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CENTER FOR AQUATIC ECOLOGY

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QUALITY MANAGEMENT OF BLUEGILL: FACTORS AFFECTING POPULATION SIZE STRUCTURE

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Disclaimer:
This study is conducted under a memorandum of understanding between the Illinois Department of Natural Resources and the Board of Trustees of the University of Illinois. The actual research is performed by the Illinois Natural History Survey, a division of the Illinois Department of Natural Resources. The project is supported through Federal Aid in Sportsfish Restoration by the U.S. Fish and Wildlife Service, the Illinois Department of Natural Resources, and the Illinois Natural History Survey. The form, content, and data interpretation are the responsibility of the University of Illinois and the Illinois Natural History Survey, and not the Illinois Department of Natural Resources.

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Executive Summary

During this 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, harvest regulations, predator stocking, and a combination of harvest regulations and predator stocking. Treatments have equal representation from regional, lake size, and bluegill size structure classifications of lakes. This segment summarizes ongoing laboratory and data analysis. The final report for this project will be completed in March 2007.

All study lakes had creel surveys completed at the end of the experiment. In this segment, as part of Job 101.1, creel data was compiled for all study lakes. Initial analysis for the study lakes was completed and analyzed as part of the post-implementation evaluation of experimental treatments. Lakes were examined for changes in PQBG 170 (proportion of bluegill over 170 mm). Creel data showed little change in the percent of anglers targeting bluegill at a lake when compared to creel data prior to the management experiment. Creel surveys were conducted on eight lakes in 2005, which completed the creel surveys for all 32 lakes in the management experiment. These surveys were 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 2005 creel surveys, completed in October 2005, will be presented in the final report. 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 continued analysis using size specific growth rates for bluegill.

The purpose of this analysis is to evaluate the biotic and abiotic factors that are important determinants of the size specific growth rate of a bluegill population. We calculated best-fit size-specific growth functions for ten lakes. Variation in size specific growth rate is large enough to justify further evaluations of the causal mechanisms that influence size specific growth. The final analysis will be presented in the final report.

In Job 101.3, we completed the processing of field samples to examine the outcome of the management experiment. All samples collected through electrofishing in previous segments were dissected and examined for maturity status, GSI score, age, and growth in this segment. These data will be used in the final analyses of the bluegill management experiment in order to determine the effect of regulations and predator stockings on bluegill population size structure. Otoliths were aged twice and verified for age agreement in all 32 of the study lakes. Length-at-age was determined in each of these lakes and compared to 1996 data. Thus far, few changes in mean size of bluegill in each age class were observed as part of the management experiment lakes between 1996 and 2005.

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 of 2006 was used to determine any shifts in bluegill size structure from 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 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 bass densities are not successfully increased.

In previous segments, conservation officers conducted interviews on select lakes, to assess angler compliance on lakes with the experimental regulation. In this segment, compliance check data was compiled and summarized in order to evaluate the affects of varying compliance levels on the success of the experimental regulation. Overall, compliance was high on most lakes. We will use these compliance check data in the final assessment of the success 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 during the course of the study that might influence the results of the management experiment. Data collected in the current segment were 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 different management treatments. These results suggest that macrozooplankton and benthic invertebrate abundance and utilization 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 previous years 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, in terms of 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 (see Table 1-1 in previous report, Diana et al 2004). 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 (Olson 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 effectively realized.

PROCEDURES

The current year's efforts were designed to use creel surveys, conducted under project F-

69-R-18, to build on previous project segments and evaluate the implementation of various management actions under Job 101.3. Creel surveys were completed on all study lakes in 2005. 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 2005 are now available and will be presented in the final report. The creel data will be used to evaluate 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 were reported in previous segments. Catch rates for bluegill were calculated for the pre and post-regulation periods for all study lakes (Table 1-1). For the final report, this data will be analyzed for changes in catch rates through the experiment among different treatments. Mean weight of bluegill caught was also calculated from pre and post treatment on the study lakes (Figure 1-1). No large differences in the mean weight of bluegill harvested by anglers were observed for any experimental treatment. This data will be combined with addition creel estimates and further analyzed for the final report.

RECOMMENDATIONS

Creel surveys were completed on all of the 32 experimental lakes by the 2005 season.

Analyses of the entire complement of 32 lakes will be included in the final report. These analyses should include inter- and intra-treatment comparisons, long-term trends in creel data on bluegill study lakes, and will be incorporated into analyses under Job 101.2 and Job 101.3.

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 projects have been dedicated to investigating methods to increase the growth of many sportfish species, and even how to produce trophy fisheries. 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. Stunted bluegill populations (most adult bluegill measuring 150mm or less) are one of the more common problems fisheries managers face. 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 quality fishing opportunities, we need to understand the factors that are driving population size structure.

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 male bluegill reproduction includes parental 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.

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). Therefore, to better understand the multivariate nature of factors that can ultimately influence individual body size it is important, to consider biotic, abiotic, ecological, and behavioral parameters in a single analysis.

In previous reports we have used AIC to relate biotic, abiotic, ecological, and behavioral parameters with the mean size of bluegill at both age-2 and age-5. However, since fish growth is primarily a function of size rather than age, we would also like to relate these variables using size-specific growth rates (Putman et al. 1995). In this report, we begin to lay the framework for this AIC analysis using fish collected in 2004-2005. We report the size specific growth rates for fish from ten lakes and present a number of biotic and abiotic variables from four of these lakes that can be used in AIC. For the final report, the size specific growth rates for all 16 lakes where we have abiotic and biotic measurements will be calculated and Akaike Information Criterion (AIC) will be used to relate the biotic and abiotic factors with the size specific growth rates of these lakes.

PROCEDURES

For this report, we calculated the size-specific growth rate for ten lakes where we have completed aging (Table 2-1 and 2-2). In order to calculate these size specific growth rates, we removed otoliths from fish from each lake. Each fish was independently aged by two readers and the radius of each otolith to each annulus was measured. The Fraser-Lee method was then used to estimate the growth (mm) of each fish during each year of life. These growth increments were then plotted against the initial length of each fish at the beginning of each growing season and the best-fit regression function (linear, quadratic, or log-linear) was determined for each lake. Two size-specific growth functions were fitted for each lake; one for 3-year old fish and the other for 4-year old fish. The derivation of separate functions for different age classes of fish allows us to relate the abiotic and biotic factors (Table 2-3 and 2-4) for each lake and year to specific fish life stages. The best-fit regression equation was then used to estimate the average size specific growth rate of fish from each age class in each lake at 60 mm (representing the average size of immature bluegill across all study populations) and 120 mm TL (representing the smallest size that bluegill begin to become sexually mature). Annual averages of the biotic and abiotic variables (Table 2-3 and 2-4) were calculated for 2000-2003 for each lake.

FINDINGS

We calculated best-fit size-specific growth functions for ten lakes (Table 2-1 and 2-2). The shape of these functions varied depending on the lake, following either a linear or quadratic, or log-linear function. The average size specific growth rate at 60 mm TL for three year old fish (Table 2-1) ranged from a low of 29.1 (Apple Canyon) to a high of 68.0 (Walnut Point) mm/yr. The average size specific growth rate at 120 mm TL for three year old fish ranged between 16.4 (Wood) and 54.5 (LeAquaNa) mm/yr. The average size specific growth rate at 60 mm TL for four year old fish (Table 2-2) ranged from a low of 33.5 (Lake of the Woods) to a high of 69.9 (Walnut Point) mm/yr. The average size specific growth rate at 120 mm TL for three year old fish ranged between 18.4 (Wood) and 58.8 (Pierce) mm/yr. This variation in size specific growth rate is large enough to justify further evaluations of the causal mechanisms that influence size specific growth. Possible causal mechanisms include lake size (ha), latitude, and a number of abiotic (surface temperature (C), secchi depth (m), phosphorous concentration (µg/L)) and biotic (chlorophyll concentration (µg/L), zooplankton densities (#/L), and benthic invertebrate density (#/m^3)) variables (Table 2-3). Other causal mechanisms might include the catch per unit effort of bluegill and other fish species that are bluegill predators or competitors (Table 2-4).

