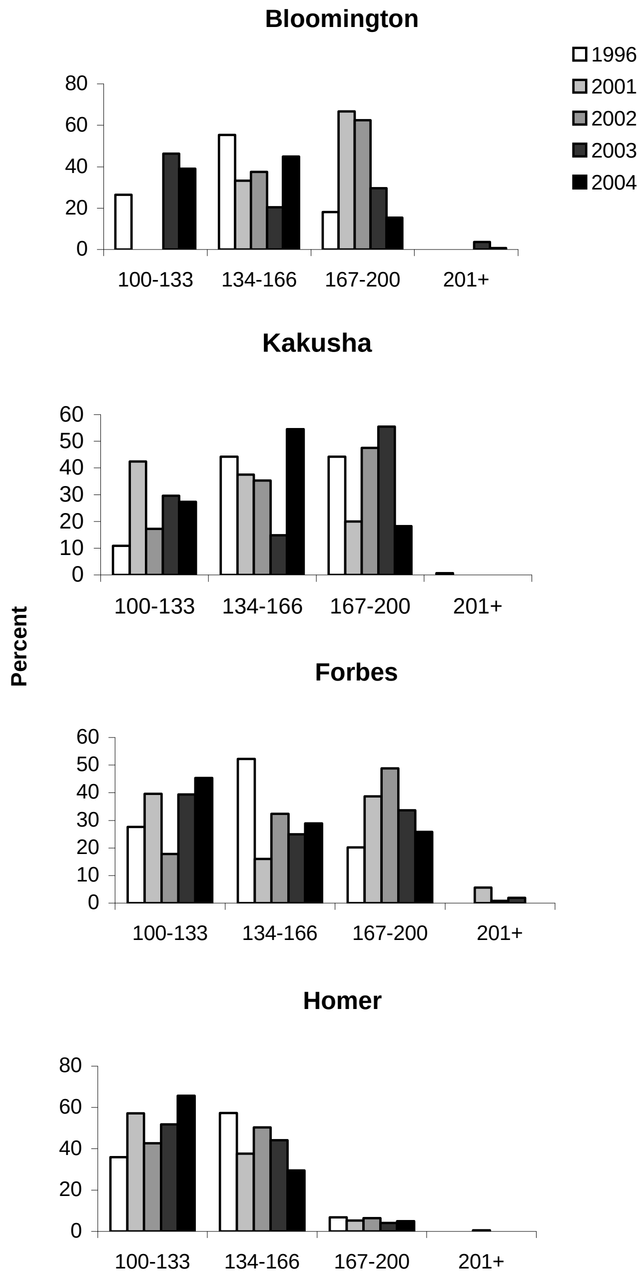

Figure 3-7: Length frequency from spring electrofishing expressed as percent of the total catch for lakes that were designated as quality bluegill lakes and are receiving the stocking and regulation treatment.