RECOMMENDATIONS

Our previous analyses found that zooplankton, temperature, and age at maturity affect bluegill growth in Illinois. Specifically, bluegill length at age-5 increased with daphnia abundance, mean summer air temperature, and age at maturity. Management strategies can address age at maturity (see Job 101.3); however, expectations of growth must be based on location of the population due to geographic and seasonal variability in summer air temperatures. Therefore, we should not expect bluegill populations in the north to experience the same growth rates as in the south despite similar management options. We will finish these analyses and present them in the final report.

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 the mechanism by which growth is affected. 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 will also take an information-theoretic approach. 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). The analyses may be required if all of the potential causative variables are to be considered simultaneously.

For the final report, we will calculate the size-specific growth rates for the remaining lakes. In addition, we will determine annual averages for the biotic and abiotic variables for the study lakes. We will compute these values for a total of 16 lakes from which we have adequate abiotic and biotic data. We will then use AIC to determine the relationship between these variables and size-specific growth rate.

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 affect 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, therefore, can be greatly impacted by harvest. Both pre- and post-maturation growth rates are directly affected by density-dependent processes (i.e., slower growth rates due to intraspecific competition 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 and densities 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 still unclear. As a result, we collected 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) that 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 strategy 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 job, we continued to evaluate data collected from/ experimental bluegill populations to determine the influence of the management manipulations on 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): harvest regulations (8-inch minimum size limit, 10 fish daily creel limit); predator stockings (largemouth bass added to increase predation on juvenile bluegill); and harvest regulations and predator stockings in combination; and 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 analysis: 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). As such, 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. A subsample of the lakes 8 of 36) were sampled for bluegill (juvenile and adults) and largemouth bass (as a predator) abundance. Samples were completed in the experimental lakes during the past segments and final analyses were begun to assess the effects of the management experiment.

All bluegill collections associated with the conclusion of the management experiment were completed in the previous segment. In this segment, all bluegill collected in 2004 and 2005 were dissected and gonads were weighed and examined for maturity status. To analyze the bluegill collected in each lake sampled, individuals were thawed and total length, weight, and sex determined. In addition, gonads were identified as to stage of development and weighed. Individuals were 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 were considered immature, having no or very little gonad development, whereas individuals with scores of four and five exhibited mature gonads; yolked eggs were present (females; Justus and Fox 1994) or testes were fully developed and running sperm (males). This data was used to determine the age of maturity for the bluegill population in each study lake. Otoliths were also removed from each bluegill for age and growth analysis. This data was used to determine age-specific growth curves, age at maturation, and abundance of cuckolders, males that mature early and steal fertilizations. All otoliths were read in whole view. When reader ages disagreed, a third reader was used to verify the correct age. The final age was then used to evaluate changes in growth using length-at-age for male and female bluegill separately. Length at age data was then compared to samples collected in 1996 to determine if changes in growth occurred.

Bluegill Population Parameters

In this segment we continued to assess 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 were 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 fall of 2005 and spring of 2006 in order to compare length frequencies between pre- and post-regulation populations. A fall sample was collected in September or October in 2005 from 11 of the 32 experimental lakes to examine population length frequencies.

Prey Availability

Prey availability may influence the relative abundance of bluegill and 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.

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.

As part of the management experiment, 16 lakes were stocked with advanced fingerling largemouth bass to increase predator densities. Largemouth bass stocking was concluded in 2004. In this segment, we continued to assess the contribution of adult stocked bass that were initially stocked as fingerlings to the bass population and any changes in total abundance of largemouth bass. We monitored growth and survival of stocked bass through the first fall after they were stocked and in subsequent years. To quantify largemouth bass abundance, fall 2005 and spring 2006 electrofishing surveys were conducted on five of the experimental lakes (Woods, Mingo, Homer, Pierce and Jacksonville). 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 and measured for total length. 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 in previous segments. 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*. In this segment, data was compiled for the final analysis. These factors will be examined in the final report to determine their influence on bluegill growth and the success of the regulations.

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 completed these cards each time they performed a bluegill regulation check on an experimental lake. The compliance data will be used to evaluate the success of the regulation for the final report.

FINDINGS

All bluegill collections were completed in previous segments. During this segment, dissection was completed on all samples collected in 2004 and 2005 from the 32 experiment lakes and sex and gonad score was determined for each collection. Aging by the first and second reader was also completed on all of the experiment lakes. Otoliths have been verified for agreement on all experimental lakes. Mean length was calculated for each age for male and female bluegill for 14 lakes in previous segments. In this segment, length at age was calculated for 8 additional lakes with verified age data (Figures 3-1 to 3-4). Very few changes in mean size-at-age were observed for male and female bluegill since initial samples in 1996. Thus far, growth rates of bluegill in the management experiments appears to remain relatively unchanged in all treatments.

In this segment, length frequency data was compiled for 2006 spring electrofishing for 11 of the 32 experimental lakes to examine changes in the relative abundance of adult bluegill. This data was then added to previous length frequency data and examined for changes in the bluegill population size structure. Length frequency analysis revealed variable changes among study lakes in response to experimental regulations (Figures 3-5 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 few changes in length frequency distribution, with some year-to-year variation (e.g., Lincoln Trail and Paris, Figure 3-5). Control lakes that were designated quality bluegill populations at the start of the experiment continued to be quality in 2006 (Figure 3-5). Control lakes that were designated stunted initially, also remained stunted (Figure 3-5).

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. Generally, regulation treatment lakes showed few changes in bluegill size structure, with some exceptions. 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 3-7). 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. One lake sampled in 2005 and 2006 that was initially designated stunted and was in the regulation and stocking treatment showed some increases in size structure in 2006 (Pierce; Figure 3-8). This lake is showing some increases in the proportion of fish in the larger size classes. Because this was a stunted lake, the increases are occurring in the 167-200 mm size class. We are also beginning to observe some fish in the larger size classes in stunted lakes (Forbes and Homer; Figure 3-8). Because there were no major shifts in size structure, we will also focus on examining changes in age of maturation.

No additional prey resource data was collected in the current segment. During 2006, we processed and analyzed zooplankton and benthos samples samples collected in 2004 and 2005 (Figure 3-9). Multiple years of data (1998-2005) 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 1998–2005. These fluctuations were generally 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 that are observed 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 variability in growth and influences on age at maturity.

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

The contribution of largemouth bass in stocked lakes varied greatly by lake (Figures 3-10, 3-11). The experimental lakes sampled in 2005 and 2006 showed some contribution of stocked largemouth bass to the total bass population, but did not show any overall increases in numbers of bass over the duration of the experiment. The total abundance of bass in the stocking lakes has been variable throughout the management experiment. Few lakes have shown increases in the total bass population as a result of the stocking of additional largemouth bass. The varied success with increasing the number of predators in the study lakes 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.

In previous segments, angler compliance was assessed through checks completed by conservation police officers. Final analysis of compliance and stocking data will be included in the final report in order to assess the success of the experimental treatments on bluegill populations.

RECOMMENDATIONS

For the final report, we will complete the final checking of aging data on all dissected bluegill. We will calculate the length-at-age and age at maturity for the remaining lakes. Data collected at the end of the experiment will be combined with those from initial samples to generate final conclusions regarding the success of the experimental regulations. We will calculate age of maturity, PQM170, and growth for bluegill in all the experimental lakes. These results will be compared to data collected before the start of the experiment. Length frequency analysis during the management experiment revealed that a few stunted lakes receiving both stocked bass and the experimental regulation were showing some indications of improvement in bluegill size structure. Overall, lakes showed a high amount of variability in size structure and few lakes showed consistent increases in size structure. Changes in bluegill growth and age of maturity must be examined before any conclusions can be made regarding the management manipulation. These analyses will reveal if any changes in age of maturity and growth occurred as a result of the management manipulations.

In the final report, we will finish examining bluegill population parameters, prey and predator abundances, and fish community variables in the study populations to determine mechanisms responsible for any alteration in bluegill population size structure that may have resulted 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, the size structure of the population.

We will examine changes in prey availability in the experimental lakes to verify that any changes or lack there of in bluegill size structure are not being caused by changes in prey abundance. Diet data processing will be completed for the final report to determine differences in prey selection by bluegill at each life stage. In addition, differences in prey selection and prey availability within populations will be determined to provide insight into optimal food resources for bluegill in these eutrophic and hypereutrophic lakes.

We will complete analysis of stocked fingerling largemouth bass in the predator manipulation treatment lakes. Stocking bass has had varied success across the 16 study lakes and will need to be related to changes in treatments. Based on data collected from conservation officers, compliance was high across most of the regulation lakes. These data will also be used in the final analysis of effects on regulation success in the treatment lakes. Analysis of changes in bluegill size structure will take the level of compliance and success of the bass stockings into account in order to fully understand reasons for changes or lack there of in bluegill size structure. 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.

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).

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Table 1-1: Pre and Post-treatment catch rates for bluegill in each experimental lake. Data was collected using creel surveys completed at the beginning and the end of the management experiment.

			Pre-Treatment			Post-Treatment		
Lake	Treatment	Qual/Stunt	Year	#/AngHr	#/Acre	Year	#/AngHr	#/Acre
Lincoln Trail	C	Q	1996	0.089	13.93	2004	0.629	158.14
Siloam Springs	C	Q	1997	0.279	129.29	2005	0.342	92.08
Glendale	C	Q	1999	0.828	103.82	2003	0.313	52.52
Apple Canyon	C	Q	2000	0.806	171.98	2005	1.185	180.86
Hillsboro	C	S	1999	0.158	19.40	2003	0.261	28.69
Paris East	C	S	1999	0.438	68.03	2004	0.473	66.69
Round	C	S	1999	0.227	13.86	2004	0.419	25.38
Sterling	C	S	2000	0.212	77.58	2003	0.154	66.14
Spring Lake South	M	Q	1996	0.319	40.42	2005	1.369	106.95
Sam Parr	M	Q	1997	1.671	481.15	2005	0.341	84.92
Murphysboro	M	Q	2000	0.642	83.36	2004	0.535	73.77
Woods	M	Q	2000	0.473	89.28	2003	0.142	66.29
Le-Aqua-Na	M	S	1994	0.147	110.85	2004	0.467	332.47
McLeansboro	M	S	1999	0.094	10.53	2003	0.305	58.30
Mingo	M	S	1999	0.393	93.14	2003	0.457	126.84
Spring Lake North	M	S	1999	1.948	135.45	2004	0.659	24.36
Busse	R	Q	1989	0.100	52.88	2004	0.380	104.94
Mermet	R	Q	1997	0.050	4.12	2004	0.725	34.76
Walnut Point	R	Q	1997	0.308	112.59	2003	0.996	394.81
Red Hills	R	Q	2000	0.284	101.62	2003	0.479	197.46
Dolan	R	S	1998	0.388	128.21	2003	0.123	50.31
Lake of the Woods	R	S	1998	0.817	819.72	2005	0.312	374.95
Tampier	R	S	1998	0.117	167.35	2004	0.172	99.55
Pana	R	S	1999	0.226	12.05	2005	0.569	27.19
Bloomington	RM	Q	1996	0.286	24.72	2003	0.240	26.48
Kakusha	RM	Q	1998	0.137	39.67	2004	0.528	150.04
Forbes	RM	Q	1999	0.470	44.98	2005	0.182	12.38
Homer	RM	Q	1999	0.300	139.29	2003	0.522	192.68
Bullfrog	RM	S	1998	0.362	951.55	2005	0.752	573.16
Jacksonville	RM	S	1999	0.304	11.62	2004	0.065	1.06
Pierce	RM	S	1999	0.207	115.90	2003	0.382	170.49
Walton Park	RM	S	1999	0.108	35.48	2004	0.186	122.60

Table 2-1: Best-fit size specific growth function, function type (linear, quadratic, or log-linear), r^2 of the best-fit function, and the sample size (n) that the function is based on growth for three year old fish from ten lakes. The size specific growth increment at 60 and 120 mm TL is also shown.

Lake	Formula	60 mm Increment	120 mm Increment	Type	r^2	n
Apple Canyon	$Y = 53.99312 - 0.81813x + 0.00673x^2$	29.14	52.74	Quadratic	0.354	84
Homer	$Y = 59.61107 - 0.16353x - 0.00114x^2$	45.69	23.55	Quadratic	0.634	51
Lake of the Woods	$Y = 56.04937 - 0.52306x + 0.00214x^2$	32.37	24.09	Quadratic	0.741	131
LeAquaNa	$Y = 54.8348 * x^{-0.00143}$	54.52	54.46	Log-Linear	0.375	36
Lincoln Trail	$Y = 55.48673 - 0.11777x + 0.00025x^2$	49.33	44.99	Quadratic	0.054	20
Mingo	$Y = 54.36948 * x^{-0.002457}$	53.83	53.73	Log-Linear	0.535	7
Pierce	$Y = 63.4313 - 0.31251x$	44.68	25.93	Linear	0.704	10
Red Hills	$Y = 61.73049 - 0.19659x$	49.93	38.14	Linear	0.333	8
Walnut Point	$Y = 59.50742 + 0.3336x - 0.00319x^2$	68.03	53.57	Quadratic	0.316	74
Wood	$Y = 69.0620 - 0.43898x$	42.72	16.38	Linear	0.784	12

Table 2-2: Best-fit size specific growth function, function type (linear, quadratic, or log-linear), r^2 of the best-fit function, and the sample size (n) that the function is based on growth for four year old fish from ten lakes. The size specific growth increment at 60 and 120 mm TL is also shown.

Lake	**Formula**	**60 mm Increment**	**120 mm Increment**	**Type**	**r^2**	**n**
Apple Canyon	$Y = 51.83110 - 0.50864x + 0.00391x^2$	35.37	47.03	Quadratic	0.44	27
Homer	$Y = 74.33226 - 0.64941x - 0.00176x^2$	41.71	21.78	Quadratic	0.88	29
Lake of the Woods	$Y = 59.61157 - 0.54571x + 0.00185x^2$	33.54	20.80	Quadratic	0.78	37
LeAquaNa	$Y = 46.14800 - 0.00263x + 0.00121x^2$	41.93	28.32	Quadratic	0.47	58
Lincoln Trail	$Y = 73.17501 - 0.37935x + 0.00074x^2$	53.08	38.33	Quadratic	0.68	43
Mingo	$Y = 62.42407 - 0.60143x + 0.00222x^2$	34.36	22.35	Quadratic	0.80	5
Pierce	$Y = 59.71175x^{-.00318}$	58.94	58.81	Log-Linear	0.68	37
Red Hills	$Y = 75.28200 - 0.33108x$	55.42	35.55	Linear	0.79	35
Walnut Point	$Y = 80.21622 - 0.07083x - 0.00168x^2$	69.91	47.51	Quadratic	0.83	5
Wood	$Y = 71.12969 - 0.57871x + 0.00116x^2$	40.58	18.36	Quadratic	0.88	17

Table 2-3: Surface area (ha), latitude (degrees), and abiotic, zooplankton (#/L), and benthic invertebrate density (#/m^3) data from Homer Lake, Lincoln Trail Lake, Lake Mingo, and Walnut Point Lake from 2000-2003. Size specific growth rates were computed using a lake specific regression equation and will be compared to the other variables using AIC. Surface temperature is based on the mean bi-weekly surface temperature collected May-August. Secchi depth, phosphorous concentration, chlorophyll a concentration and zooplankton densities are based on bi-weekly samples collected May-October. Benthic invertebrate densities are based on samples collected in June and August using a modified stovepipe sampler. We show information from 4 of the 16 lakes here.