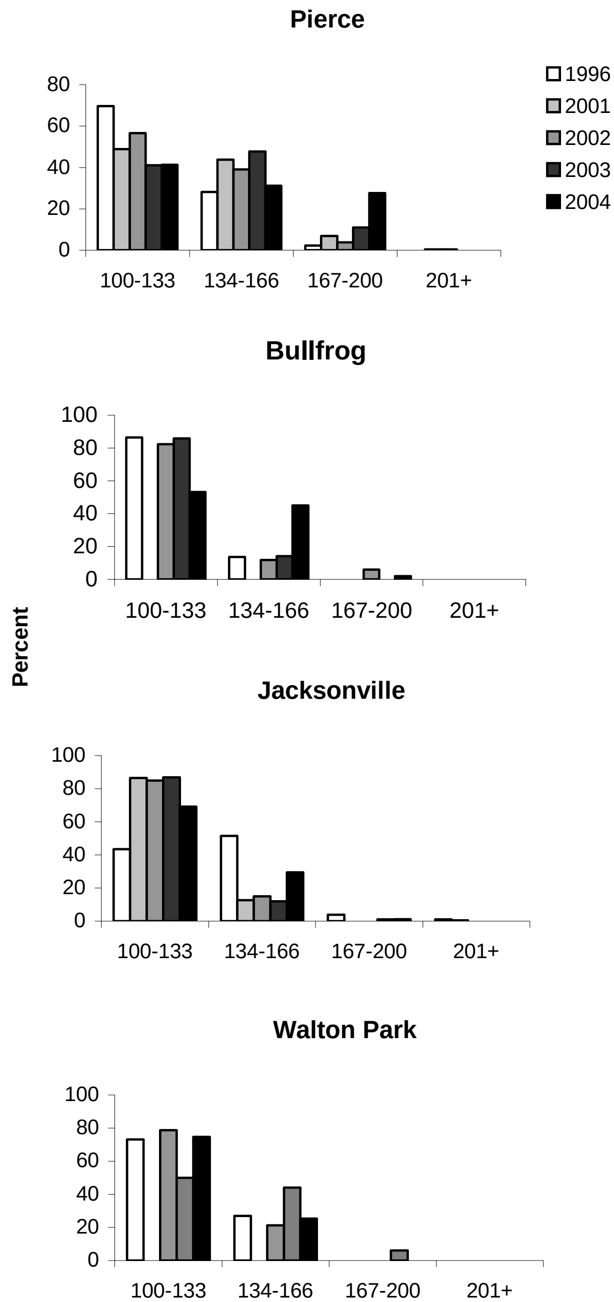

Figure 3-8: Length frequency from spring electrofishing expressed as percent of the total catch for lakes that were designated as stunted bluegill lakes and are receiving the stocking and regulation treatment.