Lake	Surface Area (ha)	Latitude (degrees)	Year	Surface Temperature (degrees C)	Secchi Depth (m)	Phosphorous Concentration (μg/L)	Chlorophyll a Concentration (μg/L)	Total Zooplankton Density (#/L)	Cladoceran Density (#/L)	Rotifer Density(#/L)	Benthic Invert. Density (#/m^3)
Homer	32.7	40.05	2000	*	0.5	113.9	26.0	362.2	14.9	239.7	2857.0
			2001	25.5	0.6	58.2	37.7	772.6	17.0	504.7	8060.0
			2002	23.9	0.6	107.7	22.2	438.3	15.6	288.4	7747.0
			2003	22.7	0.7	150.4	32.0	1502.4	10.9	1372.7	3333.0
Lincoln Trail	56.9	39.2	2000	24.5	3.1	25.1	10.8	322.3	12.2	226.8	3207.3
			2001	26.8	3.1	27.0	10.7	549.5	17.3	452.8	3984.1
			2002	25.1	1.0	81.0	17.2	342.0	7.5	260.6	6406.9
			2003	25.2	1.6	195.6	18.6	541.7	5.6	439.0	7888.4
Mingo	71.7	40.13	2000	22.6	0.9	28.5	19.3	653.8	28.2	439.9	6823.0
			2001	26.8	1.1	<1.0	16.1	446.7	16.2	247.3	5057.0
			2002	24.6	1.1	77.4	17.7	813.9	23.5	628.3	3729.0
			2003	23.6	0.7	182.1	21.3	603.5	10.0	488.8	1394.0
Walnut Point	21.8	39.42	2000	23.8	1.3	64.1	35.7	866.4	34.9	754.8	7188.8
			2001	25.5	1.1	45.8	40.4	1313.3	13.1	1241.2	2448.6
			2002	25.2	0.8	93.0	35.4	1313.0	15.6	1235.9	6054.5
			2003	24.1	0.9	255.5	34.4	1366.4	25.5	1252.5	1504.6

* = Missing Data

Table 2-4: Fish catch per unit effort (CPUE; # caught/ hour) for 2000-2003 from Homer Lake, Lincoln Trail Lake, Lake Mingo, and Walnut Point Lake. CPUE is based on the number of fish collected per hour of AC electrofishing in the spring. In the future, the relationship between this data, the size specific growth rate from each lake, and a variety of other biotic and abiotic variables will be determined using AIC. We show information from 4 of 16 lakes here.

Lake	Year	Bluegill CPUE (#/hr)	CPUE of Bluegill >140 mm TL (#/hr)	CPUE of Bluegill <60 mm (#/hr)	Largemouth Bass CPUE (#/hr)	Shad CPUE (#/hr)
Homer	2000	434.5	10.3	287.9	55.1	0.0
	2001	184.0	44.0	39.3	83.8	162.3
	2002	107.7	12.0	61.7	30.4	78.0
	2003	139.3	26.0	15.3	80.0	67.3
Lincoln Trail	2000	752.2	1.9	650.7	57.1	0.0
	2001	318.3	8.7	128.3	56.0	0.0
	2002	263.3	4.7	73.3	92.3	0.0
	2003	99.2	4.8	19.8	87.8	0.0
Mingo	2000	680.5	9.8	487.2	41.4	0.0
	2001	97.5	18.9	22.8	36.9	34.3
	2002	108.0	5.3	81.3	36.7	43.3
	2003	130.0	6.0	60.0	43.3	42.0
Walnut Point	2000	24.8	30.7	6.3	232.3	0.0
	2001	164.3	38.7	52.7	102.3	0.0
	2002	230.0	18.7	82.0	85.3	0.0
	2003	137.3	19.3	47.3	63.7	0.0

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	Predator Stocking	Regulation/Predator 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

Control

Regulation Treatment

Stocking Treatment

Regulation & Stocking Treatment

Figure 1-1: Total mean weight of bluegill harvested in each of the four experimental treatments.

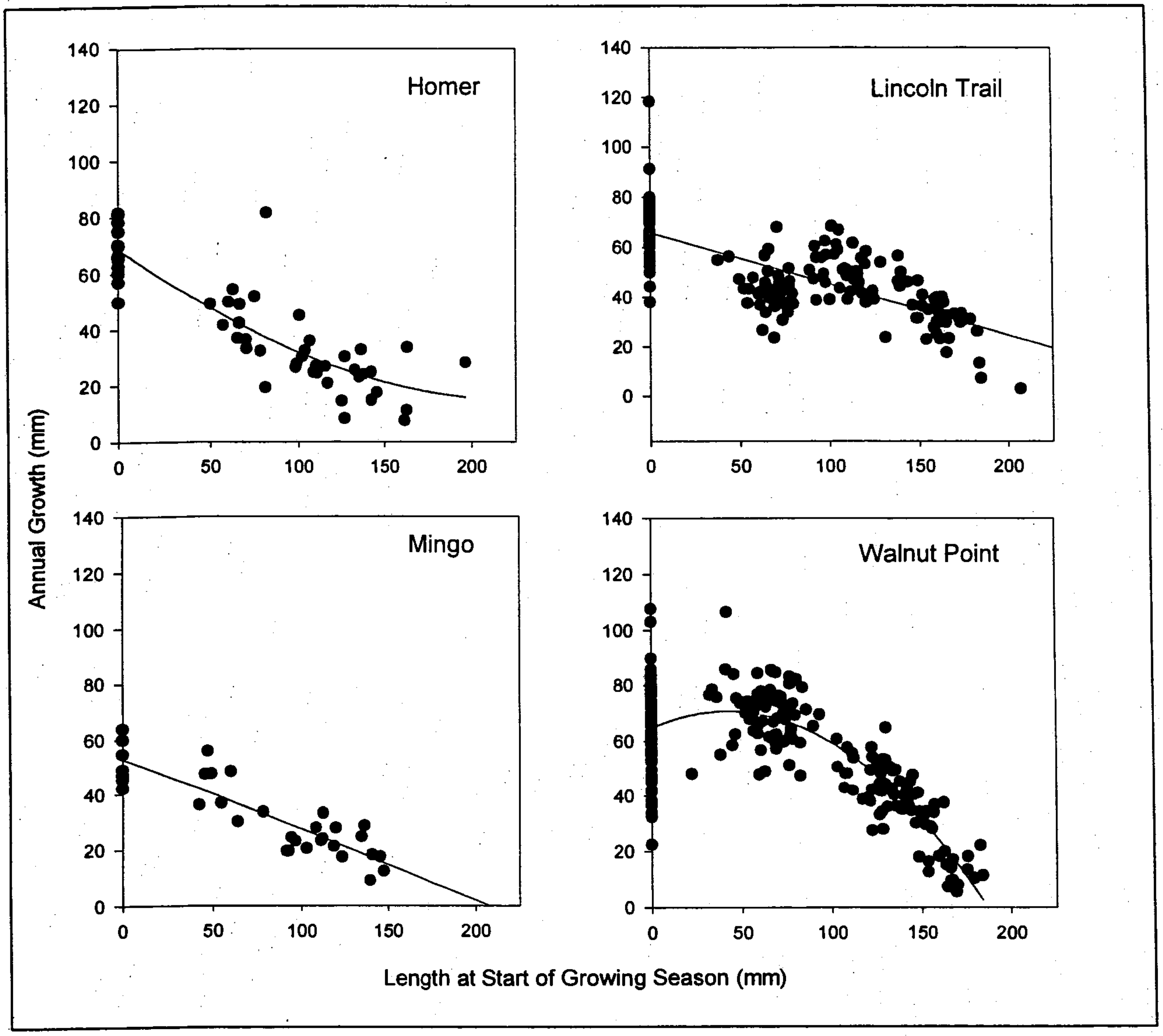
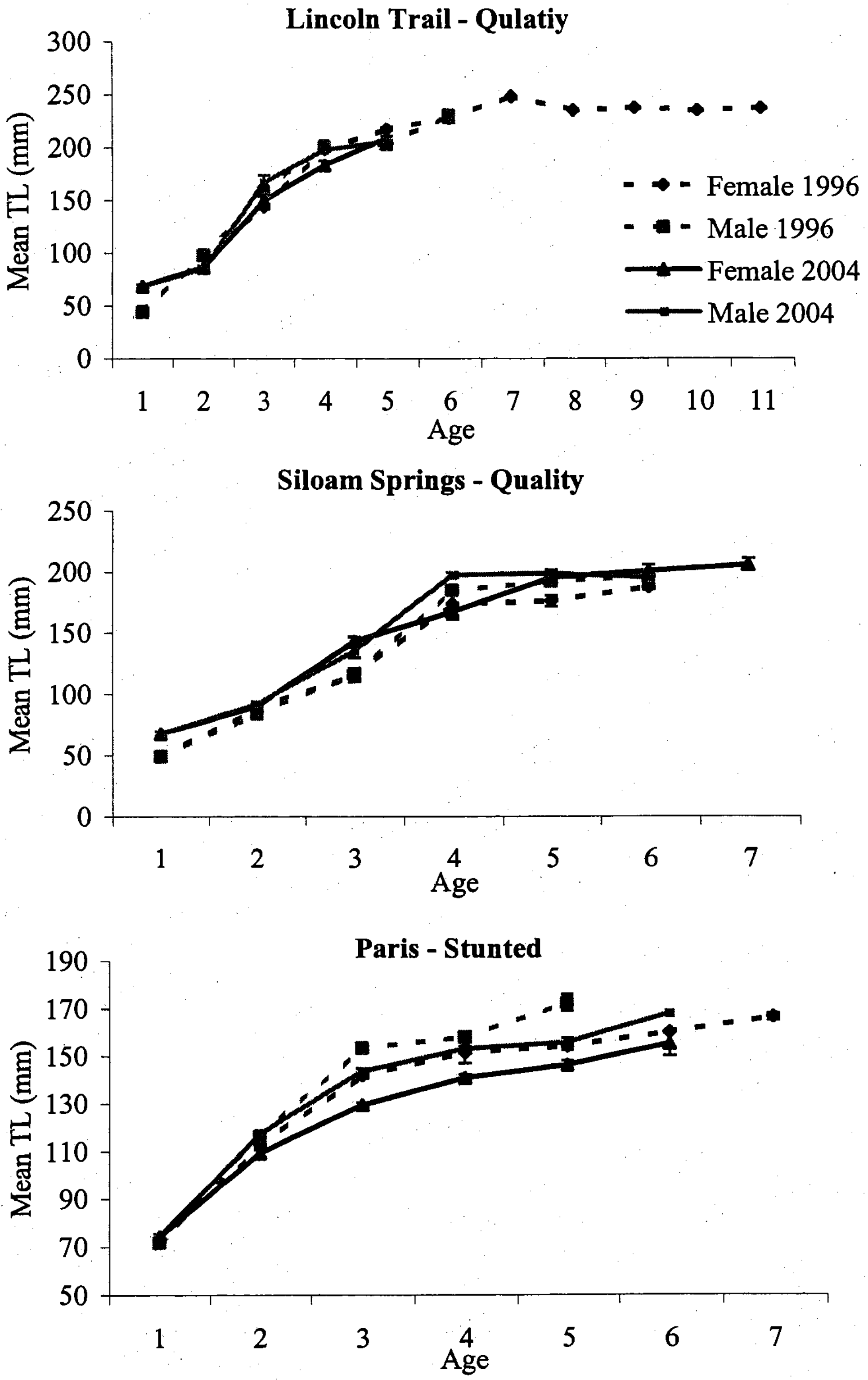


Figure 2-1: Scatterplot and regression lines describing the average size-specific growth rate of bluegill from Homer Lake, Lincoln Trail Lake, Lake Mingo, and Walnut Point Lake. Size specific growth rates were determined through the back calculation of otoliths from bluegill that were collected in spring 2004.



Lincoln Trail - Qulatiy

Siloam Springs - Quality

Paris - Stunted

Figure 3-1: Mean size at age for bluegill captured in 1996 and 2004 through AC electrofishing in lakes receiving the control treatment. Error bars represent standard error.

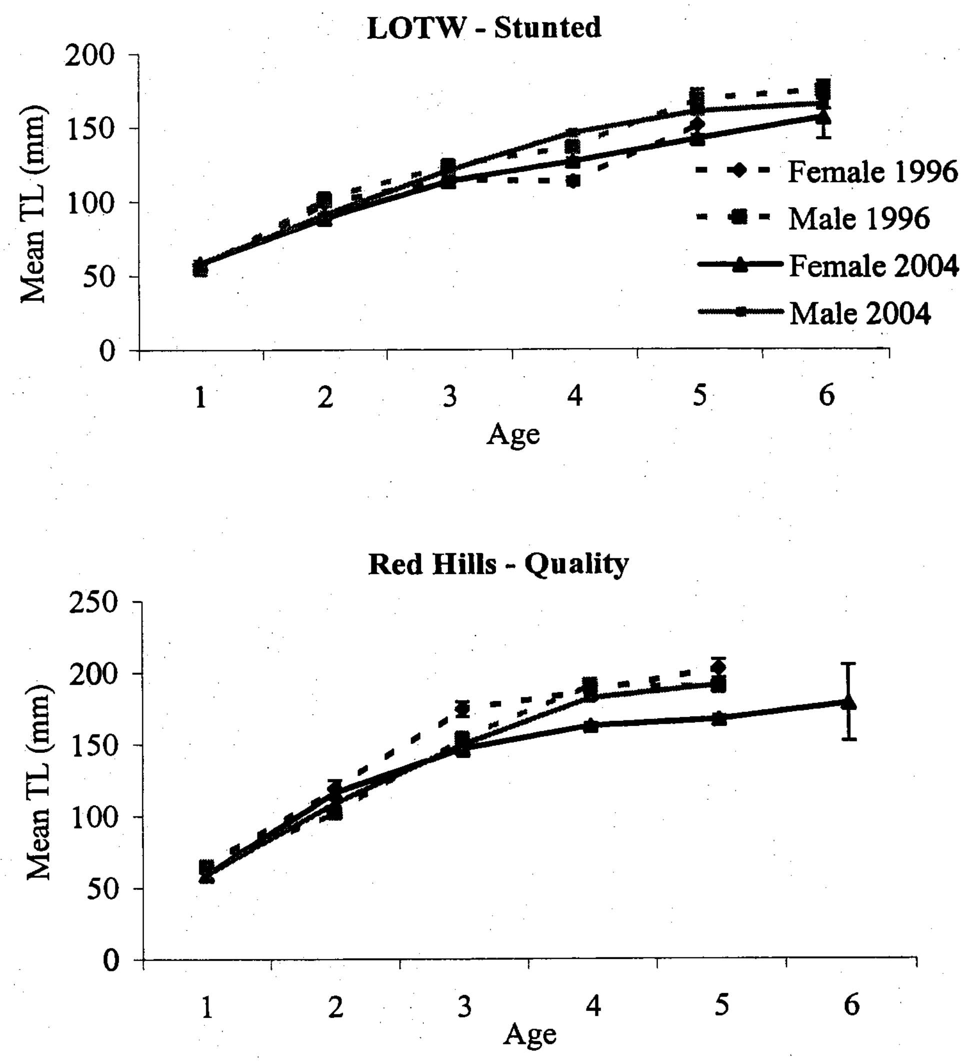


Figure 3-2: Mean size at age for bluegill captured in 1996 and 2004 through AC electrofishing in lakes receiving the stocking treatment. Error bars represent standard error.

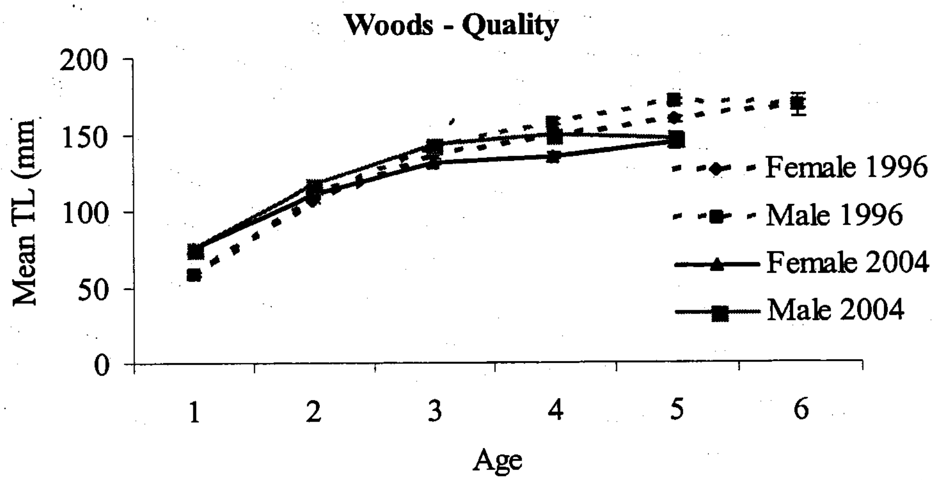


Figure 3-3: Mean size at age for bluegill captured in 1996 and 2004 through AC electrofishing in lakes receiving the stocking treatment. Error bars represent standard error.