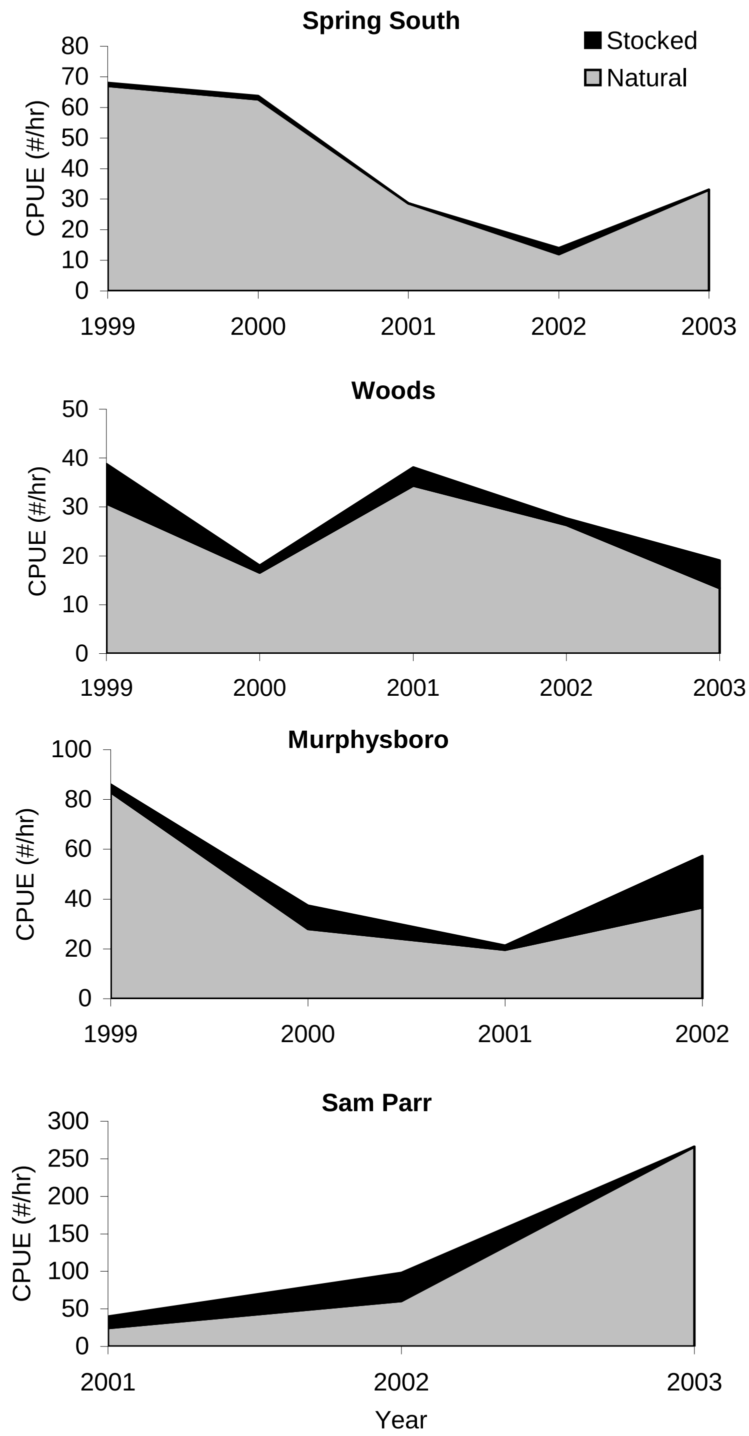

Figure 3-9: Contribution (CPUE, #/hr) of stocked (black), and natural (gray) largemouth bass to the total population in quality stocking treatment lakes during 1999-2003. Electrofishing samples were performed in the spring during May and June.