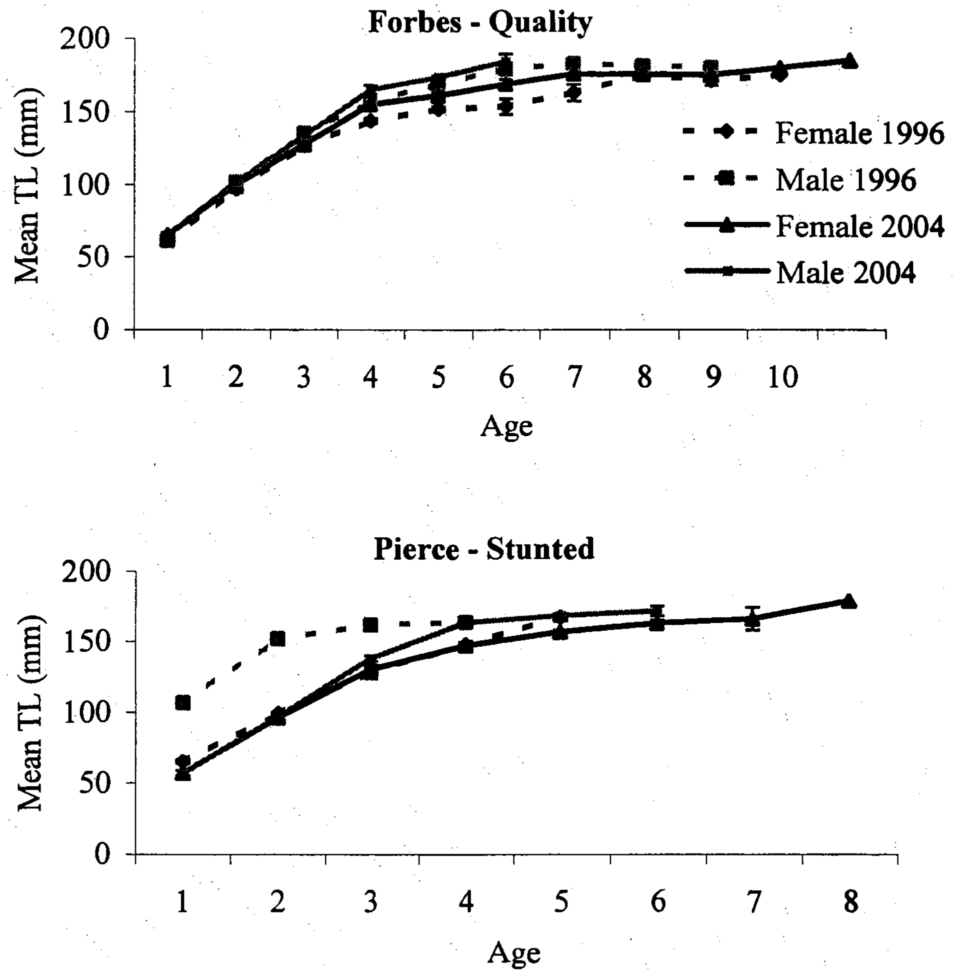


Figure 3-4: Mean size at age for bluegill captured in 1996 to 2004 through AC electrofishing in lakes receiving the stocking and regulation treatment. Error bars represent standard error.

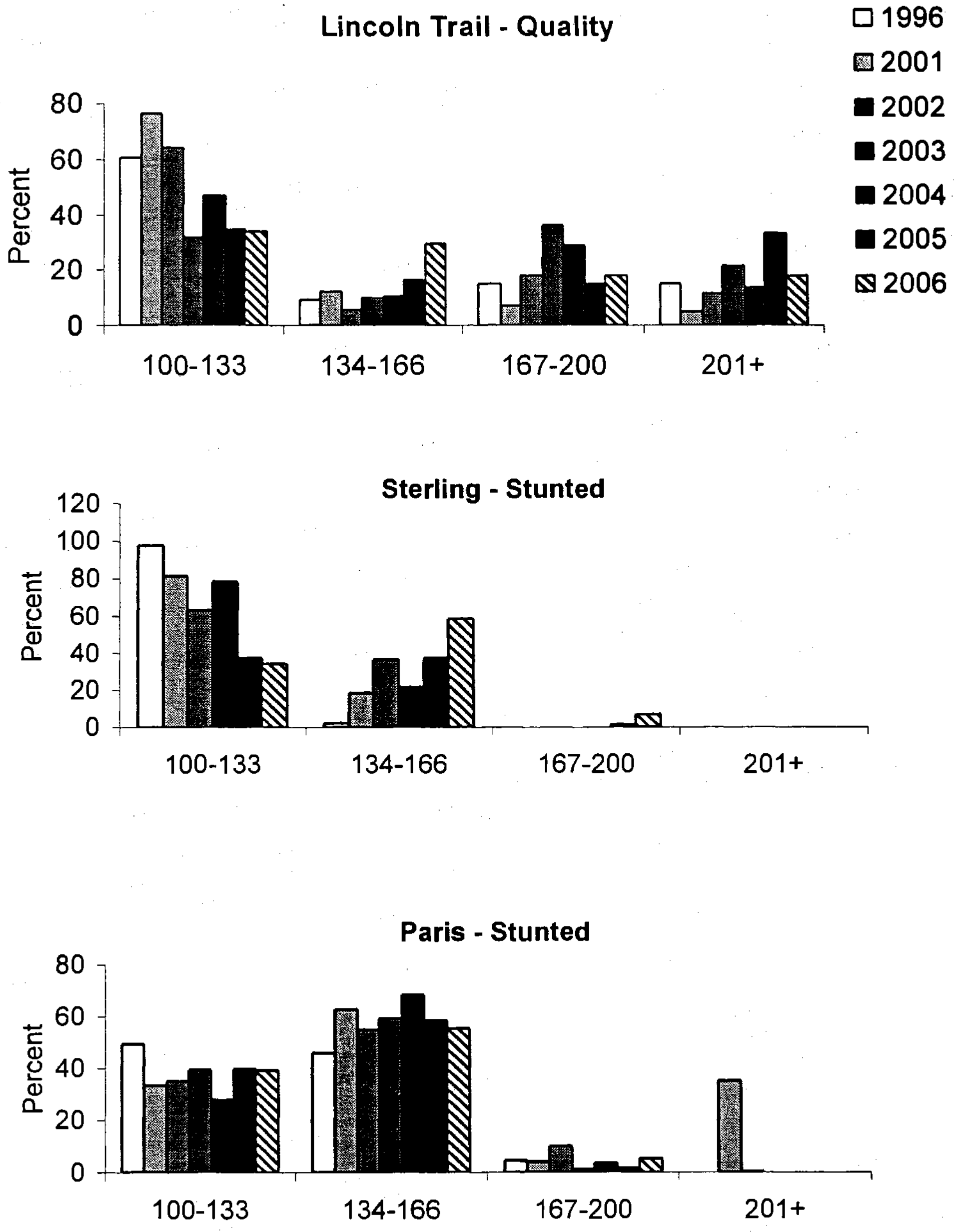


Figure 3-5: Length frequency from spring electrofishing expressed as percent of the total catch for lakes that received the control treatment.

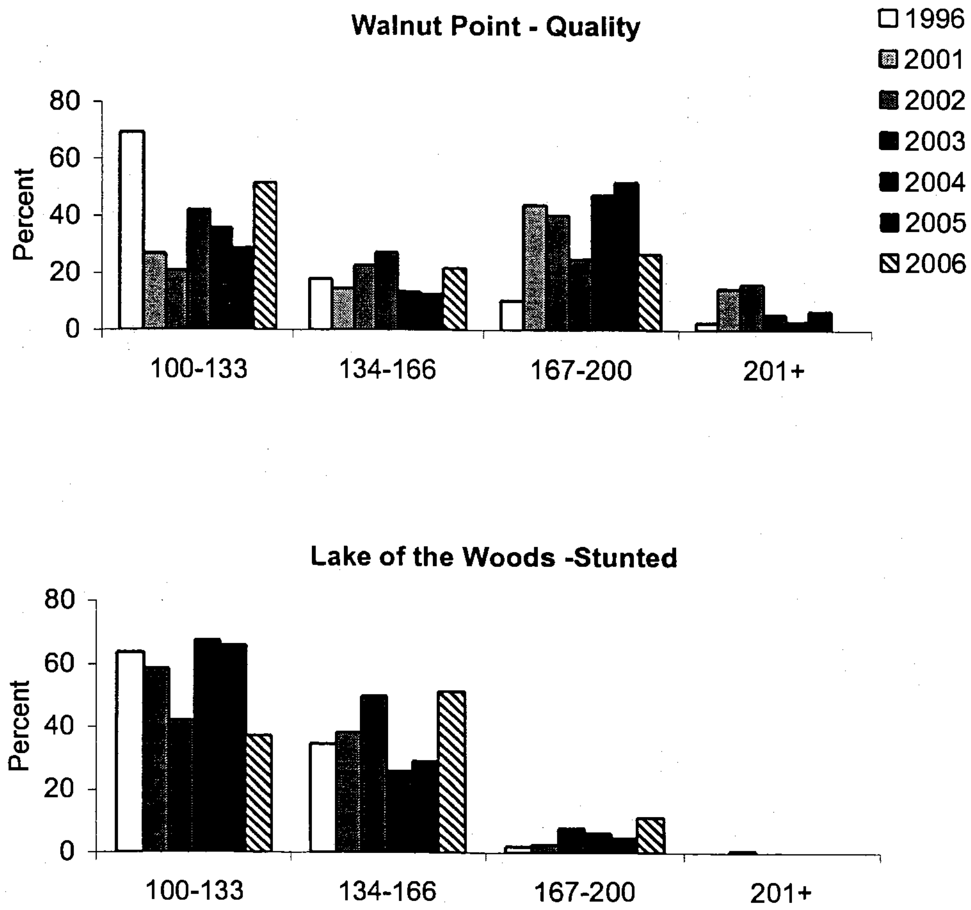


Figure 3-6: Length frequency from spring electrofishing expressed as percent of the total catch for lakes that received the regulation treatment.

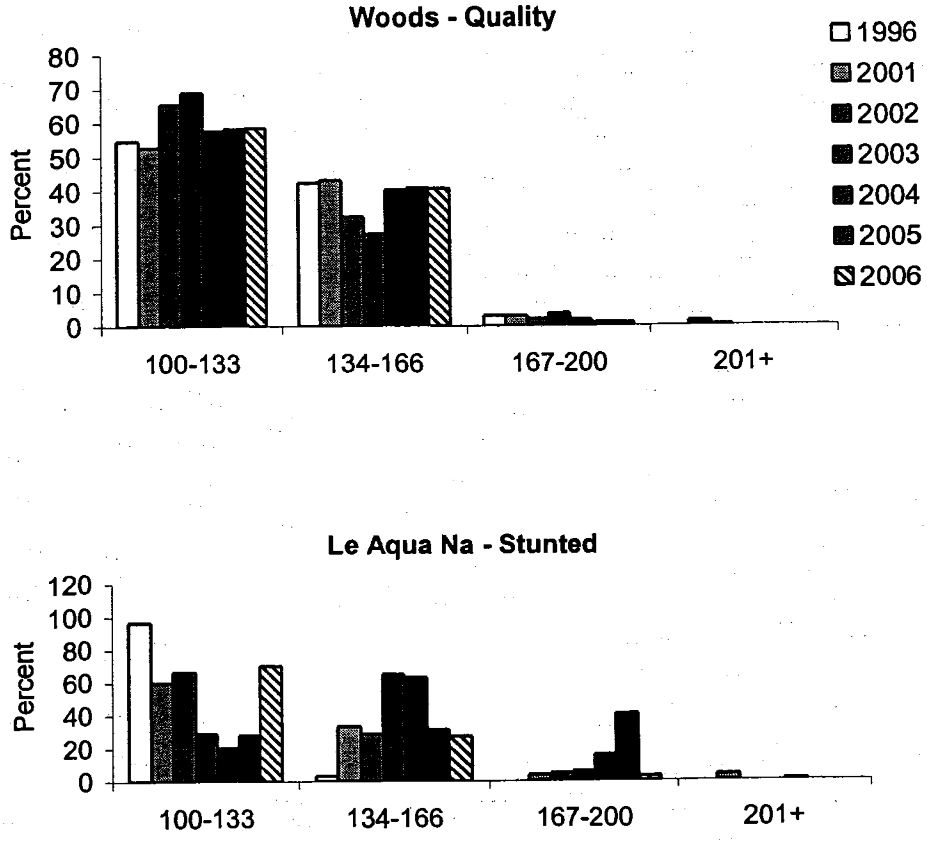


Figure 3-7: Length frequency from spring electrofishing expressed as percent of the total catch for lakes that received the stocking treatment.

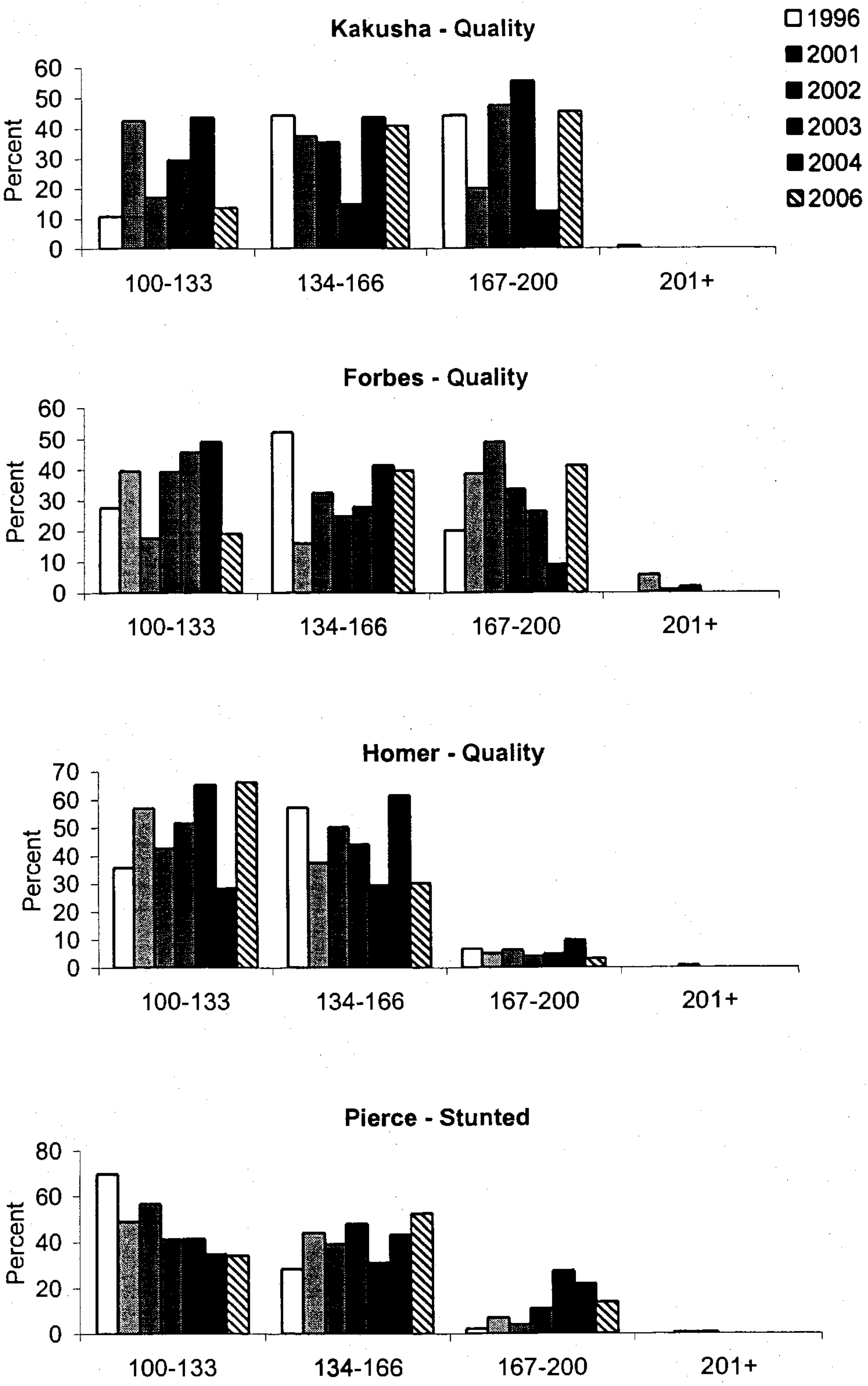


Figure 3-8: Length frequency from spring electrofishing expressed as percent of the total catch for lakes that received the regulation and stocking treatment.