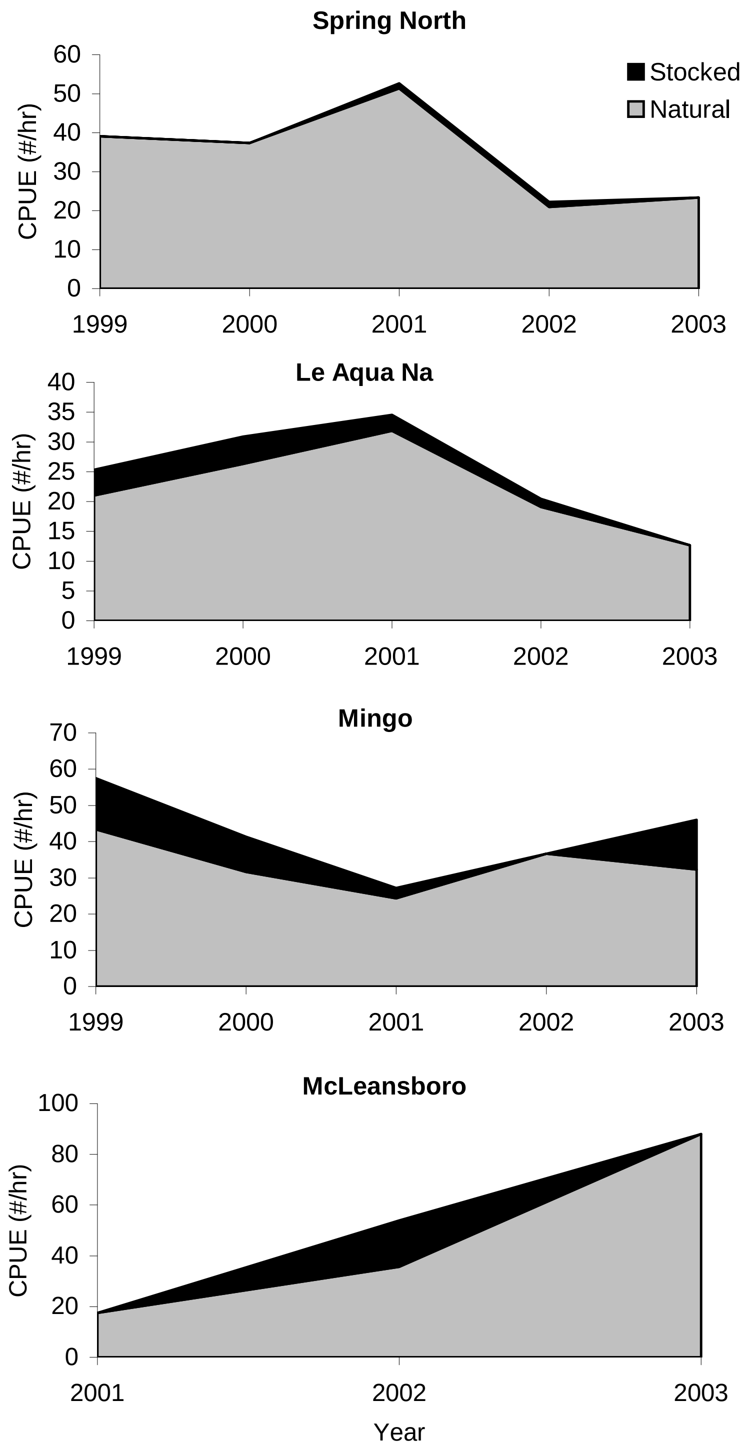

Figure 3-10: Contribution (CPUE, #/hr) of stocked (black), and natural (gray) largemouth bass to the total population in stunted stocking treatment lakes during 1999-2003. Electrofishing samples were performed in the spring during May and June.

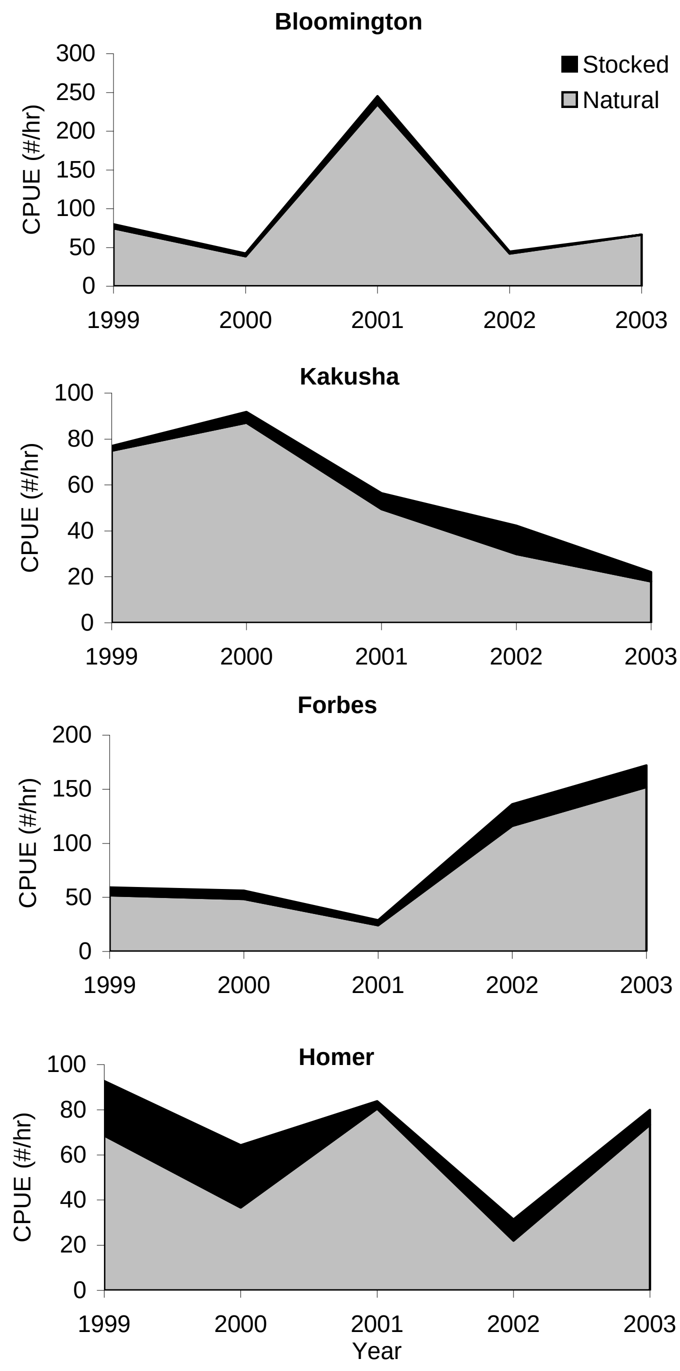

Figure 3-11: Contribution (CPUE, #/hr) of stocked (black), and natural (gray) largemouth bass to the total population in quality stocking and regulation treatment lakes in 1999-2003. Electrofishing samples were performed in the spring during May and June.