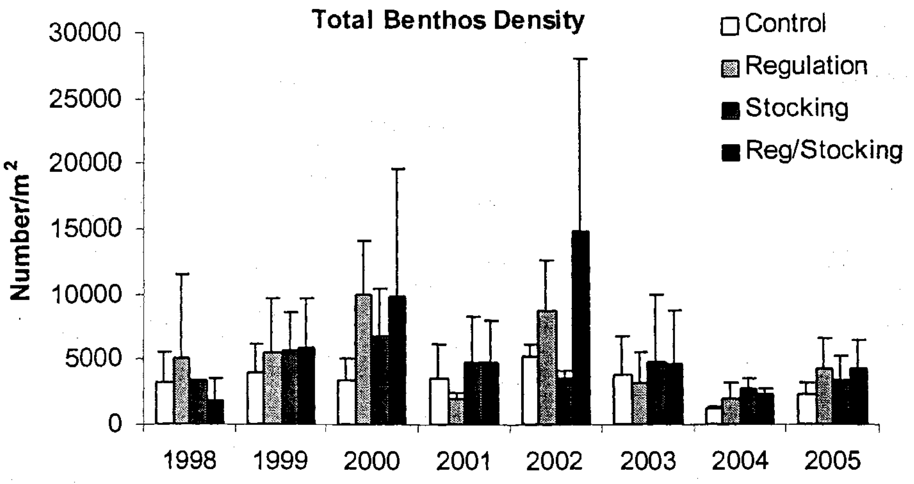
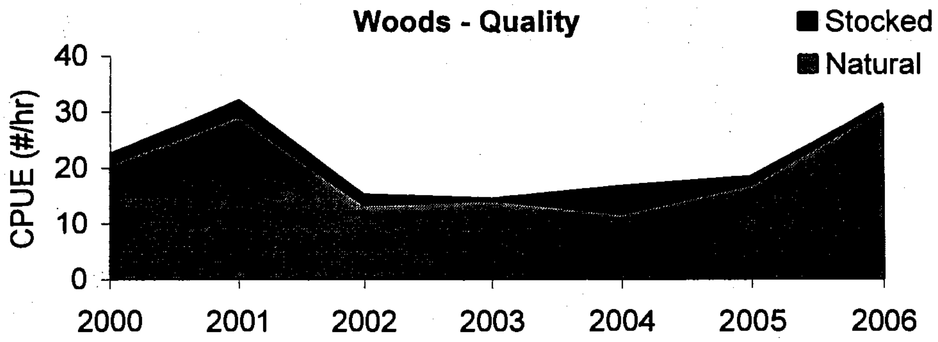


Figure 3-9: Mean benthos density by year for each treatment of the bluegill management experiment. Bars indicate standard deviation.



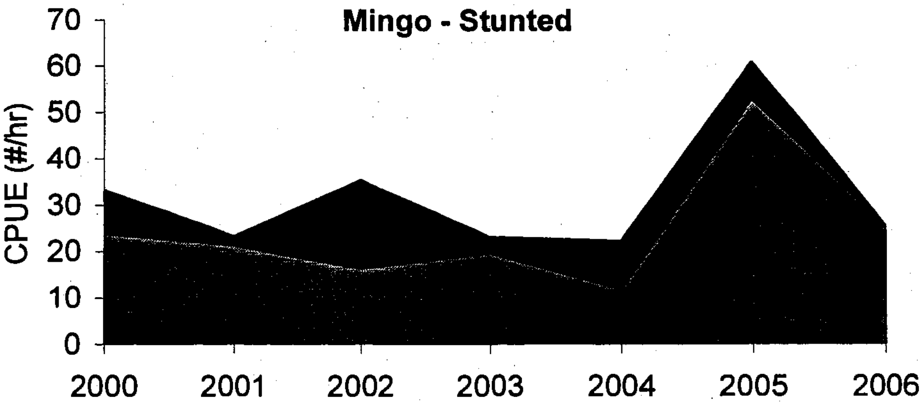


Figure 3-10: Contribution (CPUE, #/hr) of stocked (black), and natural (grey) largemouth bass to the total population in stocking treatment lakes during 2000-2006. Electrofishing samples were performed in the fall during September and August.

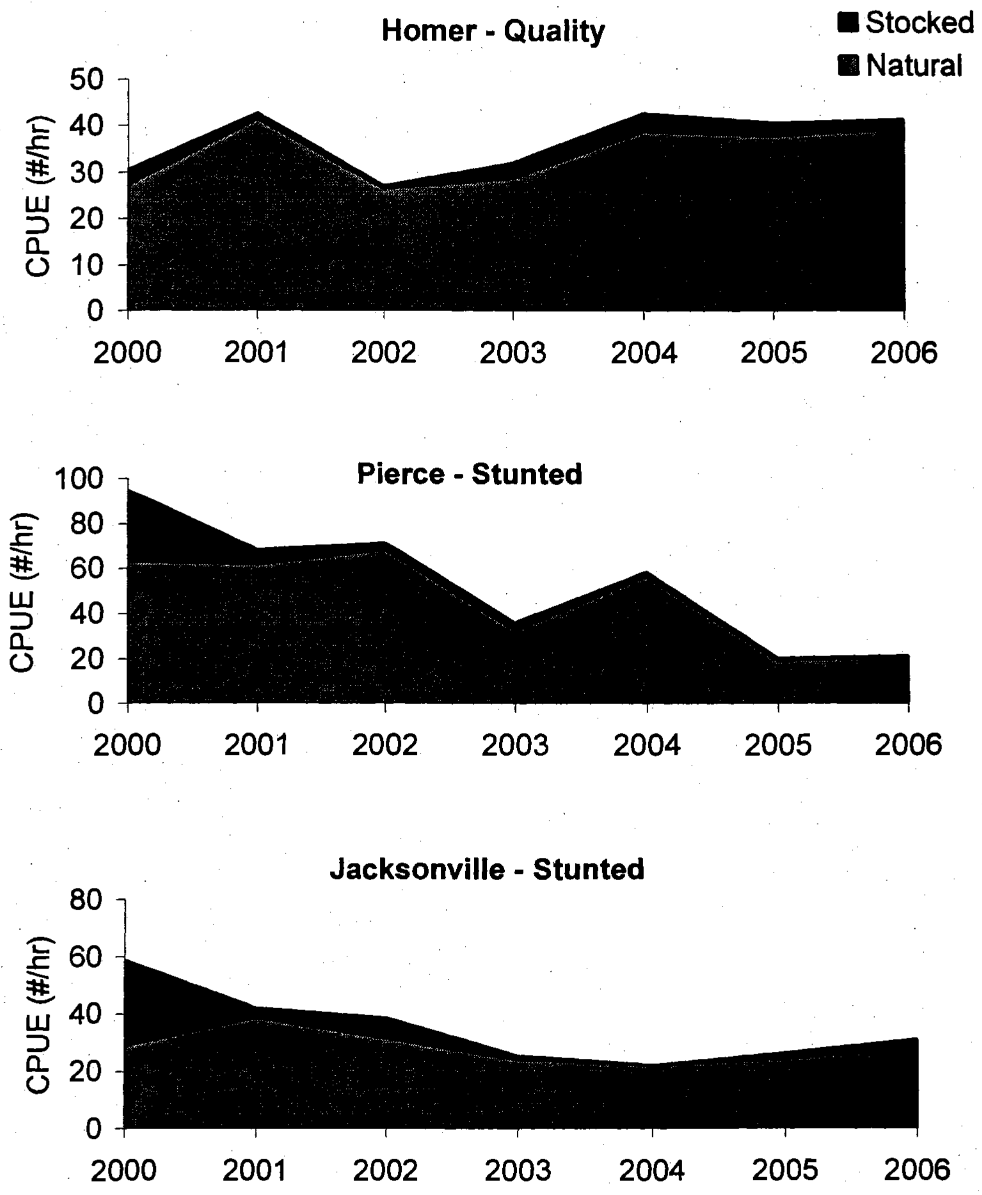


Figure 3-11: Contribution (CPUE, #/hr) of stocked (black), and natural (grey) largemouth bass to the total population in stocking and regulation treatment lakes during 2000-2006. Electrofishing samples were performed in the fall during September and August.