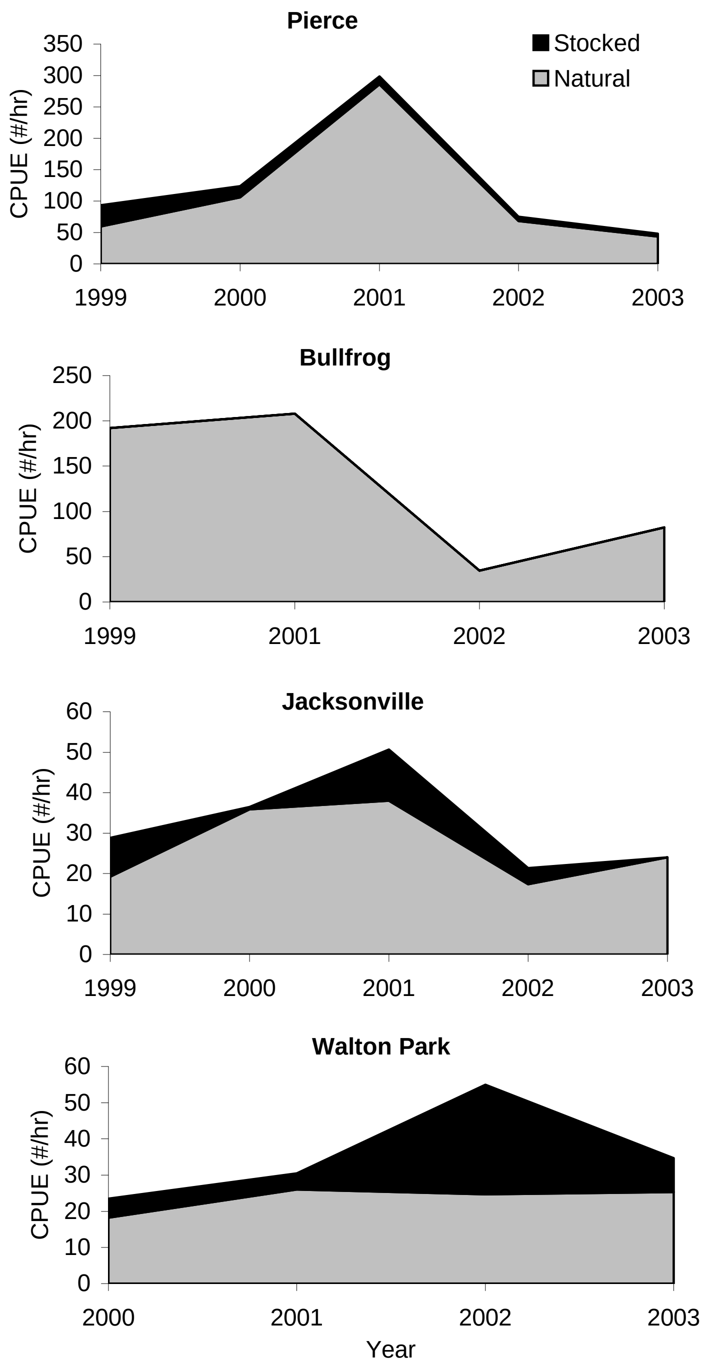

Figure 3-12: Contribution (CPUE, #/hr) of stocked (black), and natural (gray) largemouth bass to the total population in stunted stocking and regulation treatment lakes in 1999-2003 Electrofishing samples were performed in the spring during May and June.

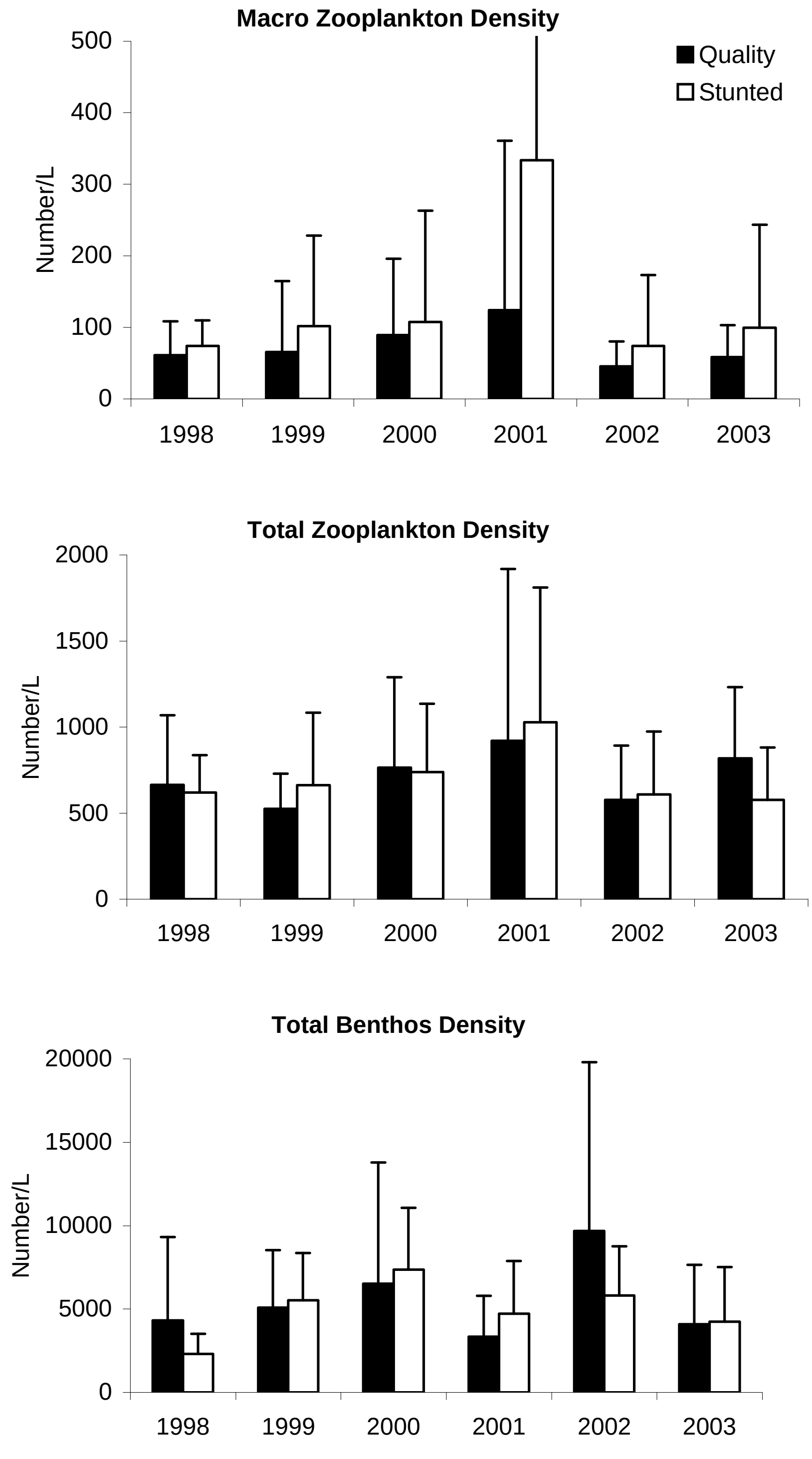

Figure 3-13: Mean zooplankton, macrozooplankton and benthos density by year in quality and stunted bluegill lakes. Bars indicate standard deviation.